Glossary Limnology 1

Biological Zonation of a lentic System: Most organisms can be classified on the basis of their typical habitat.

Benthos: The community of plants and animals that live permanently in or on the sea bottom.

Littoral (intertidal zone): The trophogenic zone along the shore till the compensation depth where NPP occurs. It is rich in species diversity and number - especially algae and higher plants.

- **Epilittoral**: Sedentary organisms of the shoreline; e.g. macrophytes, diatoms, etc.
- **Profundal**: Depths of 180m and deeper.

Limnion: Temperature related zonation of the open water body of lentic systems; i.e. summer stratification due to solar radiation produces several trophic zones - see also ecological aspects - depth zones.

- **Epilimnion**: The upper warm and illuminated surface layer of a lake; narrower than the trophogenic zone.
- **Metalimnion**: The transitional zone between epi- and hypolimnion; i.e. the zone of the thermocline.
- **Hypolimnion**: The cool and poorly illuminated bottom layer of a lake, below the thermocline.

Nekton: Pelagic animals that are active swimmers; i.e. most of the adult fishes.

Pelagial: The environment of the open water of a lake, away from the bottom, and not in close proximity to the shoreline. It is Lower in species number and diversity than the benthos. The pelagial of rivers exhibits a directed and continuos flux (spatial relocation = amount_{H2O}/cross-surface area).

Plankton: Passively drifting or weakly swimming organisms in fresh waters; i.e. microscopic plants, eggs, larval stages of the nekton and benthos (such as phyto-plankton, zoo-plankton).

- **Neuston**: The epipelagic zone few centimeters below the waterline; i.e. within the water surface; rich in DOM, and bacteria. It has to cope with extensive UV-radiation. Organisms that inhabit this zone include tiny crabs cladoceres *Scapholeberis sp.*, ostracods *Notodromas monacha*, zooplankton *Arnaudovia hypneustonica*.
- **Pleuston**: Organisms or phenomena of the (epi-)pelagic zone considered to include the space a few centimeters above the waterline which comprises the community of running, crawling organisms, as well as the large floating assemblages blown about by the wind; e.g. water cabbage *Pistia sp.*, floating plants and animals, such as *Salvinia natans, Azolla sp., Lemna sp.,Eichhornia crassips*; certain bugs *Stenus bipunctatus*, spiders *Dolomedes sp.*, etc.
- **Seston**: To overall suspended material (dead or alive) in water; e.g. plankton, sediment particles, DPOM, etc.

Biological Zonation of a lotic System: Although a stream is split into several characteristic regions, the separate biocenosis do overlap over quite extensive stretches along a river system:

- **Krenal** (Kryal: a creek originating from a glacier): The area close to the origin of a spring, well, and is dominated by submerged macrophytes.
- **Rhithral**: Midsection of the river, also referred to as the Salmonidae-zone, where the average temperature is <20°C. Spermatophytes and other higher plants situated at both banks of the river outcompete macrophyte coverage by excessive shading. Fauna is characterized by a diverse selection of metazoa (simuliidae, chironomidae, ephemoptera, plecopteridae, amphipoda, turbellaria, etc.)
- **Potamal**: The low-land and slow flowing river section with an average temperature >20°C.

River Continuum Concept: The relative abundance of functional groups of benthic invertebrates (collectors, shredders, grazers, and predators) changes from headwaters to river mouth. The upper headwater section is dominated by shredders and collectors, while the lower headwater section is dominated by collectors and grazers. The river mouth itself reveals an overwhelming presence of collectors.

- **Coarse particulate organic matter** (CPOM): It consists largely of leaves and twigs supplied into the upstream regions, where riparian vegetation dominates small streams. Here, respiratory processes outweigh productive processes, leaving the P:R-ratio <1. Downstreams, CPOM contributions are < relative to the size of the river.
- **Fine particulate organic matter** (FPOM): Originates from CPOM; along w/ DOM, they dominate the central-lower river section. In response, benthic invertebrate diversity alters due to changed food supply; P:R-ratio >1.
- Finally, phytoplankton as collectors dominate over zooplankton as predators in the lower section; P:R-ratio <1.

Patch Dynamic Concept: The concept of communities as consisting of a mosaic of patches within which abiotic disturbances and biotic interactions proceed; e.g. division of a river system in fundamental zones.

Serial Discontinuity Concept: Sequence of discontinuous events due to a series of widening and narrowing of the river bed. Dams, gorges, and other geographical obstruction, along with a sudden change in substrate composition result both in an altered habitat, as well as, changed species diversity.

Ecological Aspects influencing the occurrence of life in limnic waters.

Allochotonous: Organic matter entering a stream, lake or ocean but derived from an adjacent terrestrial system; e.g. falling leaves from a tree located at the banks of the river.

Autochotonous: Organic matter produced within a community e.g., fresh-water plants within a river.

Biocenosis: A self-sufficient community of organisms naturally occupying and interacting w/n a specific biotope.

Biotope: The smallest region of a habitat uniform in environmental conditions and in distribution of life forms; e.g. a tidal pool, a forest canopy, etc.

Competition: Interaction b/w members of the same population or of two or more populations to obtain a resource that both require and which is available in limited supply. It limits the overall fitness of an organism.

- **Exploitative Competition**: Competition in which any adverse effects on an organism are due to reductions in resource levels caused by other competing organisms ("on a first come, first serve basis").
- **Mechanical Competition**: Competition in which low resource distribution (death rate matches birth rate) favors organism A over organism B, while an elevated resource level generates a reversed effect (organism B dominates over organism A).

Depth (concept of): According to their functions, limnic systems are divided into various depth zones.

- **Compensation Depth**: The fluctuating depth at which phytoplankton receives just enough light (over a 24h-period), to produce enough new carbohydrate to supply its own metabolic needs. The depth at which photo-synthetic production matches respiratory or metabolic consumption. In terms of light intensity:
  $I_{CD} = 0.5 \cdot I_0/100$ [W/m^2] I_0, incident global solar radiation [W/m^2]
- **Critical Depth**: The greatest depth to which a phytoplankton cell can circulate while still obtaining enough sunlight to produce as much new carbohydrates as its metabolic needs require. Cells that circulate deeper receive too little light, while near the surface, to compensate for the time they spend in darkness; thus it can exceed the compensation depth considerably.
- **Euphotic Zone**: The depth range from the surface layer of a lake till the depth where the penetrating solar radiation is about 1% (100% = radiation intensity immediately below the air-water line).
- **Mixing Depth**: The depth at which phytoplankton cells are relocated during a turbulent exchange of water bodies due to thermohaline convection, wave, or other currents. If the mixing depth exceeds the critical depth, no NPP will be produced; whereas, if the mixing depth is less than the critical depth, photosynthesis will result in NPP. In shallow lakes algal blooms in spring are a common event, as the critical depth exceeds the maximal depth of the lake itself.
- **Trophogenic Layer**: The layer where solar radiation easily penetrates making photo-autotrophic productivity possilbe(surplus). It includes the uppermost pelagial and the littoral.
- **Tropholytic Layer**: The hypolimnion of a water body where no photo-autotrophic production is possible. Only heterotrophic (destruents, saprophytes, etc.) and chemo-lithotrophic organisms can survive at these depths.

Ecosystem: A holistic concept of plants and animals habitually associated with them and all the physical and chemical components of the immediate environment which together form a recognizable self-contained entity. Even though it is an open system, it is capable to regulate itself via the many biochemical cycles.

Ecophysiology: The energy flow through a trophic entity is not only determined by abiotic and biotic factors, but is also subject to interspecific competition and prey-predator systems. Thus, the energetic flow, besides the input and output pattern, experiences "top down forces" (predation) and "bottom up forces" (resources).
Resources can be light for phototrophic organisms, ions, etc; temperature is not a resource!

Ecotone: A transition zone between two distinct habitats that contains species from each area of transition in which certain game or vegetation overlap; usually, the region of primary importance for human subsistence - the overlapping, thus critical areas of bordering ecosystems in a biotope of time and space.

- **Hyporhesic** Habitat.: The benthic fauna that occupies the interstitial or lives within the cracks and holes among the stony substrate of the river bed (lotic system). It is characterized by limited spatial availability, an intense light- as well as temperature- and O_2-gradient; also the interface between the free flowing waters of the river bed and the groundwater layer.

Energy Efficiency: The efficiency of energy flowing through a trophic entity varies according to the ability to metabolize the raw materials provided.

- **Gross Growth Efficiency** (GGE): It determines how much of the ingested energy is used in the production of biomass: K1 = production·100 / ingestion [%] (GGE is usually between 20-50%).
- **Net Growth Efficiency** (NGE): It determines how much of the ingested energy is assimilated:
  K2 = production·100 / assimilation [%] (NGE is usually between 30-60%).

Diapause: A state of arrested development or growth, accompanied by greatly decreased metabolism, often correlated with the seasons (usually only applied to insects); e.g. certain copepods in the nauplius phase withdraw themselves for an entire summer season into the sandy substrate.
Endocyst: Once environmental conditions deteriorate, certain organisms are capable of forming a differentiated cell, that can withstand unfavorable living conditions.
Fitness: The relative contribution that an individual makes to the gene pool of the next generation. Fitness is expressed in a population by reflection within each organism and all the way down from the organ, organelle to the molecule and genes. It can be expressed mathematically; because it usually refers to the fittest, it is generally <1.

$$\text{Fitness} = \frac{\text{Genotype of the individual } i}{\sum \text{genotypes of the population}}$$

Fitness expresses also survival, growth, and reproduction of an organism in a given environment.

- **Proximate Factor**: A cause that triggers a process; e.g. migration in autotrophic algae, triggered by metabolic requirements, food particle distribution, etc. Particularly, organisms which have a very low operational photosynthetic compensation point (autotroph at low PhAR - see also eco-physiology - Light Comp. Point).
- **Ultimate Factor**: An evolutionary programmed pattern triggers a process. Vertical migration for the sake of fitness-increase in order to avoid predation.

Habitat: (L. habitare, to inhabit) The environment of an organism, the place where it is usually found. Dependence of an organism upon abiotic factors increases with the organisms inability of locomotion; e.g. nekton vs. plankton.
Growth Kinetics: It involves measuring the growth of natural lab-cultures of phytoplankton or bacteria at several different nutrient concentrations. Growth (μ) can be measured by counting cells, spectrometric or fluorometric estimates or other means. The nutrient substance (S) added must be growth-limiting, whereas all other nutrients maintained at optimum.

$$\mu = \frac{\mu_{max} \cdot S}{K_S + S} \quad [?]$$

μ_{max}, measured maximum growth rate [?]
S, nutrient concentration [?]
K_S, half saturation constant, that is the substrate concentration at which half the maximum growth rate occurs

Lifecycle: Only about 2% of all organisms are found in the pelagial; the majority (98%) is found at the benthos.

- **Biphasic** (planktotrophic): Organisms that spend their juvenile stage as planktotrophic larvae and become sessile once adult stage is reached, e.g.: porifera, cnidaria, and others.
- **Holo-**P.: Organisms that spend their entire lifecycle in the pelagial; e.g. copepods. Contrary to biphasic.
- **Hypo-**(Typhozoo)-P.: Organisms living on or a few centimeters above the bottom; e.g. *Protista, Mysidiacea*.

Niche: The role played by ("occupation or profession") and the address of a particular species in its ecosystem; i.e. the range of conditions, resource levels and densities of other species allowing survival, growth and reproduction of organisms or species, hence *hyperdimensional* if condition, resources, etc. are seen in n-dimensions.

- **Complimentary** N.: The tendency for coexisting species which occupy a similar position along one niche dimension, e.g. altitude, to differ along another, e.g. diet.
- **Fundamental** N.: The potential range of all environmental conditions under which an organism can thrive.
- **Realized** N.: The part of the fundamental niche that a species actually occupies in nature due to inter-/intra-specific competition.

N. **Partitioning**: The tendency for coexisting species to differ in their niche requirements; an effect often observed in relatively closely related species; e.g. the herbivore plankton species *Daphnia galeata*, and *D.hyalina* feed upon the same resources, but *D.hyalina* practices Vertical migration, whereas *D.galeata* does not.
Photosynthesis (rate of): The rate determined by the amount of CO_2 used and O_2 released; in [mol, ppm] or weight [$g_{GAS}/t_{Drymass}$] of the isotope ^{14}C. The amount of dissolved CO_2 in the water determines the photosynthetic rate; a low amount of CO_2 leads to the consumption of O_2 (photo-respiration) to raise the dissolved CO_2 level.

- **Light Compensation Point** (LC): The amount of light (PhAR) at which CO_2 uptake equals CO_2 release; a >LC indicates a high light flux for photosynthesis to balance respiration; a <LC, indicates that photosynthetically compensated C-balance is kept even at low light flux; release in [$\mu mol/(m^2 \cdot s)$]; The rate of photosynthesis follows a trapezoid pattern in which solar radiation below the LC results in respiration, while above LC photosynthesis will take place. Excess radiation can lead to photo-inhibition, thus, suppressing photosynthesis to as far as the compensation point. It should be mentioned though, that temperature will maximize photosynthesis while the angle of the rising slope will remain the same in both low and high temperatures.
- **Photosynthetic Active Radiation** (PhAR): The range utilized for photosynthesis by plants; an average of 47% of the incoming solar energy falls within the spectral range of 380-710nm (corresponds to the visible spectrum).

Population: Any group of individuals, usually of a single species, occupying a given area at the same time.
Tolerance Spectrum (Reaktionsnorm): The ability of a species or population to maintain survival and prosperous growth rates or population densities away from their optimal requirements. Certain biotic factors can widely fluctuate (euryecoic), while other factors have to be quite narrow (stenecoic) to enable survival of a species.
Ecologic tolerance (nature - in situ) is usually a lot narrower than physiological tolerance (laboratory - in vitro) where all nutrients are provided at a constant rate; i.e. the organisms exposed to the natural environment suffers a certain amount of stress related foraging, which results in synergetic effects narrowing the tolerance spectrum.

- **Bottleneck**: A critical phase in an organisms life cycle where it is especially vulnerable; e.g. *Daphnia sp.* carry their eggs with them, limiting mobility, thus facilitate predation.
- **Euryecoic Species**: Species that can support a vast fluctuations of environmental conditions away from their optimal growth rate or population densities.
- **Stenecoic Species**: Species that tolerate only narrow or now fluctuations of environmental conditions.

Trophic Interactions: see there
Vertical Migration (VM): Spatial variation in a diurnal oscillation of phytoplankton in lakes caused by the sun; as plankton sinks down at sunrise avoiding over-exposition, it creates a scattering layer at a certain depth (depth at which photosynthetic production matches respiratory or metabolic consumption), which will cease to exist once the plankton drifts back to the surface at sunset. Such vertical shifts are also present on a larger scale following seasonal patterns. Triggers of VM are unknown, perhormones of planktivore fish seems to play a key role.

- **Midnight sinking**: The tendency that plankton tends to sink due to cessation of beating cilia - phase of rest.
- **Proximate Factor**: A cause that triggers a process; e.g. migration triggered by metabolic requirements such as photosynthesis, food particle distribution, etc. Particularly, organisms which have a very low operational compensation point of photosynthesis - i.e. can achieve photosynthesis at low PhAR-levels.
- **Ultimate Factor**: An evolutionary programmed pattern triggers a process. Vertical migration for the sake of fitness-increase in order to avoid predation.

Limnology: (Gk. limnos, pool, lake, swamp) The scientific study of freshwater, in-lake waters. Physics and chemistry of freshwater bodies and their classification, biology, and ecology of the organisms living in them.

- **Holistic Approach**: It takes into account the topology, the chemical characteristics (pO_2), photo-autotrophic productivity of a water column (water body), as well as, the organisms contained in the sediments, and their interactions. Certain indicator organisms are used to classify a body of water; i.e. Chironomidae larvae, etc.
- **Reductionistic Approach**: The attempt to classify a body of water according to its characteristic organism that are influenced by both abiotic as well as biotic factors in their growth and reproduction patterns. Certain organisms may persist any changes (tolerance spectrum), suggesting a/normal conditions.
- **Trophodynamic Concept**: The organizing concept that describes a community in terms of energy flow through its various trophic levels (position in the food chain is assessed by the number of energy-transfer steps to reach that level); it decreases as one approaches the tip; i.e. primary producer, herbivore-, carnivore zoo-plankton, and top predator.

Applied Limnology: Management of freshwater ecosystems should be both environmentally sound and ecologically reversible to allow for unforeseen negative effects. Precipitation, groundwater input, organic input at the air-water interface, acidification of weakly buffered lakes, leisure time activities, xenobiotic inputs (e.g. pestizides), boat traffic with increased wave action, and sedimentation in lakes as well as regulation of river systems. Canalization of river beds do negatively influence the ecological structure of a body of water.
Conversion of an eutrophic body of water into the oligotrophic state should be attempted in the following way:

- **Restoration**: Symptomatic treatment without attempting to uproot the real polluting causes.
  Hypolimnic Aeration: An airlift pump on the lake bed lifts anoxic water to the surface in an inner tube and simultaneously adds oxygen. Excess gas is vented to the atmosphere and the still cold, but now oxygenated water, is returned to the hypolimnion via an outer tube. Stratification is preserved with this technique.
  Phosphate Precipitation: Ca_3SO_4, $Al_2(SO_4)_3$, etc. are used to bind phosphate compounds (PO_4^{3-}) which will settle down, depriving the water body of dissolved phosphorous.
  Biomanipulation: Involves the use of zoo-planktivorous fish to reduce net primary productivity, which is eventually followed by the use of carnivorous fish do lower the number of secondary consumers.

- **Sanitation**: Once the main polluting sources have been established, sanitation involves the complete stop of in flowing pollutants by external or internal means or a combination of both;
  External Means include the complete stop of polluting run off by installing waste water canalization along the lake shoreline with subsequent phosphate precipitation in a purification plant; introducing phosphate substitute in detergents and washing powders.
  Internal Means: Hypolimnic aeration, pumping out hypolimnic bottom water, removal of heavy metal loaded sediments or coverage of contaminated sediments with an impermeable material (reduces resuspension); further methods can include P-precipitation, biomanipulation.

Renaturation of River Systems: Converting a regulated river bed into its natural or a similar state; it involves the removal of rectifying structures (changes that increase structural and vegetative diversity), enlarging the river bed to allow periodic expansion (floodplains), increase its overall length (meandration), as well as increasing its structural patterns (roughness, retention to enable turbulent flow) which favors settlement of benthic organisms.

Symptoms of a Limnic System out of balance:

- **Acidification**: A decrease in the buffering capacity of any water body will release an ever increasing number of protons; acid rain and Ca-poor substrates (silicate) can facilitate such a development. Photo-oxidation changes primary reagents to acidic secondary products; e.g. exhaust gases of industrial and combustion processes:
  $SO_2 \rightarrow H_2SO_4 \rightarrow 2H^+ + SO_4^=$ $NO_x \rightarrow HNO_3 \rightarrow H^+ + NO_3^-$
  A lowered pH facilitates dissolution of metals from the sediments (are toxic to aquatic life forms; e.g. Al, Fe, Cu, Zn, Pb, Cd) while Hg will precipitate with chloride. Liming of acidified lakes represents a short term remedy by increasing the buffering capacity of the water.
- **Biological Oxygen Demand** (BOD_5): Describes the oxygen level left in a sample of water after a 5 day incubation period at a given temperature and under darkness after it has been used up by microbial activity.
- **Eutrophication**: Eutrophic waters have both ample supplies of major and minor nutrients and high rates of primary productivity (net photosynthesis) that feed a large population of herbivores. Thus, most eutrophic lakes are shallow and unstratified. Oxygen levels do fluctuate heavily in that the epilimnion is supersaturated, while the hypolimnion experiences deoxification. In general, the more eutrophic a water system, the more turbid and the more favorable becomes the growth conditions for reed grass (Schilf); whereas, submerged macrophytes decline in abundance and diversity. Water transparency is generally low, with a Secchi depth of 0.1-2m.
  Typical **symptoms** of eutrophication:
  i) Increased biomass production of the phytoplankton.
  i) Color change and loss of transparency due to the increasing number of phytoplankton.
  i) Stratified lakes suffer from hypolimnic O_2 depletion which, will kill most aerobe benthic organisms.
  i) Accumulation of H_2S results in a lowered pH of bottom waters, which dissolves iron and manganese ions from the sediment; and if acidification continues, even heavy metals may experience resusupension.
  i) Lack of oxygen enforces the production of CH_4 within the sediment.
  i) The epilimnion will be dominated by filamentous, epiphytic algal blooms, as well as, weedy submerged plants along the shores while reed grass withdraws.
  i) Finally, severe eutrophication causes toxic blue algal blooms that cause death of the epilimnial fish fauna.
  Phosphorous Loading Curve (Vollenweider Model): The total phosphorous-chlorophyll relationship is used to predict the effects of the watershed on phytoplankton blooms. Lakes can be separated into three groups - eutrophic, oligotrophic and mesotrophic (in-between). If phosphorous is growth-limiting and the total phosphorous chlorophyll *a* relationship applies, then changes in loading will change chlorophyll and thus the trophic state. It can be mathematically expressed as:
  $q_s = \bar{z}/\tau_N$
  $L_C = 10 \cdot q_s \cdot [1+\sqrt{(\bar{z}/q_s)}] = 10 \cdot q_s \cdot (1+\sqrt{\tau_N})$ $[g/(m^2 \cdot a)]$
  q_s, quotient [m/a]
  $\bar{z}$, average depth [m]
  τ_N, water renewal time [a]
  Oligotrophication: Oligotrophic waters lack high nutrient levels or low supply rate of at least one major nutrient (e.g. N, P, silica) resulting in a low primary productivity that cannot sustain high herbivorous populations and fish. Oxygen levels are evenly distributed throughout the epilimnion and the hypolimnion. Deep, stratified lakes usually are oligothrophic in that transparency enables light to penetrate beyond the thermocline - Secchi depth 8-40m.
  Re-oligotrophication: Refers to an eutrophic water body that shifts from a condition of high nutrient content with algal blooms to one containing low level of nutrients and little plant growth. The two swifts from oligo-trophic to eutrophic and back to the oligotrophic state occur in an envelope-shaped curve (hysteresis); i.e. due to stored P-deposits in the sediments, re-oligotrophication is lot slower than eutrophication was reached.

Organisms in Lakes and Stream - separated by group and site of occurrence:

Algae: Traditional term for a series of unrelated groups of photosynthetic eukaryotic organisms that lack multicellular sex organs (except for caryophyta); the haploid phase generally dominates the life cycle, while reproduction involves swimming eggs and sperm. Abundance in limnic systems largely depends upon the level of trophication, but in general fluctuates between $1 \cdot E^2$-$1 \cdot E^4$ orgs/m^2.

Benthic Organisms: The community of plants and animals that live permanently on the bottom. These are either grouped into sizes, **Macro**-, **Meio**-benthos (interstitial fauna), **Micro**-, **Nano**-benthos (flagellates, protists, amoeba, cilliates) benthos or according to the auto/heterotrophic characterization as **Phyto-**, or **Zoo**-benthos.

- **Epibiota**: Organisms that overgrow sedentary or other benthic organisms.
- **Macro-zoobenthos**: The fauna of the upper littoral which includes larvae of insects, snails, mussels, oligochaeta, turbellaria, nematods, copepods, etc.

Microorganism: Prokaryotic cells that lack a unit membrane-bound (true) nucleus and other organelles; usually have its DNA in a single circular molecule. They also have a unique cell wall constituent, the peptidoglycan; a thin sheet composed of N-acetylglucosamine, N-acetylmuramic acid; also called murein. Genetic analysis of the 16SrNA enables taxonomists to identify bacterial strains. Generally, the more oligotrophic a system, the larger the fraction of bacteria versus phytomass. An eutrophic system in relation to phytomass contains less bacterial biomass. Microbial abundance ranges from $1 \cdot E^5$-$1 \cdot E^7$ cells/mL.

A prokaryote's nutritional requirements ranges according to the classification given below:

- **Autotroph**: (Gk. autos, self; trophos, feeder) Organism able to use CO_2 as sole source of carbon.
- **Auxotroph**: A mutant that has a growth factor requirement.
- **Heterotroph**: Utilization of chemotrophic food sources; can be further differentiated into:
  Chemo-litothroph: Organism obtaining its energy from the oxidation of inorganic compounds.
  Chemo-organotroph: Organism obtaining its energy from the oxidation of organic compounds.
- **Phototroph**: An organism that obtains energy from light.

Nektonic Organisms: Pelagic animals that are active swimmers, such as most of the fish, and mammals.

Nekton: Reptiles and mammals are weakly represented in limnic systems (the only exception are the seals of lake Baikal, Dugongs, and Manatees). Other, more common are adult fishes like petromyzoniformes (lampreys), scipenseridae (sturgeons, paddlefish), anguiniformes (eels), clupeiformes (herrings), salmoniformes (salmon, trout, chub, greyling, char, smelts, pikes), cypriniformes (minnows, carp, suckers, catfish), cyprinodontiformes (killifish, pupfish), gasterosteiformes (sticklebacks), mugiliformes (mullet), perciformes (basses, sunfish, perch, archerfish, cichlids, icefish), scorpaeniformes (sculpins), gadiformes (cods).

- NO of **Lentic Waters**: Pelagic animals that are active swimmers, such as most of the adult fishes. According to the fish fauna, the following reductionistic characterization can be used:
  Bream Lake (Brachsen): Lakes with a moderate to medium level of eutrophication; dominated by benthic grazers such as carps (*Abramis brama*),
  Pike Lake (Hecht): Shallow lakes lacking the profondal; macrophytes are usually present in large quantities which are used as nurseries and hiding grounds for species which the pikes feed on.
  Pike-Perch Lake (Zander): Shallow, flat, turbid and eutrophic lakes lacking the otherwise dense macrophytic coverage; with the pike-perch as the top predator.
  Trout Lake (Salmoniden): Oligotrophic to slightly eutrophic lake with the pO_2 still >50%; eggs deposited in the profondals of the lake.
- NO of **Lotic Waters**: Active swimmers, such as most of the adult fishes. The composition of the fish fauna characterizes a distinct section of a stream:
  Salmonidae-Zone (lachsartige + Äschenregion): also known as the trout-zone or the grayling-zone. Oligotrophic to slightly eutrophic section of a fast flowing stream with the pO_2 still >50% and relative cold water temperatures. Salmonidae require gravel substrate for their spawn.
  Barbel-Zone (Barben *Barbus barbus*): Moderately flowing stream with extensive areas of sandy substrate.
  Bass-Section (Stör + Flunder *Pleuronectes flesus*, Kaulbarsch *Acerina cernua*): Usually the area associated where the river enters the ocean; but includes also estauries and wetlands with sturgeon and flounder as the most predominant predators.
  Bream-Zone (Brachsen *Abramis brama*): Slow-flowing stream with a muddy substrate and an intense makrophytic vegetation.

Plankton: Passively drifting or weakly swimming organisms; separation according to function and size:

Virioplankton: Comprise the largest group with up to $1 \cdot E^8$ orgs/m^2 and by far the smallest 20-150[nm].

Bacterioplankton: Concentration of up to $1 \cdot E^6$ orgs/m^2, ranging from 0.3-10[µm] in size; range from photo-lithotrophic to photo-autotrophic, anaerobic to aerobic and hyper-thermophilic to bariophilic strains.

Mycoplankton: Fungi and fungilike organisms with about $1 \cdot E^4$-$1 \cdot E^5$ orgs/m^2 and up to 100[µm] large; e.g. actinomycetes, phycomycetes, oomycetes, ascomycetes, and basidiomycetes.

Phytoplankton: Planktonic plants, usually single celled algae (excluding macrophyta), like diatoms, dinoflagellates, cyanophytes, chlorophytes, chrysophytes, cryptomonads, euglenoids, certain rhodophyta, etc.; e.g. coccoid cyanobacteria, *Synechococcus sp.*, N-fixing colonial / multicellular organisms like *Anabena sp., Nostoc sp.*; Phytoplanktonic abundance ranges from $1 \cdot E^3$-$1 \cdot E^6$ orgs/m^2.

Zooplankton: Animal forms of plankton or protists, sometimes also split into protozoo - and metazoo-plankton. Reproduction of zooplanktonic organisms in limnic systems is predominantly partinogenetic, whereas in marine systems it is generally bisexual. The protists include certain protozoans, cilliates, ameboids, sporozoans, rotifera; whereas the metazoa include various crustaceans, such as copepods, mysidacea, amphipoda, decapoda, cladocera, turbellaria, nematoda, annelida (oligochaeta, hirudinea), mollusca (snails, bivalves), crustacea (crayfish), insecta (plecoptera, odonata, ephemoptera, hemiptera, megaloptera, trichoptera, coleoptera, diphtera), and the eggs and larvae of benthic and nektonic animals. Their abundance accounts for $1 \cdot E^2$-$1 \cdot E^4$ orgs/m^2 at body sizes that range from 10[µm] to 1[mm].

Psammon: (Gk. resemblance or relationship to sand) A community made up of microscopic plants and animals that live in-between the grains of sand along sea shores and lake-shore areas.

Water: A molecule that contains two bonding of H-atoms to one centrally located O-atom. The overall arrangement of the water molecule is bent (due to a lone e-pair of O) in an angle of 104.5°. 96% of all water molecules are of pure water $^1H_2{}^{16}O$; the remaining water molecules are made of O (^{17}O, ^{18}O) and H (^2H, ^3H) isotopes. Due to the bent characteristic, water molecules in liquid phase aggregate into clusters of 6, whereas in the solid phase these molecules arrange themselves into a linear pattern causing a net increase in volume (ice is less dense than water).

Water Bodies: Differentiation among bodies of water regarding to their flow characteristics.

Groundwater: The water below the surface - in the ground, trapped in a system of underground caves and crepes (also known as **stygal**) that reemerges somewhere back to the surface. The flow of groundwater predominantly results from a pressure gradient as a result of inclined impermeable bottom layers (**aquifuge**). Because light is not available, organisms living in this environment are rarely autotrophic; thus, mainly consumers and detritus feeder (i.e. bacteria, at an average density between $1 \cdot E^4$-$1 \cdot E^5$ orgs/mL and around $1 \cdot E^7$ orgs/mL in eutrophic ground waters). Metazoa are restricted by the narrow framework of this habitat, which results in convergent adaptations of aquatic organisms (slender crustacea, isopods, ostracods, synarcadia, amphipods, cladocera, mites, nematods, etc. with degenerated eyes and unpigmented cuticula). Allochtonous input and the permeability of the layers separating the groundwater body from the surface level determine the nutrient balance and the population density of these organisms. Temperature fluctuations are extremely small and will only occur as a result of seasonal fluctuations.

- **Aquifere**: Hydro-geologic underground channel system in which water can flow at a speed of up to several cm/day. Filtering effect of the substrate ceases once pore diameter exceeds a certain threshold; whereas, extremely tiny pore diameters will bring hydraulic conductivity to a halt (aquifuge).
- **Aquifuge**: Layers impermeable to water; e.g. clay which is expressed by a low penetration coeff. k_f of $<1E^{-9}$m/s.
- **Stygophilic Organisms**: Organisms that readily withdraw into the underground water system.
- **Stygoxenic Orgs**.: Passively into the underground water system introduced organisms.

GW-**Connectivity**: The groundwater system seen as a complex network and coherent channels is a crucial for split sub-populations of aquatic organisms to reunite for reproduction purposes.

Lentic Waters: Also called lentic environments, characterizes a relatively still water of a lake which do evolve periodic wave action.

Lotic Waters: Characterization of a flowing river or stream with a typically aperiodic wave pattern (current, circulation, etc.); streams do support a very intense sedentary fauna, because currents provide the organisms with sufficient nutrients in form of oxygen and food.

Water Budget: The balance between the rates of water added and lost in an area. A body of water is usually identified by its temperature-salinity curve or chemical content, normally consisting of a mixture of two or more water types. The global water balance is split as follows: **Atmospheric Water Vapor**: 0.0009% (average latent period: 9 days); **groundwater**: 0.3% (average latent period fluctuates heavily); **lakes**: 0.009% (average latent period: 1-100 years); of which 70% are freshwater lakes and 30% saltwater lakes; **river**: 0.00009% (average latent period: 10-20 days); **polar Glaciers**: 2% (average latent period: $16 \cdot E^3$ years).

Water Cycle: A solar-driven global exchange involving evaporation, precipitation, runoff, and transpiration that cycles water from the atmosphere to the earth's surface through organisms and back again.

Evaporation: Physical process by which a liquid or solid is transformed to a gas. 96% of the global water reserves are stored in the oceans; only 4% are distributed as freshwater over landmasses and 2% are bound in polar ice-caps. 96% of global evaporation occurs over oceans, of which only 78% is returned directly via precipitation, the remaining 18% come down over landmasses, which return via river run-offs.

Condensation: Physical process by which a vapor becomes liquid or solid. When water vapor condenses, heat is released, and the surrounding temperature is raised. Precipitation in the form of rain is condensed water.

Water Circulation (overturn): General term for describing a water current flow within a large area (aperiodic wave); usually a closed circular pattern, and are essential for the distribution of plankton. In aquatic systems, separation of distinct water bodies is caused by circulation (in terrestrial systems, separation is brought about by gravitation).

Convection: A mass motion within a fluid resulting in transport and mixing of that fluid. Convection, along with conduction and radiation, are the principle means of energy transport within lakes.

- **Langmuir** C.: Vertical surface-water circulation causing a water vortex of several meters in diameter - a phenomenon usually observed in oceans or in deep fresh water lakes.

  Convergence: Situation in which waters of different origins come together at a point or, more commonly, along a line known as a convergence line (minor water level depression, often accumulating floating detritus and positively buoyant organisms such as zooplankton); often associated with down-welling. Along such a line, the denser water from one side sinks under the lighter water from the other side.

  Divergence: Horizontal flow of water in different directions from a common center or zone; often associated with upwelling (minor water level elevation along a divergence line; aggregating negatively buoyant organisms such as phytoplankton).

Coriolis C.: Apparent force on moving particles resulting from the earth's rotation. It causes moving particles to be deflected to the right of motion in the northern hemisphere (resulting in a clockwise circulation) and to the left in the southern hemisphere (counter-clockwise rotation); the force is proportional to the speed and latitude of the moving particle and cannot change the speed of the particle. It is effective only in larger lakes.

Thermohaline: Pertaining to both temperature and salinity.

- **T. Circulation**: General term describing a water current flow within a large area; usually a closed circular patterns. Vertical circulation induced by surface cooling, which causes connective overturning and consequent mixing. (swap of surface water of low nutrient content with bottom water of high nutrient content). Once the spring sun heats up the upper layers (epilimnion), convection ceases.
- **T**. **Convection**: Vertical movement of water is observed when the vertical equilibrium is disturbed - due to decreasing surface water temperature or increasing surface water salinity (surface water becomes heavier than the layers underneath it); thermohaline convection occurs only in the epilimnion (thickness of epilimnion in the summer is narrower than in fall or winter);

Water Circulation Patterns in Lakes: Destratification (absence of a thermocline) occurs as heat loss from conduction and evaporation (due to lack of solar influx) triggers characteristic certain water-mixing patterns such as:

- **Amictic** C.: Lakes with year round ice cover that never mix.
- **Meromictic** C.: Very deep or chemically stratified lakes that mix only partially.
- **Holomictic** C.: Lakes that mix thoroughly, from top to bottom.

  Dimictic C.: Lakes that mix twice a year; once in fall and once in spring; they are covered with ice in winter and may show inverse stratification in summer.

  Monomictic C.: Lakes that are not subject to ice formation; have one long mixing period; warm MCLs never freeze and circulate in winter, while cold MCLs circulate in summer once the ice has melted.

  Oligomictic C.: Lakes that do mix in irregular intervals; e.g. in intervals >1 year.

  Polymictic C.: Shallow lakes that mix irregularly every few days, or even daily, and all year round.

Eddy: Circular movement of water usually formed where currents pass obstructions, between two adjacent currents (usually of different temperature) flowing counter each other. Clusters of water become separated and form islets of warm or cold deep water; which, later on, gradually spread horizontally at a certain depth establishing thin layers to finally integrate completely with the main water body.

Water Properties: According to the various physico-chemical properties, water possesses several distinct characteristics:

Chemical Properties of Water: Properties of water and how it reacts with other substances.

- **Buffer**: A solution that resist any change in pH when small amounts of acid or base are added; i.e. a weak acid or base with its conjugated counterpart in relative high concentrations; HCO_3^- and H^+ are typical components of a buffer system in freshwater bodies.
- **Gases** dissolved in water: Due to the air-water barrier gasses do not readily dissolve in water (phase change). Even though, atmospheric gasses, like oxygen, carbon dioxide (aerob), and methane (anaerob) are the most important gasses found in sea water. Seawater at 0°C may contain 50% more dissolved gasses (e.g. O_2) than seawater at 20°C. Freshwater, which is less dense than seawater, can hold an even larger amount of dissolved gases, so can cooler water over warmer water.
  Henry's Law: The solubility of a gas in a liquid is proportional to the pressure of the gas above the solution; solubility ∝ c (applicable only if solute concentration is low). At low pressures, solvent does not react with gas. The higher the water temp., the less gas will be dissolved. k, Henry's variable [mol/(l·Pa)]
  $c = k \cdot p$ [mol/l] p, partial pressure [1/atm] = [Pa]
- **Carbon dioxide** (CO_2): Heavy, colorless gas; it is the fourth most abundant constituent of dry air; over 99% of terrestrial CO_2 is found in the oceans. Carbon dioxide is the major constituent of carbonate:
  Salts of CO_2 are H_2CO_3 (dissolves easily) and $CaCO_3$ (resistant precipitate), whereas $Ca(HCO)_2$ dissolves easily
  I) $CO_2 + H_2O$ ↔(pH<4)↔ H_2CO_3 (carbonic acid) ↔(pH 7-10)↔ $H^+ + HCO_3^-$ (bicarbonate) ↔(pH>10)↔ $2H^+ + CO_3^=$
  II) $Ca^{2+} + CO_3^= \leftrightarrow CaCO_3$ (calcium-carbonate)
  III) $CaCO_3 + H_2CO_3 \leftrightarrow Ca(HCO)_2$ (calcium-dihydrogen-carbonate)
- **Hardness**: The quality of water produced by soluble salts of calcium ions (Ca^{2+}), magnesium ions (Mg^{2+}), or other alkaline earth substances, which form an insoluble curd with soap and thus interfere with its cleansing powder. Hardness commonly is expressed in terms of mg $CaCO_3$.
  German Hardness (dH): 1dH = 10mg CaO = 18mg $CaCO_3$
  Soft water: <10°dH; Hard water 10 - 20°dH; water beyond 30°dH is not good for as drinking water any more.
- **Osmosis**: (Gk. osmos, impulse or thrust) The diffusion of water, or any other solvent, across a differentially permeable membrane; in the absence of other forces, the movement of water during osmosis will always be from the region of greater potential to one of lesser water potential.
  O. **Pressure**: The pressure needed to balance the flow of solvent through a semipermeable membrane; i.e. the pressure required to stop osmosis. Salty water increases the osmotic pressure; resulting in a net sucking force from a water-body with no or lower level of salinity. Fluctuating salinity levels has beneficial or detrimental effect upon organisms, rendering it more beneficial or hostile [N/m^2].
- **pH** (**p**otential **h**ydrogen): The negative logarithm of the hydronium ion concentration [c_{H30+}] in a solution; at a temperature of 25°C; $pH = -\log(c_{(H3O+)})$, $K_C = c_{(H3O+)} \cdot c_{(OH-)} / c^2_{(H2O)}$
  e.g.: auto-dissociation of pure water $2H_2O(l) \leftrightarrow H_3O^+(aq) + OH^-(aq)$.
  pH<7 indicates an acidic solution, while pH>7 a basic solution. In general, the lower the pH the more heavy metals can be dissolved from the substrate into the solution.
- **Salinity**: Measure of the quantity of dissolved salts in water. It is formally defined as the total amount of dissolved solids in water in parts per thousands [‰] by weight when all the carbonate has been converted to oxide, the bromide and iodide to chloride, and all organic matter completely oxidized. Lakes are often classified according to their overall salinity; e.g. meso-, oligo-, polyhaline.
- **Trace Elements**: The growth of a plant is dependent upon the amount of "foodstuff" (trace elements) presented to it in minimum quantities; e.g. CO_2, PO_4^{3-}, NH_4^+, SO_4^{2-}, etc.

Physical properties of W.: The observable properties without transforming it into any other substance.

- **Absorption** of Light: Certain surfaces and colors absorb the visible spectrum of light. Water easily absorbs the UV-spectrum (wavelengths <350nm) and the IR-spectrum (wavelengths >800nm), leaving the PhAR spectrum almost untouched (400-750nm). Ice efficiently absorbs in the bluish spectrum (around 400nm: 1m thick ice absorbs 70%; whereas a 0.2m thick layer of snow up to 99%).
- **Albedo**: The fraction of light that is reflected by the surface of a lake or ocean; it changes accordingly when wind or ice-cover modulates or shields the surface. E_A, Emission from above
  Albedo = E_B/E_A [-] E_B, Emission from below

- **Attenuation** of Light: Reduction in light intensity caused by the absorption and scattering of light energy in water; i.e.: a lessening of the amplitude of a wave with distance from the origin. I_0, max. light intensity
Attenuation (A) = $100\cdot(1 - I_0/I_D)$ [%]suspended I_D, light intensity at a certain depth
Attenuation can empirically determined by using the **Secchi Disc**: A white disk used to measure the transparency of the water by observing the depth at which the disk disappears from the view.
- **Density**: Ratio of the mass to its volume: $\rho = m/V$ [kg/m^3]. Density of water is temperature dependent in that it increases with higher levels of salinity and is heaviest at a temperature of 4°. Density is a crucial factor for aquatic life in terms of sinking velocity, feeding techniques, etc. Freshwater is less dense than seawater.
- **Compensation Depth** - see there - ecological aspects.
- **Conductivity**: The intrinsic property of a substance to conduct electric current; reciprocal to resistivity [1/Ω]
- **Flow Patterns of Water**: The horizontal movement of water.
Laminar F.: Is the turbulence-free flow of fluid in a vessel or past a moving object; a parabolic gradient of relative velocity exists in which the fluid layers closest to the wall or body have the lowest relative velocity (with maxim speed at the center of a circular tube and zero at the borders). The resistance (drop in pressure) of laminar flow rises linear with speed. Lotic systems never reveal laminar flow.
Turbulent F.: As the flow speed of real fluids increases; its ability to follow the contours of a solid obstacle decreases; it tears away of the surface and forms a wave of turbulence, carrying away energy (flow pattern doesn't follow a parabolic graph anymore). Resistance of turbulent flow rises nonlinear with speed.
Reynold's Number: The tendency of a flowing gas or liquid to become turbulent is proportional to its velocity and density and inversely proportional to its viscosity; it indicates the change from laminar to turbulent flow. With increased speed, laminar flow sooner or later will change into a turbulent one: $R_N = \rho\cdot v_{AV}\cdot d/\eta$ [-]
ρ, density of water 1000 [kg/m^3]
v_{AV}, average velocity [m/s]
η, viscosity index [kg/s]
d, diameter [m]
- **Scattering** of Light in Water: Occurs when the scattering particles are much smaller than the wavelength of an incident light and have resonance at frequencies higher than the scattered light; the shorter the wavelength the more light is scattered. Scattering within the first few cm of the epilimnion quickly reduces photo-inhibiting UV-radiation. Scattering is the cause why daylight sky is blue (due to N_2, O_2-molecules). On the other hand, a red sunset occurs when the sun is already low in the sky, therefore the path through the atmosphere is considerably longer than at midday; more blue is scattered, leaving more and more red; furthermore long-waves bend better than short waves, if the sun is about to vanish beyond the horizon, in reality it already past the horizon, just the bent red long waves give us this illusion that it is still there.
Scattering of light in water is due to **seston** (suspended material like plankton, sediment particles, and DPOM); the higher the primary production, the more light is scattered, the more turbid the water appears.
Rayleigh's law: $i = a/\lambda^4$ [?]
a, absorption coefficient [?]
λ, wavelength [m]
- **Specific Heat Capacity**: The quantity of heat per unit mass required to raise the temperature by 1°C;
$c = Q/(m\cdot\Delta T)$ [J/(kg·K)];
A body of freshwater can store more heat than a body of seawater; consequently temperature extremes are less likely to occur in freshwater lakes.
- **Solar Radiation**: Emission and propagation of energy through space or through matter in the form of electro-magnetic waves; the solar spectrum (260 - 3000nm) reaches the earth's outer atmosphere with ≈ 1.39kW/m^2 (at an altitude of 80km), compared to approx. 500W/m^2 peak intensity of all radiative components and wavelengths penetrating the earth's surface (average solar radiation reaching the ground equals about 51%).
Black Body: A body that absorbs all the radiation incident upon it (eye). Good absorbers (bad reflectors) are also good emitters; e.g. the sun. A black pot filled with hot water looses heat (KE) faster than a white pot.
Black body radiation: $E = \sigma\cdot T^4$ [W/m^2]
σ, Stefan's const. $5.6703\cdot E^{-8}$ [W/(m^2·K^4)]
T, temperature [K]
Wien's displacement law: The wavelength at which the power is at maximum varies inversely with the temperature; the surface temperature of the sun is 6000[K] which peaks at λ_{max} = 483nm, according to the following equation:
$\lambda_{max} = 2.898\cdot E^{-3}$ [m·K]/T [m]
T, temperature [K]
- **Temperature**: The quantity that tells how warm an object is, with respect to some reference. A measure of the average kinetic energy per molecule in a substance, measured in [°C] or in [K].
Surface ice of a body of water forms only once the entire mass of water has been cooled down to 4°C. Thus, water organisms at the bottom of a lake will not die due to solidification of its watery body contents.

T. **Pattern**: The high heat capacity of water constitutes for a quite stable, oceanic climate at landmasses surrounded by the sea (surface water). Mixing of alternate water bodies in lakes are mainly due to density differences caused by temperature differences - which are a main cause for the eddies.
Thermocline: The vertical regions of greatest change in temperature. Vertical negative temperature gradient in some water layers is appreciably greater than the gradients above and below it; i.e. a layer in which such a gradient occurs. The principal thermoclines in lakes are either seasonal, due to heating of the surface water in summer or permanent (in the tropics - eddies). During the summer months, a thermocline is formed between epi-, and hypolimnion; whereas, during the winter it can be found at the surface (or below the ice cover).

- **Viscosity**: The internal resistance, or friction, offered to an object moving through a fluid [$N \cdot s/m^2$]. Cohesion and viscosity increase with falling temperature. Viscosity is crucial for both neuston and pleuston.
  Stokes Equation: Almost every planktonic organism is heavier than the surrounding aqueous environment.
  The Stoke's equation describes the relationship b/w the organisms density, its environment among other physical properties:

  $$v_s = \frac{2 \cdot g \cdot r^2}{9} \frac{(\rho_{org} - \rho_{H2O})}{\mu \cdot \phi} \quad [m/s]$$

g, gravitational constant	9.81 [m/s^2]
r, average radius of organism	[m]
ρ, density	[g/m^3]
μ, viscosity of water	[m]
ϕ, resistance of shape	[m/g]

  Inclusions like lipids and vacuoles, as well as turbulences within the water body significantly do affect an organisms overall density in that v_s tends to decrease.

Wave: A periodic disturbance that moves through or over the surface of a medium with a speed dependent upon the properties of the medium causing ridges, deformations, or undulations of the surface. In contrast to circulation and currents (aperiodic waves), periodic waves are not involved in active transports of masses.
Generative Forces (with thermal circulation and wind forces among the most important ones):

- **Pressure Gradient**: Geostrophic currents.??
- **Seiche**: Standing-wave oscillation of a lake that swings like a pendulum, after the cessation of the originating force, which may have been either seismic, atmospheric, wave-induced or tidal.
- **Tidal** F.: Alternating horizontal movement of water associated with the rise (flood) and fall (ebb) of the tide caused by celestial forces - only evident in very large lakes.
- **Thermohaline Circulation**: The circulation of water due to temperature differences; see there.
- **Tectonical** F.: A seismic wave, a Tsunami, is a long period wave produced by an earthquake or volcanic eruption - only evident in very large lakes.
- **Wind** F.: Waves generated by wind; the laminar flow of air over the water surface causes the atmospheric pressure to decrease, forcing the water level to localized elevations, creating a rippled surface. The stronger the wind forces, the higher the waves. Wave action in lakes is limited to the epilimnion.

Shallow Water Wave: When waves enter waters with a depth of less than 1/20 the wavelength. The orbits flatten (wave particles move in elliptical orbits) with depth due to interference from the seafloor. This interference changes both the speed and wavelength and height of the incoming wave; because the horizontal dimension of the orbit remains unchanged, but wavelength shortens along with increased height, the wave finally break when becoming too steep.
Wave Orbits: The path of a water molecule affected by wave motion. Waves posses potential energy (displacement of water above the sea level) as well as kinetic energy (due to the orbital motion of the water molecules). In deep water waves the orbit is nearly circular, and in shallow water waves, the orbit is nearly elliptical. The surface orbit is followed by a successive deeper wave orbit which decreases exponentially as one goes deeper.
The overall area covered by these orbits decrease exponentially:

$$A_Z = A_0 \cdot e^{-2 \cdot \pi \cdot z/\lambda} \quad [m^2]$$

A_0, cross area of initial orbit	[m^2]
z, order of the orbit	[-]
λ, wavelength	[m]

Trophic Interactions:

Decalcification: The process of removing Ca from a "hard water" lake.

- **Biogenic** D.: Autochthonous precipitation of calcium by certain algae; extreme exposure to sunlight, and lack of CO_2 trigger the production of Ca-crystals depositions [$Ca(HCO)_2$] during photosynthesis. Reversion of this process is brought about by an oversupply of dissolved CO_2 (acidification).

Biogeochemical cycles: The movement of chemical elements between organisms and non-living compartments of atmosphere, lithosphere, and hydrosphere. **Nutrient**: Any of the number of organic or inorganic compounds or ions used primarily in the nutrition of primary producers that move through the hydrosphere. N- and P- compounds, among others, are essential nutrients for the buildup of genetic material and protein synthesis.

- **Nitrogen Cycle**: Global bacterial conversion of nitrogen outweighs abiotic fixation by a ratio of 6:1. Nitrogen fixing bacteria convert atmospheric nitrogen (N_2) to inorganic forms useful to plants. Denitrifying bacteria convert some of useful fixed nitrogen back to atmospheric unusable form, completing the global cycle. Ammonium (NH_4^+), nitrate (NO_3^-), and nitrite (NO_2^-) are taken up as nutrients by plants and converted into organic compounds. These are consumed by animals and eventually by decomposing bacteria. The organic nitrogen compounds are converted back to ammonium, nitrite, and nitrate by other bacteria, completing the biological cycle.
  Ammonification: The conversion of organic nitrogen compounds, nitrate, or nitrite to ammonium under anaerobe conditions in the hypolimnion.
  Denitrification: Microbial reduction of nitrate to elemental nitrogen (N_2).
  Nitrification: The microbe mediated oxidation of ammonia to nitrate within the epilimnion.
  Nitrogenase: Fixation of atmospheric nitrogen by certain autotrophic bacteria which are equipped with a heterocyst.
  Free amino acids and proteins can be utilized by several microscopic organisms as a nitrogen source.
- **Phosphorous Cycle**: P in the form of inorganic phosphate (orthophosphate = PO_4^{3-}) is eroded from land soils and rocks and enters the lake. The phosphate is used by plants and converted to organic form (in DNA, RNA, ATP). Plant organic phosphate is transferred to animals and eventually to decomposer bacteria, which liberate the phosphate in inorganic form. Some phosphate becomes locked in lake-bed deposits (**sink**), leaving the biosphere until it is liberated by geologic uplift, erosion, or any other disturbing event.
  Phosphate Precipitation: In eutrophic waters, orthophosphate, in conjunction with AL_2^{3+}, Fe^{3+}, $3Ca^+$, and under basic conditions forms a indissoluble co-precipitate; thus, orthophosphate will sediemntate (be withdrawn from the epilimnion), resulting in an oligotrophic effect.
  In the epilimnion, Iron(III)-Hydroxy-Phosphate $Fe(OOH)\approx PO_4^+$ is formed once the partial pressure of O_2 reaches 0.5mg/L; as pO_2 falls to 0.1mg/L, the iron complex becomes reduced to Fe(II) which causes an accumulation of liberated phosphate ions - oligotrophy, usually occurs in the hypolimnion
  Soluble Reactive Phosphate (SRP): Particulate or colloidal bound phosphate that can be filtered out with filters about 0.1µm wide.
  Total Dissolved Phosphate (TDP): The amount of dissolved phosphate contained in a body of water; usually determined by oxidizing agents (acidic solutions).
  Total Phosphate (TP): The total amount of phosphate (SRP, TDP) within a body of water.

Energy Flow: The pattern of energy flow through a trophic compartment (organism) is outlined by the food uptake (U), ingestion (I), respiratory processes (R), metabolism (M), somatic and reproductive growth (Gs, Gr), liquid energy loss by excretion (E), and solid energy loss via feces (F).

Ingestion (I) $= M + F + Gr + E$

Production (P) $= I - (R + F + E) = M$

Assimilation (A) $= I - (R + F + E) = I - R - E = I - M$

Efficiency of Assimilation (Assimilation coefficient A_i) $= A\cdot 100/I$ [%]

Microbial Food Web (also known as the **Microbial Loop**): The food web made of microorganisms (viruses, heterotrophic bacteria, autotrophic picoplankton, protista, etc) that consume DOM (mainly in the form of DOC, i.e. carbon of phytoplankton, zooplankton, planktivores and herbivores) and convert it to POM; only POM can be utilized by the members of the classical (linear) food web (larger carnivores, fish, and mammals. The microbial loop interferes especially with the linear chain of consumers at the start of the food chain.

- **Heterotrophic Nanoplankton** (HNF): Bacteria usually reveal exponential growth, thus show a huge turnover capacity.

Organic Matter: Any carbohydrate molecule originating from biogenic processes.

- **Detritus**: **D**ead **o**rganic **m**atter (DOM) produced by the breakup of organisms, as small particles suspended in the water or resting on the bottom. In the pellagial, detritus derives from the food chain dominated by grazers, whereas the littoral is characterized by the detritus of the phytal. The profondal relies upon the particle rain of the trophogenic regions (epilimnion).
- **Dissolved** OM (DOM): Suspended organic material, such as carbohydrates, fatty acids, lipids, enzymes and vitamins of either alochtonous or autochtonous origin. One can speak of DOM once the average diameter is less than 0.1µm.
- **Lake snow**: Macroscopic particle rain of **d**ead **o**rganic **m**atter (DOM, >0.3mm) from the trophogenic regions (epilimnion) to the tropholytic regions of a lake. It consists mostly of algae, phyto- and zooplankton debris that are colonized by bacteria, fungi, and other consumers. It is similar to the phenomena of marine snow observed in marine environments.
- **Particulate** OM (POM): Organic matter composed of particles that are not superficially bound together, such as phosphorous, nitrogen or even entire microorganisms. One can speak of POM once the average diameter exceeds 0.1µm.
- **Seston**: To overall suspended material (dead or alive) in water; e.g. plankton, sediment particles, DPOM, etc.

Productivity (dynamics of): The formation of new organic substances in a body of water (littoral, profundal, etc.) over time; it is lowered by inefficiencies of the process itself; i.e. sedimentation, death, etc. that can not be detected directly; gross productivity can be summarized as:

$P_G = dB/dt = \Delta(B_0 + B_t)/dt = P_N - L$

B_0, biomass at t = 0 [kg]
B_t, biomass at t = 0+x [kg]
L, losses (theoretical)
P_N, net productivity

It can be quantified by executing cell count, chlorophyll-*a* levels, ATP, TOC (total organic C), etc.

- **Bacterial Productivity**: Neglecting the de-novo synthesis of certain amino acids by bacteria itself, autotrophic bacteria can contribute up to 20% to the euphotic PPR, and up to 30% of the total PPR. Growth rates can be monitored by using radioactive isotopes such as ^{1}H, ^{14}C, etc.
  In relation, oligotrophic waters have a higher bacterial activity than eutrophic waters. The activity of phages do not necessarily lower the productivity of bacteria. Sedimentation of bacteria does only occur in bacterial aggregations (individual cells do not sink - see Stoke's equation) or attached on heavier substrates.
- **Primary Productivity** (PPR): The rate at which biomass is produced per unit area, volume by plants, etc. According to ecophysiological principles, it fluctuates according to the dark and light reaction patterns of the autotrophic organism involved; i.e. sedentary aquatic organisms rely on the zonation of the water body (depth zone), while phytoplankton rely upon water mixing patterns (i.e. currents).
  Gross Primary Production (GPP): The amount of new carbohydrate material produced each day (or longer time interval) by plants of an ecosystem. Some of this is consumed by their own metabolic processes, while the excess material is considered to be NPP; permanent exposure to light will reveal the GPP (over a 24h cycle).
  Net Primary Production (NPP): The amount of new carbohydrates produced by plants, per unit time, in excess of their own metabolic needs; exposure to the natural over a time frame of 24h (diurnal-nocturnal rhythm) will reveal the NPP: $NPP = P_G - R$
  P_G, sum of anabolic (gross) productivity
  R, catabolic processes, respiration
- **Secondary Productivity** (SPP): The rate at which biomass is produced per unit area, or volume by heterotrophic organisms.
  $$SPP = A - R = \frac{n\cdot(w_1-w_2)}{t_2 - t_1}$$
  A, assimilation
  N, number of individuals
  w_x, weight at time x
  t_x, time
- **Transfer Efficiency**: The transfer of biomass from one trophic level to the next can be estimated by using the following rule of thumb:
  $$E_T = \frac{P_L\cdot 100}{P_{L-1}} \approx 5\text{-}20\%$$
  P_L, productivity at a trophic level
  P_{L-1}, productivity at the lower trophic level

Trophic Level: (Gk. trophos, feeder) A step in the movement of energy through an ecosystem, represented by a particular set of organisms (see ecological aspects - productivity).While the classic model of trophic levels dispays the linear relationship between autotrops, heterotrophs, carnivores, and top predators, modern models reveal a complex interwoven network where bacterial consumers can be found at any trophic level. In any case, the number of species per level reflect the stability of an ecosystem.

- **Autotrophic** (Level of Primary Producers) An organism that is independent of outside sources for organic food materials and manufactures its own organic material from inorganic sources.
- **Heterotrophic** (Level of Secondary Producers): An organism with a requirement for energy-rich organic molecules from outside (animals, fungi and most bacteria).

Often, the sum of productivities of several heterotrophic levels can exceed the overall productivity of the autotrophic producers; this obvious paradox is caused by the recycling of detritus by microscopic secondary producers such as zooplankton.

Turnover: The circulation of organic matter within an ecosystem over time. DOM of the trhophogenic layer of an eutrophic lake has a turnover period of only a few minutes, while the period of a secondary consumers, or top predators can reach weeks or even months.

Viral Loop: The cycle of production, consumption and sedimentation of virioplankton. Virus usually rest dormant on organic substrate until they come in contact with a bacteria which they can infiltrate (bactariophages inject nucleic acid into host); the injected genetic material causes synthetization of viral code while bacterial genome degenerates. In the final stages, assembly of new virus' within the host cell terminates with the death of the bacteria (lysis), and the release of new bacteriophages, which themselves infect other bacteria. The infected host bacteria, on one side, and predation, sedimentation of bacterial and viral detritus, on the other side form the framework of the entire loop.