Topic No.1

Introduction to Limnology

Freshwater systems – lakes, wetlands, rivers and streams, have been critical to the establishment of civilizations throughout human history. From ancient times, civilizations have been established based on their proximity to water. Water bodies are essential to humans not only for drinking but also for transportation, agriculture, energy production, industry and waste disposal. Contaminated runoff from expanding urban and agricultural areas, airborne pollutants and hydrologic modifications such as drainage of wetlands are just few of the many factors that continue to degrade surface waters. Determining which of these factors has the most significant influence on the quality of a water body requires knowledge about the interaction of the water body with its watershed and how the various inputs affect its physical, chemical and biological characteristics. One of the critical sciences required to understand these aquatic ecosystem interactions is called limnology.

The term Limnology was coined by Francois-Alphonse Forel (1841 – 1912) who established the field with his studies on Lake Geneva. Interest in the discipline rapidly expanded and in 1922 August Thienemann (a German Zoologist) and Einar Naumann (a Swedish Botanist) co-founded the International Society of Limnology (SIL, for originally Societas Internalis Limnologiae). Forel's original definition of limnology, oceanography of lakes was expanded to encompass the study of all inland waters.

Welch (1935) conceived the problem of "Biological productivity" as the central theme of Limnology. He defined Limnology as that branch of science which deals with all causal influences which determine it. According to Schwoerbel (1987), Limnology is the science of inland waters viewed as ecosystems together with their structures, materials and energy balance. Kiihnelt (1960) considered limnology as a sub set of ecology along with "Oceanography" (which is concerned with marine ecosystem) and "Epheirology" (which deals with terrestrial habitats). In short, Limnology is the study of all aquatic systems including lakes, wetlands, marshes, bogs, ponds, reservoirs, streams, rivers etc. with regard to their physical chemical and biological characteristics.

The term Limnology is derived from Greek word; Limne means lake and logos means knowledge. Limnology is often regarded as a division of ecology or environmental science. It is however, defined as "the study of inland waters" (running and standing waters fresh and sometimes saline; natural or manmade). This includes the study of lakes, ponds, rivers, reservoirs, swamps, streams, wet lands, bogs, marshes etc. Hence, it is commonly defined as that branch of science which deals with biological productivity of inland waters and with all the causal influences which determine it.

Biological productivity, as used in the above definition, includes its qualitative and quantitative features and its actual and potential aspects. Under the term inland waters are included all kinds or types of water – running or standing; fresh, salt or other physicochemical composition which are wholly or almost completely included within the land masses. Causal influences involve various factors – physical, chemical, biological, meteorological etc which determine the character and quantity of biological production.

Limnology encompasses an integration of physical, chemical, and biological components of inland aquatic ecosystems with the drainage basin, movements of water through the drainage basin, and biogeochemical changes that occur en route, and within standing (lentic) waters and exchanges with the atmosphere. The lake ecosystem is intimately coupled with its drainage area and atmosphere, and with its running (lotic) waters and ground waters that flow, and metabolize en route, components of the land being transported to the lake.

Topic No.2

Importance of limnology as a science

Although modern limnology encompasses the study of all inland waters, its development is particularly identified with the study of lakes. Much of the conceptual framework around which the science was built was derived from studies on lakes, and most of the early limnologists were lake scientists.

Limnology is the study of the chemistry, biology, geology, and physics of waters that are found within continents. In contrast, oceanography is the study of open ocean waters. Waters found within continents may be lakes, reservoirs, rivers, or wetlands (land where water covers the surface for at least part of the year) Although most limnologists specialize in freshwaters, the study of saline lakes, like the Great Salt Lake, also falls under the discipline of limnology.

One of the more important goals of limnology is providing guidelines for water management and water pollution control. Limnologists also study ways to protect the wildlife that lives in lakes and rivers as well as the lakes and rivers themselves. Some limnologists are working on construction of artificial wetlands, which could serve as habitats for a variety of animal and plant species and aid in decreasing water pollution.

Importance of limnology

- Limnology is important because it deals with the study with every part of the freshwater.
- It investigates the physical and the chemical quality of the fresh water.
- It studies about the biodiversity of the freshwater.
- It helps to develop the new scientific technology for the conservation of the freshwater.

In addition to scientific interest and basic knowledge, limnology can provide some important applications like,

- Planktonic successions
- Study of evolution of lakes and reservoirs
- Geomorphology

- Hydrodynamic and its effects.
- The ration of allochthonous (externally derived) to autochthonous (internally derived) material.
- Comparison between lakes and reservoirs

Today, limnologists focus much of their attention on integrating ideas from geology, physics, chemistry, and biology into understanding lakes and rivers. They also focus much attention on understanding how humans impact these important ecosystems.

Topic No.3

Water as medium of life

Water is medium of life. Without water life is impossible. About 71% of earth surface is covered with water. 97% of this water is saltwater present in oceans while only 3% is available as freshwater.

Importance of Water

- Water makes up about three quarters of human body, for good reason.
- Water is the body's transportation and sanitation system.
- Vital organs like brain, heart, lungs, digestive system, every major system in your body relies on water for cushioning and to maintain the proper balance of electrolytes.
- It maintains blood volume, regulates temperature, keeps the tissues in the eyes and mouth functioning properly, it dissolves waste products and carries them out of the body, and it delivers nutrients from food to all the body's tissues.
- Water is not only important for human beings but also plays an important role to balance the entire ecosystem by various ways:
    - By its presence in the atmosphere it absorbs the Sun’s heat.
    - The rain water scours the hills and carries the sediments into rivers, valleys etc.
    - Percolating water into rock crusts takes part in the formation of mineral deposits.
    - In Polar Regions, water in the form of the caps influences climatic and geographical changes.
- Water plays the most important role in agriculture. Agriculture is impossible without irrigation throughout the crop season. Irrigation ensures proper plant growth.
- Water is used in huge quantities in the industries like steel industry, chemicals, fertilizers, textiles, cement, electricity, petrochemicals and paper. Mining, food etc. these industries require water for following or the other reasons:

- Cooling.
- Generation of power.
- Cleaning purposes.
- Fire protection.
- Air conditioning.

- Thermal power plants also require large volume of water for the purpose of cooling and disposal of fly ash. Water is used in thermal power generation.
- Fish, wildlife and recreation facilities play an important role in nation's life and adequate water supply is vital for their continued development and important. Swimming, boating, fishing is the important outdoor recreational activities which are impossible without water.

Topic No.4

Physical properties of water

Some physical properties of water are,

Molecular shape

Polarity

Surface tension

Specific heat capacity

Density

Viscosity

Solubility

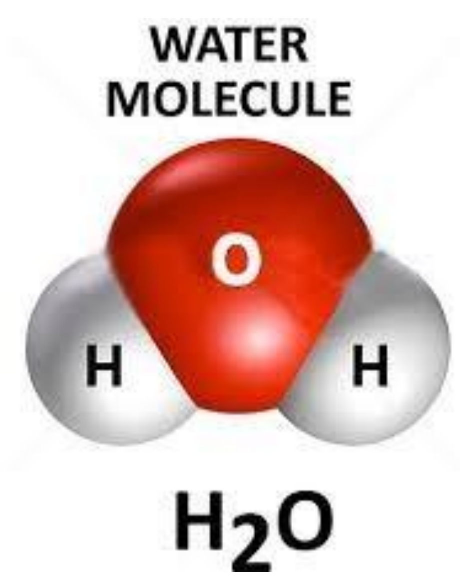
Dissolved Oxygen

Cohesion

Adhesion

Molecular shape and polarity:

The shape of each water molecule influences the way it interacts with other water molecules and with other substances. Water acts as a polar solvent because it can be attracted to either the positive or negative electrical charge on a solute. The slight negative charge near the oxygen atom attracts nearby hydrogen atoms from water or positive-charged regions of other molecules. The slightly positive hydrogen side of each water molecule attracts other oxygen atoms and



negatively-charged regions of other molecules. The hydrogen bond between the hydrogen of one water molecule and oxygen of another holds water together and gives it interesting properties, yet hydrogen bonds are not as strong as covalent bonds. While the water molecules are attracted to each other via hydrogen bonding, about 20% of them are free at any given time to interact with other chemical species. This interaction is hydration or dissolving.

Surface tension and cohesive properties:

Water shows cohesive properties. This allows long columns of water to be formed and drawn up in the vascular tissue of trees (and smaller plants). It is also responsible for surface tension where water meets air - an important feature for small pond insects, and in the functioning of lungs.

Specific heat capacity:

Water has a particularly high heat capacity - higher than any other common substance. This is the amount of heat (usually expressed in calories, kilocalories, or joules) needed to raise the temperature by one degree (usually expressed in Celsius or Kelvin). Specific heat takes mass into account. The specific heat of water is 1 calorie/gram °C = 4.186 joule/gram °C, This makes water useful for storing heat energy, and stabilizes temperature within bodies of water (ponds, lakes, seas) as well as the bodies of animals.

Dissolved Oxygen:

Oxygen saturation in water medium. Dissolved oxygen range for healthy biological system is, 5-12 mg/liter.

Density:

Mass a substance per unit volume. Liquid is more dense than ice, that's why ice floats on liquid water. The density of liquid water is maximum at 4°C

Viscosity:

The quantity of internal resistance in the fluid or simply the thickness of a fluid. Honey is more viscous than water because it is more thick and hence offer more resistance in flow than water.

Topic No.5

Chemical properties of water

Some chemical properties of water are,

- **pH**
- **Alkalinity**
- **Salinity**
- **Total dissolve solids**
- **Hardness**

pH

pH is a measure of how acidic/basic water is. The range goes from 0 - 14, with 7 being neutral. pHs of less than 7 indicate acidity, whereas a pH of greater than 7 indicates a base. pH is really a measure of the relative amount of free hydrogen and hydroxyl ions in the water. Water that has more free hydrogen ions is acidic, whereas water that has more free hydroxyl ions is basic. The pH of water determines the solubility (amount that can be dissolved in the water) and biological availability (amount that can be utilized by aquatic life) of chemical constituents such as nutrients (phosphorus, nitrogen, and carbon) and heavy metals (lead, copper, cadmium, etc.). For example, in addition to affecting how much and what form of phosphorus is most abundant in the water, pH also determines whether aquatic life can use it. In the case of heavy metals, the degree to which they are soluble determines their toxicity. Metals tend to be more toxic at lower pH because they are more soluble.

Alkalinity

Alkalinity is defined as the capacity of natural water to neutralize acid added to it. Total alkalinity is the amount of acid required to reach a specific pH (pH = 4,3 to 4,8). Total alkalinity includes Hydroxide alkalinity [OH^-], Bicarbonate alkalinity [HCO_3^-] and Carbonate alkalinity [CO_3^{2-}].

Salinity

A measure of total concentration of ions dissolved in water.

Fresh water: 0-0.5 ppt

Brackish water: 0.5-25 ppt

Saltwater: 25-35 ppt

Total dissolve solids

Total dissolved solids (TDS) is a measure of salt dissolved in a water sample after removal of suspended solids. TDS is residue remaining after evaporation of the water.

Hardness

Hardness is correlated with TDS (Total dissolved solids). It represents total concentration of Ca^{2+} and Mg^{2+} ions, and is reported in equivalent $CaCO_3$. Other ions (Fe^{2+}) may also contribute. Hardness expressed as mg/L $CaCO_3$ is used to classify waters from "soft" to "very hard". This classification is summarized in Table 2.2.

Relationship of Hardness Concentration and Classification of Natural water (F. Joseph; Jr. Malina)

Hardness as mg/L $CaCO_3$	**Classification**
0 - 60	Soft
61 - 120	Moderately hard
121 - 180	Hard
>180	Very hard

Hardness observed for streams and rivers throughout the world ranges between 1 to 1000 mg/L. Typical concentrations are 47 mg/L to 74 mg/l $CaCO_3$.

Topic No.6

Freshwater ecosystems

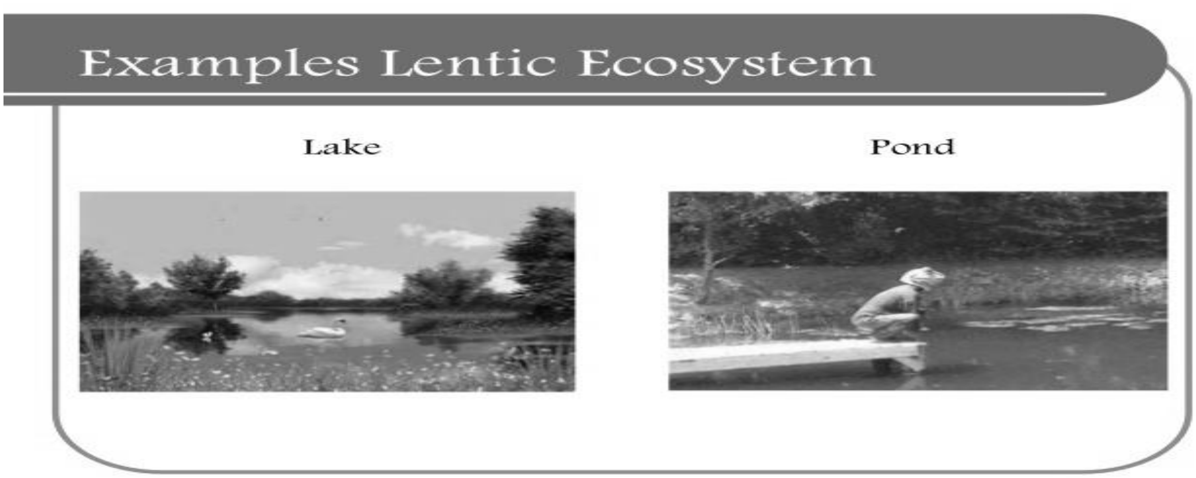
Freshwater ecosystems are a subset of Earth's aquatic ecosystems. They include lakes and ponds, rivers, streams, springs, and wetlands. They can be contrasted with marine ecosystems, which have a larger salt content. Freshwater habitats can be classified by different factors, including temperature, light penetration, and vegetation.

Freshwater ecosystems can be divided into lentic ecosystems (still water) and lotic ecosystems (flowing water).

1. Lentic ecosystems

A lake ecosystem includes biotic (living) plants, animals and micro-organisms, as well as abiotic (nonliving) physical and chemical interactions.

Lake ecosystems are a prime example of lentic ecosystems. *Lentic* refers to stationary or relatively still water, from the Latin *lentus*, which means sluggish. Lentic waters range from ponds to lakes to wetlands, and much of this article applies to lentic ecosystems in general. Lentic ecosystems can be compared with lotic ecosystems, which involve flowing terrestrial waters such as rivers and streams. Together, these two fields form the more general study area of freshwater or aquatic ecology.



2. Lotic ecosystems

The ecosystem of a river is the river viewed as a system operating in its natural environment, and includes biotic (living) interactions amongst plants, animals and micro-organisms, as well as abiotic (nonliving) physical and chemical interactions.

River ecosystems are prime examples of lotic ecosystems. Lotic refers to flowing water, from the Latin lotus, washed. Lotic waters range from springs only a few centimeters wide to major rivers kilometers in width. Much of this article applies to lotic ecosystems in general, including related lotic systems such as streams and springs. Lotic ecosystems can be contrasted with lentic ecosystems, which involve relatively still terrestrial waters such as lakes and ponds.

Original efforts to understand and monitor freshwater ecosystems were spurred on by threats to human health (ex. Cholera outbreaks due to sewage contamination). Early monitoring focused on chemical indicators, then bacteria, and finally algae, fungi and protozoa. A new type of monitoring involves differing groups of organisms (macro invertebrates, macrophytes and fish) and the stream conditions associated with them.

Topic No.7

<u>Lotic-system: Streams and Rivers</u>

The study of freshwater is known as limnology. Those water bodies that hold running water are termed as lotic water bodies. Rivers and streams rarely display the vertical stratification patterns found in standing bodies of water because of their turbulent flow. Although slight differences in temperature can exist between the surface and bottom waters of deep lotic systems, the greatest changes take place as water moves downstream. Flowing water systems frequently possess greater habitat heterogeneity than lentic systems. They also are more permanent ecosystems on a geological or evolutionary scale. Both heterogeneity and permanence tend to increase species diversity. The area drained by a stream and all of its tributaries is called its watershed. Any rain that falls within the watershed will pass through the main stream channel. Examples of lotic water bodies are

1. Rivers
2. Streams
3. Springs

1. Rivers

Water flow is the key factor in lotic systems influencing their ecology. The strength of water flow can vary between systems, ranging from torrential rapids to slow backwaters that almost seem like lentic systems. The speed of the water flow can also vary within a system and is subject to chaotic turbulence. This turbulence results in divergences of flow from the mean downslope flow vector as typified by eddy currents.

2. Streams

A stream is a body of water with a current, confined within a bed and banks. A shallow fast flowing water body smaller than rivers. Streams are important as conduits in the water cycle, instruments in groundwater recharge, and corridors for fish and wildlife migration.

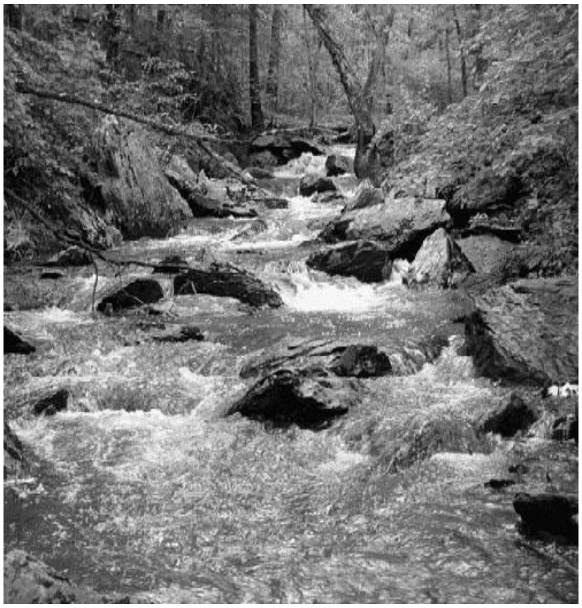
3. Springs

A spring is a water resource formed when the side of a hill, a valley bottom or other excavation intersects a flowing body of groundwater at or below the local water table, below which the subsurface material is saturated with water. A spring is the result of an aquifer being filled to the point that the water overflows onto the land surface. A freshwater body in which water flows out of the ground.

Topic No.8

Streams

A small, shallow and fast moving water body that supports variety of aquatic flora and fauna. A watershed, or drainage basin, is the land area that delivers runoff, sediment, and dissolved substances to a stream. In many areas, streams begin in mountainous or hilly areas that collect and release water falling to the earth's surface as rain or snow melts during warm seasons. Streams have low depth and narrow banks. Streams are important as conduits in the water cycle, instruments in groundwater recharge, and corridors for fish and wildlife migration. The biological habitat in the immediate vicinity of a stream is called a riparian zone. The study of streams and waterways in general is known as surface hydrology and is a core element of environmental geography.



Streams receive nutrients from Falling leaves, Animal, feces, insects and Biomass washed into streams during heavy rainstorms or by melting snow. Thus, the levels and types of nutrients in a stream depend on what is happening in the stream's watershed. Streams receive their water from Precipitation Melting snow and Groundwater. They lose water by evaporation sinking into the ground discharge at their terminus or mouth.

The velocity of a stream depends on following factors

- Volume of water
- Stream channel width and depth
- Slope or gradient of stream

Topic No.9

<u>Stream order</u>

A stream order assigns numerical designations that indicate where in a watershed drainage system a certain stream segment lies.

- First order stream
- Second order stream
- Third order stream and so on……….

First order streams

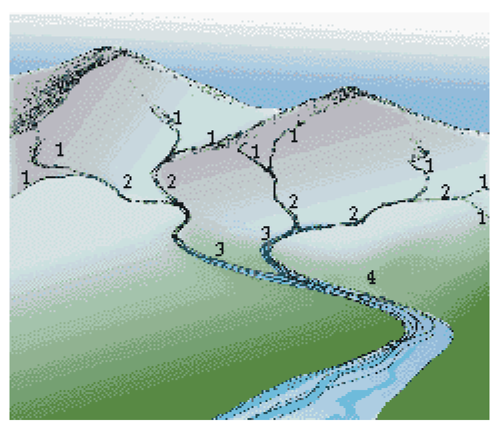
It can be thought of as "starter" streams. Most often they are located in the upper parts of a watershed, and water enters them from over land, seeping groundwater, or springs rather than by flowing in from another stream.

Second order streams

They are fed by two or more first order streams.

Third order streams

They are formed by the joining of two or more second order streams. Stream orders above 7 are considered large rivers. The highest order stream in North America, the Mississippi River, is a 12th order stream.



Streams higher up in a watershed tend to be smaller and of lower order because they are the recipients primarily of seeps and springs and only limited over land flow.

The higher the stream order--the more streams that feed into it--the larger the size of the stream. In general, the higher the order (for example, 3rd order versus 1st order), the more likely the stream is to be influenced by events occurring higher up in the watershed. This also means the more of the watershed you control, the greater the impact--positive or negative--your management decisions have.

Topic No.10

Rivers

Small streams join to form rivers, and rivers flow downhill to the ocean. Rivers and streams are powerful transporting agents as they roll and push material on their bed down the channel. The suspended matter gives river water a muddy look. A river is a natural flowing watercourse, usually freshwater, flowing towards an ocean, sea, lake or another river. In some cases a river flows into the ground and becomes dry at the end of its course without reaching another body of water. Small rivers can be referred to using names such as stream, creek, brook, rivulet, and rill. Rivers are part of the hydrological cycle. Water generally collects in a river from precipitation through a drainage basin from surface runoff and other sources such as groundwater recharge, springs, and the release of stored water in natural ice and snowpacks (e.g. from glaciers). Potamology is the scientific study of rivers while limnology is the study of inland waters in general.

The downward flow of surface water and groundwater from mountain to the sea typically takes place in three zones characterized by different environmental conditions:

- Source zone
- Transition zone
- Floodplain zone

Source zone:

Source zone containing mountain (headwater) streams. Headwaters are often small streams with cool waters because of shade and recently melted ice or snow. They may also be glacial headwaters, waters formed by the melting of glacial ice. Headwater areas are the upstream areas of a watershed, as opposed to the outflow or discharge of a watershed. The river source is often but not always on or quite near the edge of the watershed, or watershed divide.

Transition zone:

- Transition zone containing wider, lower-elevation streams.

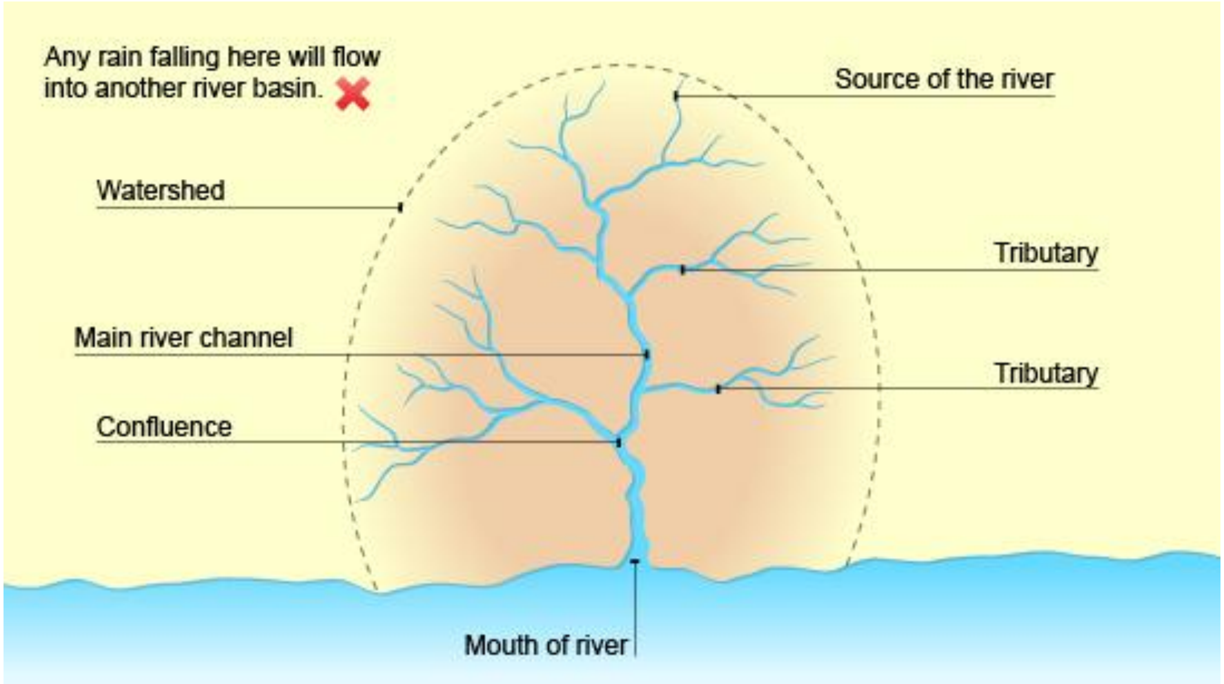
Floodplain zone:

- Floodplain zone containing rivers, which empty into the ocean.

Topic No.11

Drainage Basin

A drainage basin is an area of land that contributes the water it receives as precipitation to a river or network of rivers. Drainage basins are defined by topographical features, called drainage divides, which determine the direction the water flows. Drainage basins have many different characteristics that influence how quickly or slowly the main river within them responds to a period of intense rainfall.



- **Drainage basin** - the area of land drained by a river.
- **Catchment area** - the area within the drainage basin.
- **Watershed** - the edge of highland surrounding a drainage basin. It marks the boundary between two drainage basins.
- **Source** - The beginning or start of a river.
- **Confluence** - the point at which two rivers or streams join.
- **Tributary** - a stream or smaller river which joins a larger stream or river.
- **Mouth** - the point where the river comes to the end, usually when entering a sea.

Topic No.12

Morphology and flow in rivers

The terms **river morphology** is used to describe the shapes of river channels and how they change in shape and direction over time.

The study of river morphology is accomplished in the field of **fluvial geomorphology**, the scientific term.

Fluvial geomorphology is the study of the form and function of rivers/streams and the interaction between rivers/streams and the landscape around them.

The fluvial system of the river valley can be divided into three main zones.

Fluvial geomorphology is the study of the form and function of rivers/streams and the interaction between rivers/streams and the landscape around them.

The fluvial system of the river valley can be divided into three main zones.

Fluvial geomorphology

An erosional zone

A transport zone

A depositional zone

The three zones of a fluvial system

Erosional zone

In the first or upper zone the erosional process predominates and the stream and riverbeds are generally degraded. The streams join together and their slopes are generally steep. The bed material is characteristically composed of gravels.

Transport zone

The second (middle) zone is considered as near equilibrium condition between the inflow and outflow of water and sediment. The bed elevation in this equilibrium zone is fairly constant and the river generally flows in a single channel.

The sediment material generally composes gravels and sands of various sizes.

Depositional zone

The lower zone is characterized by net sedimentation and river bed aggradations. There is branching of the river into channels and the slope of these channels is rather flat. The bed material generally composes of fine sand to silt and clay.

The river's mouth is classified into two types:

1) Delta
2) Estuary

Delta:

Land formed by the material accumulated by the river into contact with the sea.

Estuary:

The place where the river comes into contact with the sea, where sea water enters into the mouth of the river. The mix water is now called estuarine water.

Topic No.13

Channel Morphology

The basin or valley trough containing the flowing water is the stream or river channel. The channel is described physically in terms of length, width, depth, cross-sectional area, slope etc. The channel is usually bordered on one or both sides by a flat area called the **flood plain**. Much of the soil of the flood plain is connected hydrologically to the water of the channel.

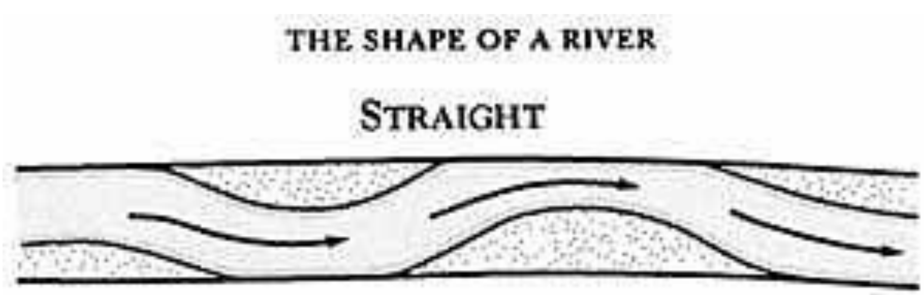
River channels vary greatly in cross-sectional size and shape but are usually bounded by defined banks which separate the channel from the floodplain or valley side. The bankfull dimensions of a channel combine with the velocity of the flow to determine the discharge it can convey. In general, discharge increases with increasing catchment area, and the width and depth of the channel and the velocity of the water also increase downstream. Channel dimensions adjust through erosion and deposition so that the channel can convey all but the highest flows it experiences. Width is easier to adjust than depth and flow velocity, so channel widening or narrowing is a common response. Local features such as bedrock help to determine whether such change occurs.

The forms of river channels are,

- Straight
- Meandering
- Braided

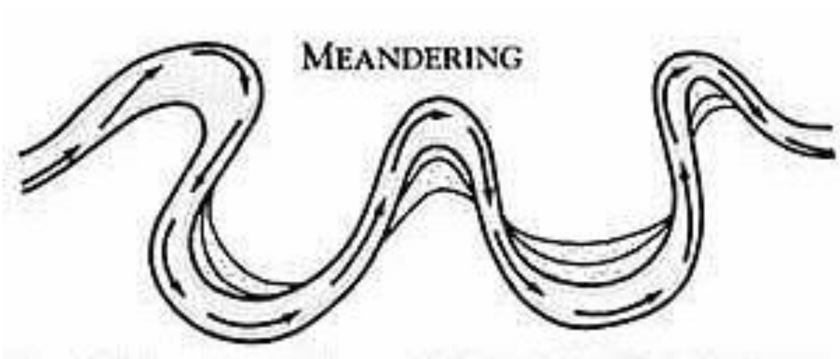
Straight channel

Straight stream channels are rare and are found in the most tectonically incised/active areas. Even in straight channel segments water flows in a sinuous fashion.



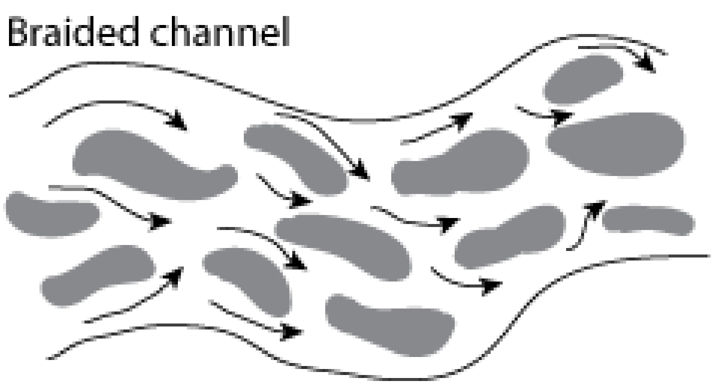
Meandering channel

A meandering channel is one that takes twists and turns over its length. Meanders are bends in a river that form as a river's sinuosity increases



Braided channel

Develops when a stream channel is divided into several smaller ones by the accumulation of in-channel deposits. Sand or gravel bars accumulate subdividing the flow of water into many smaller channels.



Topic No.14

River continuum concept

The river continuum concept, first proposed by Vannote and some others in 1980, provides a model of changes that might take place as water travels from headwater streams to larger rivers.

The RCC proposes a progressive shift in following parameters from headwaters to down water,

Physical gradients and energy inputs

Trophic organization

Biological communities

The River Continuum Concept is based on the idea that a watercourse is an open ecosystem that is in constant interaction with the bank, and moving from source to mouth, constantly changing.

Living communities and food types

The continuous differences of properties within the river are dependent primarily on the specific composition of the organisms in different sections of the water. Throughout the continuum of the river, the proportion of the four major food types; shredders, collectors, grazers (scrapers) and predators changes.

Shredders

Shredders are organisms that feed off of coarse particulate organic material (CPOM) such as small sections of leaves. They ingest the organic matter along with volunteer organisms (fungi, microorganisms) attached to the source. The preferred size of the CPOM is about one millimeter. Therefore shredders must break it up into a finer particulate. In the process of shredding, much of the now finer organic matter is left in the system, making its way further downstream.

Some common shredders include the Mayfly (Ephemeroptera), Odonata (damselflies) and stone fly (Plecoptera) larvae.

Collectors

Collector organisms are designated by their use of traps or other adaptive features to filter and catch organic matter. The preferred particle size for collectors lies between 0.5 and 50 micrometers. This group includes fly larvae, nematodes, and many other animal groups.

Grazers

The grazers (scrapers) feed off of periphyton that accumulates on larger structures such as stones, wood or large aquatic plants. These include snails, caddisflies (Glossosoma genus), and other organisms.

Topic No.15

Streams communities

Life in First-and second-order streams:

In the headwaters of a stream the water is shallow, the stream bottom is often rocky, and there are few aquatic plants. A lack of food limits the number of animals that can live there. In early order streams the benthic community of organisms, called benthos, is a key part of the food web. These include benthic macro invertebrates, such as mussels, aquatic insects, and other invertebrates visible without the aid of a microscope. Because there is little aquatic plant growth at the headwaters, animals at the bottom of the food web depend on the leaves, stems, and animals that may fall into the stream from the land. Aquatic insects, such as stonefly nymphs, chew and tear leaves and stems into tiny bits. They are called shredders. Small pieces not eaten by shredders are eaten by filtering and gathering collectors. Grazers (snails, for example) appear further downstream as the channel widens. Here sunlight strikes the stream bottom allowing algae to grow on rocks and plant stems. Grazers feed on the algae. Productivity increases as you go downstream. Food becomes more abundant and diverse, and so does the aquatic community. Most fish that live in headwater streams are small predators such as darters or minnows that are able to hug the bottom and keep from being washed downstream. They feed on smaller animals, such as aquatic insect nymphs and larvae. Since the fish also eat shredders and collectors, they search for areas where there are lots of these kinds of insects.

Life in Third- through fifth-order streams:

Mid-level streams have both rooted and floating aquatic plants and algae. In these larger streams more types of animals have niches in which to live. Grazers such as snails and water pennies eat the growing number of plants. Collectors increase with the varied plant life. As the plant diversity increases, shredders begin to decrease. A large variety of fish species live in the deeper and more varied mid-level streams.

When two streams come together, the waters mix and flow downstream together. Individual characteristics of the streams and nutrients from each watershed combine and form a still larger stream or river.

Life in High-order streams:

In very large rivers, few rooted plants may grow because the water is too deep and turbid (cloudy). Here, there are more collectors than shredders. One major group of collectors in big rivers is mussels living in the river's benthic zone. Fish in large rivers are also an important part of the food web. Catfish species represent a variety of feeding behaviors. Some species tend toward being scavengers, others omnivores or predators. Other fish such as suckers may prey on small mollusks. Predators such as sunfish may specialize in eating insects, while others such as the spotted bass consume smaller fish. Predators range in size from tiny zooplankton to 300 pound alligator gar. Otters are small carnivorous mammals that are often the top predators in streams and feeds on mussels, fish, turtles, frogs, etc.

Topic No.16

Lentic system: Lakes and ponds

Standing bodies of freshwater that supports variety of life. Wind action is very vital in these water bodies because it increases the content of dissolve oxygen that is necessary for the aquatic life in these water bodies. A lentic water bodies includes biotic (living) plants, animals and micro-organisms, as well as abiotic (nonliving) physical and chemical interactions.

Examples of such water systems are

1. Ponds

2. Lakes

3. Wetlands

The lentic water bodies possess following zones

1. Littoral zone

2. Limnetic zone

3. Profundal zone

4. Benthic zone

Littoral zone:

The littoral zone adjoins the shore (and is thus the home of rooted plants) and extends down to a point called the light compensation level, or the depth at which the rate of photosynthesis equals the rate of respiration. Within the littoral zone producers are of two main types: rooted or benthic plants, and phytoplankton (plant plankton) or floating green plants, which are mostly algae.

Limnetic Zone:

The limnetic zone includes all the waters beyond the littoral zone and down to the light compensation level. The limnetic zone derives its oxygen content from the photosynthetic activity of phytoplankton and from the atmosphere immediately over the lake's surface. The atmospheric source of oxygen becomes significant primarily when there is some surface disturbance of water caused by wind action or human activity.

Profundal Zone:

The bottom and deep water area of a lake, which is beyond the depth of effective light penetration, is called the pro-fundal zone. In north-temperate latitudes, where winters are long and severe, this zone has the warmest water (4°C) in the lake in winter and coldest water in summer.

Benthic Zone:

The benthic zone is the ecological region at the lowest level of a body of water such as an ocean or a lake, including the sediment surface and some sub-surface layers. Organisms living in this zone are collectively called the benthos, e.g. the benthic invertebrate community, including crustaceans and polychaetes. The organisms generally live in close relationship with the substrate bottom and many are permanently attached to the bottom.

Overturn

The mixing of water from the bottom of the lake with the water close to the surface of lake. This occurs during spring and fall. Lake Overturn enhances the dissolve oxygen content of lake that is necessary for survival of life present in the lake water.

Topic No.17

Lakes

Lakes are large natural bodies of standing freshwater formed when precipitation, runoff, or groundwater seepage fills depressions in the earth's surface. A lake is an area of variable size filled with water, localized in a basin that is surrounded by land, apart from any river or other outlet that serves to feed or drain the lake. Lakes lie on land and are not part of the ocean (except for sea lochs in Scotland and Ireland), and therefore are distinct from lagoons, and are also larger and deeper than ponds, though there are no official or scientific definitions. Lakes can be contrasted with rivers or streams, which are usually flowing. However most lakes are fed and drained by rivers and streams.

Lake formation

Natural lakes are generally found in mountainous areas, rift zones, and areas with ongoing glaciation. Other lakes are found in endorheic basins or along the courses of mature rivers. In some parts of the world there are many lakes because of chaotic drainage patterns left over from the last Ice Age.

Deep lakes normally consist of four distinct zones

1. Littoral
2. Limnetic
3. Profundal
4. Benthic

1) Littoral zone:

The littoral zone adjoins the shore (and is thus the home of rooted plants) and extends down to a point called the light compensation level, or the depth at which the rate of photosynthesis equals the rate of respiration. Within the littoral zone producers are of two main types: rooted or benthic plants, and phytoplankton (plant plankton) or floating green plants, which are mostly algae.

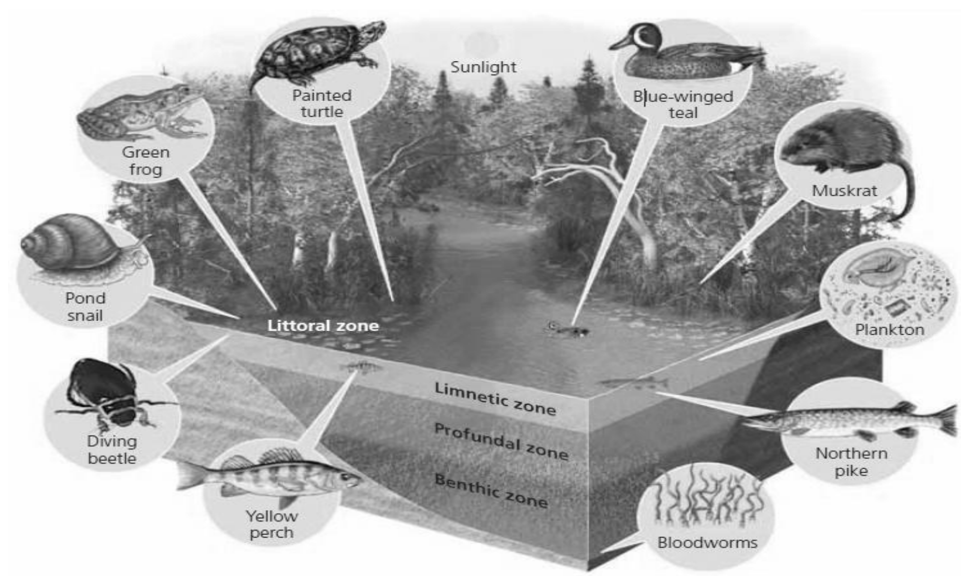
2) Limnetic Zone:

The limnetic zone includes all the waters beyond the littoral zone and down to the light compensation level. The limnetic zone derives its oxygen content from the photosynthetic activity of phytoplankton and from the atmosphere immediately over the lake's surface. The atmospheric source of oxygen becomes significant primarily when there is some surface disturbance of water caused by wind action or human activity.

3) Profundal Zone:

The bottom and deep water area of a lake, which is beyond the depth of effective light penetration, is called the pro-fundal zone. In north-temperate latitudes, where winters are long and severe, this zone has the warmest water (4°C) in the lake in winter and coldest water in summer.

4) Benthic Zone:



The benthic zone is the ecological region at the lowest level of a body of water such as an ocean or a lake, including the sediment surface and some sub-surface layers. Organisms living in this zone are collectively called the benthos, e.g. the benthic invertebrate community, including crustaceans and polychaetes. The organisms generally live in close relationship with the substrate bottom and many are permanently attached to the bottom.

Topic No.18

<u>The origin of lakes</u>

The **study of geomorphology** contributes significantly to understanding the origin of lakes and the dynamics of the formative processes of lake ecosystems (Swanson, 1980). **Morphology,** the study of lake shapes, is related to the origins of each system.

Morphometry deals with the quantification of these forms and elements. Lake morphology and morphometry basically depend on the processes from which lakes originated. Natural lakes, rivers, streams and reservoirs have a short lifespan from the geological point of view. The disappearance of lakes can be the object of prognosis. Some are very old, and the history of the events that occurred in the water basin and the lake itself is recorded in the sediments. These sediments can be dated with techniques that determine naturally occurring 14C activity. Countless fragments of undecomposed aquatic organisms and vegetation can be used to determine the sequence of events occurring in lakes: the remains of **diatoms** and zooplankton, the remains of vertebrates and pollen in the sediments. These fragments can also provide precise information on the changes of vegetation in the drainage basin over geological time. Lakes that were formed from specific geomorphological events in certain geographical areas have similar characteristics and are therefore grouped into **lake districts**. Although these characteristics are similar, there are differences in the **morphometry**, **productivity** and **chemical composition** of the water. Comparative studies of lakes in the same district and between different lake districts allow for regional classification. For example, in the **lakes of the Medio Rio Doce** in eastern Brazil, the process that originally formed the lakes is probably the same (De Meis and Tundisi, 1986), but considerable differences exist among the lakes in terms of morphometry, productivity, and chemical composition of water. These differences are due to the presence of relatively ancient rivers and streams in the aquatic system that gave rise to the lakes.

Lakes are also referred to as **lentic systems** (from the Latin *lentus*, meaning *lens*). The **geomorphology** (basin structure) of lakes plays a significant role in establishing the physical, chemical and biological conditions, whose series of events, given the limits of the climatic conditions in the lacustrine basin, largely depend on the basic operating mechanisms provided by the initial morphometric and morphological conditions established by the geomorphological pattern. The influx of nutrients, stratification, **thermal de-stratification** and **retention time** all depend on the lake's geomorphology.

The rivers that form a hierarchical hydrographic system comprise the **hydrographic network** and occupy a **drainage basin**, the territorial expanse of land bathed or traversed by a hydrographic network (Ab'Saber, 1975). The drainage basin may cover tens of thousands or millions of km2 in area. The localization of lakes in the original fluvial system leads to a discussion of the most common types of flow that occur.

The principal forms of hydrographic networks are categorized in several **drainage patterns** important in characterizing the types of regional evolution of the networks of rivers and the interrelationships between climatic factors, rock type, and the nature of terrains. Drainage patterns also provide basic information on the processes of formation of lakes in the regional context. Drainage basins, which are regional domains of hydrographic networks, can be classified based on the destination of the running water.

According to the original definition by Forel (1892), a lake is a body of stationary water, occupying a given basin and not confluent with the ocean. Several authors make the distinction between lakes, ponds, wetland areas, coastal lagoons and fluvial ponds adjacent to large, medium or small rivers (from a few square meters to tens or hundreds of thousands or millions of square kilometres). All inland water systems originated from a variety of natural processes and diverse formative mechanisms that vary from region to region and from one geologic era to another. Hutchinson (1957) identified 76 types of lakes grouped into 11 types of formation (see Chart 3.2). Other authors, such as Bayly and Williams (1973), listed morphogenetic classifications of lakes based on regional experiences. Bayly and Williams' classification, for example, is based on Australian lakes. In addition classifying lakes based on **geomorphology**, it is important to consider the continuity or **intermittence** of systems, lakes with wet seasons and extremely irregular flooding, wetland areas, flood-plains and channels of rivers, lakes, and coastal lagoons, perennial or intermittent lagoons that are unconnected to coastal waters or permanently connected through channels. All inland water systems are subject to a continuous process of change produced by the contribution of the respective drainage basins, and therefore are transitory features in the landscape.

Inland water systems contain:

- Sediments from tributaries of the water basin (linear and **laminar**, or layered, erosion) or from diffuse drainage.
- Material accumulated through transport by wind.
- **Deposits** from wind and tide activity.
- Structured biological material deposited in lakes (remains containing carbonates, phosphorus).

The average lifespan of natural lakes and artificial reservoirs vary according to their volume, area (lake) or area of drainage (reservoir), maximum and average depth, retention time of water, the morphometry and morphology of the drainage basin and the lake, and also of the reservoir.

Lakes are formed by the action of following process,

- **Glaciation**
- **Tectonic activity**
- **Volcanic activity**
- **Biological activity**

Topic No.19

Lakes formation by Glaciers

Glaciation is the formation, movement and recession of glaciers. Glaciation was much more extensive in the past, when much of the world was covered in large, continental ice sheets. Although several geological phenomenon account for the formation of numerous lakes on Earth, most lakes were formed as a result of glacier activity. Earth's glacial ice formed and extended into what is now Canada, the northernmost United States, and northern Europe. As the heavy, thick ice pushed along, it scoured out top soil, creating crevices in the former landscape. Glacial growth peaked about 20,000 years ago, after which time the ice slowly began to melt. As the ice melted, the glaciers retreated, but the basins formed by glaciers remained and filled with water from the melting glaciers. Lake basins formed at the edge of glaciers were generally not as deep as basins underneath glaciers. The shallower lakes are called ice-block or depression lakes; the lakes formed under glaciers are called ice-scour lakes.

Alpine Glaciation

Glaciers formed in mountainous regions of high elevation. They are confined to a valley and flow downhill due to gravity. Large ice masses often accumulate in bowl-shaped hollows called cirques, which are located near the peaks of mountainous regions in areas of heavy precipitation and low temperatures. As the ice in the cirque becomes plastic, it begins to flow down the mountainside, forming long, narrow rivers that comprise alpine, or valley, glaciers. This type of glaciation is usually associated with erosional features; although the formation of depositional features is also possible.

Glacial till or glacial drift

Glacial drift is sedimentary material that has been transported by glaciers. It includes clay, silt, sand, gravel, and boulders. Glaciers are found in the cryosphere regions of the Earth where the temperature remains below the freezing point of water. Although glacial ice is mainly found in the Polar Regions today, evidence suggests that glaciers covered a larger area of the Earth's surface in the past. Due to fluctuations in the Earth's climate, its topography has changed over time causing erosional and depositional processes by glaciers. Glaciers are capable of transporting vast amounts of sediment ranging in size from large house-sized boulders to fine-grained clay-sized material as they are very solid. The sediment can be found either on the surface of the glaciers or embedded within it.

There are two types of glacial drifts:

- Stratified drift

  This is sediment deposited by glacial melt water that is sorted and layered. It includes rivers, lakes and marine deposits.

- Glacial marine drift

  Rock debris that is deposited on the sea floor or lake bed as an unsorted chaotic deposit when glaciers reach oceans or lakes as large icebergs and melt over time.

Kettle pond

A depression in a glacial outwash drift made by the melting of a detached mass of glacial ice that became wholly or partly buried. The occurrence of these stranded ice masses is thought to be the result of gradual accumulation of outwash atop the irregular glacier terminus. Kettles may range in size from 5 m (15 feet) to 13 km (8 miles) in diameter and up to 45 m in depth. When filled with water they are called kettle lakes. Most kettles are circular in shape because melting blocks of ice tend to become rounded; distorted or branching depressions may result from extremely irregular ice masses.

Alluvial Dam

The accumulation of sediment (mud, sand, etc.) deposited by fresh running water into a channel: The alluvial deposits are controlled by channels, vegetation covers, channel densities, sources of geology, climates, and dirt surface deformations.

Plunge basin

A depression that is created by the action of falling water from waterfalls. As the glaciers melt they released water that falls and creates a basin. A basin that is developed beneath the falling water. In some instances the depth of a plunge basin may nearly equal the height of the cliff causing the falls. Plunge pools eventually cause the collapse of the cliff face and the retreat of the waterfall. Retreat of waterfalls is a pronounced feature in some places.

Topic No.20

Lakes formation by Tectonic activity

The lake is formed by movements of the Earth's crust, such as faults that result in depressions. They are often formed in rift valleys (Graben). The basin created by broken earth crust is known as Graben and it can host a lake.

Due to the warping (simple deformation), subsidence (sliding downwards), bending and fracturing (splitting) of the earth's crust, tectonic depressions occur. Such depressions give rise to lakes of immense sizes and depths. They include Lake Titicaca, and the Caspian Sea.

When two lithospheric plates are rubbing against each other by travelling in opposite directions, the fault that separates them is called a strike-slip fault. This motion tends to fracture and pulverize the rocks along the fault. These fractured rocks are then easier for water to erode than the surrounding rock, leading to linear depressions along the fault trace, which can then easily fill with water. The term for these water-filled depressions along the path of a fault is "sag pond". A good example is Lake San Andreas south of San Francisco.

Rift valley lakes

A rift valley is formed when two blocks of earth move apart letting the 'in between' block slide downwards. Or, it's a sunken land between two parallel faults. Rift valleys are deep, narrow and elongated. Hence the lakes formed along rift valleys are also deep, narrow and very long. Water collects in troughs (Valley in the rift) and their floors are often below sea level. The best known example is the East African Rift Valley which runs through Zambia, Malawi, Tanzania, Kenya and Ethiopia, and extends along the Red Sea to Israel and Jordan over a total distance of 3,000 miles. It includes such lakes as Lakes Tanganyika, Malawi, Rudolf, Edward, Albert, as well as the Dead Sea 1,286 feet below mean sea level, the world's lowest lake.

Lake Baikal

Lake Baikal is the largest freshwater lake in the world (by volume) and the world's deepest lake found in Russia. It is 1741-meter deep and a host to 2000 species of plants and animals. Lake Baikal is considered one of the clearest lakes in the world, according to CNN Traveler. During the summer, when the lake is full of melted ice from the Siberian mountains, it is sometimes possible to see more than 130 feet (39 m) down. The stunning clarity is the result of the melted ice's purity, plankton that eat floating debris and a lack of mineral salts in the lake.

About 80 percent of the more than 3,700 species found at Lake Baikal are endemic, meaning they are found nowhere else on Earth. Other land-based species around Lake Baikal include bears, reindeer, elk, wild boar, Siberian roe deer, polecats, ermine, sable and wolves. American minks, imported from Canada, also live around Lake Baikal, according to Baikal World Web. More than 50 species of fish live in Lake Baikal, according to Baikal World Web. Aquatic invertebrate species include more than 100 species of flat worms, more than 700 species of anthropods (insects, arachnids and crustaceans) and more than 170 species of mollusks. These invertebrates all help purify the water.

Topic No.21

Lakes formation by Volcanic activity

During a volcanic explosion the top of the cone may be blown off leaving behind a natural hollow called a crater. This may be enlarged by subsidence into a caldera. These depressions are normally dry, bounded by steep cliffs and roughly circular in shape.
In dormant or extinct volcanoes, rain falls straight into the crater or caldera which has no superficial outlet and forms a crater or caldera lake. The outstanding ones are the Crater Lake in Oregon, U.S.A. which in fact occupies a caldera; Lake Toba in northern Sumatra and Lake Avernus near Naples.

In volcanic regions a stream of lava may flow across a valley, become solidi-fied and thus dam the river forming a lake, e.g. a lava flow blocks the Jordan valley forming the Sea of Galilee which is an inland lake, rather elongated in shape.

The crust of a hollow lava flow may collapse. The subsidence leaves behind a wide and shallow depression in which a lake may form, e.g. Myvatn of Iceland.

Volcanic Landforms

- Volcanic landforms are divided into extrusive and intrusive landforms based on weather magma cools within the crust or above the crust.
- Rocks formed by cooling of magma within the crust are called ‘Plutonic rocks’.
- Rocks formed by cooling of lava above the surface are called ‘Igneous rocks’.
- In general, the term ‘Igneous rocks’ is used to refer all rocks of volcanic origin.

Extrusive Volcanic Landforms

- Extrusive landforms are formed from material thrown out during volcanic activity.
- The materials thrown out during volcanic activity includes lava flows, pyroclastic debris, volcanic bombs, ash and dust and gases such as nitrogen compounds, sulphur compounds and minor amounts of chlorine, hydrogen and argon.

Intrusive Volcanic Landforms

- Intrusive landforms are formed when magma cools within the crust [Plutonic rocks (intrusive igneous rock)].
- The intrusive activity of volcanoes gives rise to various forms.

Topic No.22

Lakes formed by biological activity

Several species of relatively large animals can make lakes. Mainly following biological activities are involved in the formation of water reservoir.

1) **Beaver ponds**
2) **Wallows**
3) **Human activity**

Beaver ponds

There are two kinds of beavers: the American and the European. The European beaver, found in Norway, Poland, Germany and France, lives in burrows. But the American beaver builds a dam across a stream or lake to construct his home or lodge. The lodges are made of huge logs of trees.The American beaver constructs solid dams and lodges because it has the mind of an expert engineer among all the creatures in the animal kingdom. And it is hard-working too. Moreover, building fortress like lodges and dams helps it escape unfriendly animals.

It is a fascinating process. The beaver first chooses a site towards the narrow end of a stream. Then it starts to fell trees. The animal stands on its hind legs and gnaws at the tree trunk with its sharp chisel-like teeth. The branches are cut off and the tree is then dragged or floated to the chosen site to dam the water. The tree acts like a wall. The beaver uses broken branches, stones and mud to make the dam watertight. On this structure it builds a large dome-shaped lodge with two underwater entrances. One is a general entrance while the other entrance helps the beaver escape the animals that could harm it. The beaver uses the lodge to store food as well as to raise its young. Since lakes and rivers freeze in winter, the lodge becomes a refuge from preying animals. Due to its underwater entrances the beaver can come and go as it pleases under the ice. Beaver dams also act as channels to control the flow of water in a stream or lake.

Wallows:

A wallow is a natural depression in the prairie that holds rain water.

The wallows serve as temporary watering holes and they are a spot favored by the buffalo to "wallow in" to cool off and drink from on hot days.

Human activity:

In contrast to natural processes of lake formation, reservoirs are man-made water-bodies, usually formed by constructing a dam across a flowing river. Upon completion of the dam, the river pools behind the dam and fills the artificially created basin. A dam also may sometimes be constructed on the outlet channel of a natural lake as a means of providing better control of the lake’s water-level (examples being Lake Victoria, Africa, and Lake Tahoe, USA). However, these latter water-bodies typically retain their natural lake characteristics.

Reservoirs are found primarily in areas with relatively few natural lakes, or where the lakes are not suitable for human water needs. They are much younger than lakes, with life spans expressed in terms of historical rather than geological time. Although lakes are used for many of the same purposes as reservoirs, a distinct feature of reservoirs is that they are usually built by humans to address one or more specific water needs. These needs include municipal and drinking water supplies, agricultural irrigation, industrial and cooling water supplies, power generation, flood control, sports or commercial fisheries, recreation, aesthetics and/or navigation.

Topic No. 23

General features of lakes

The **study of geomorphology** contributes significantly to understanding the origin of lakes and the dynamics of the formative processes of lake ecosystems (Swanson, 1980). **Morphology,** the study of lake shapes, is related to the origins of each system. **Morphometry** deals with the quantification of these forms and elements. Lake morphology and morphometry basically depend on the processes from which lakes originated.

The **geomorphology** (basin structure) of lakes plays a significant role in establishing the physical, chemical and biological conditions, whose series of events, given the limits of the climatic conditions in the lacustrine basin, largely depend on the basic operating mechanisms provided by the initial morphometric and morphological conditions established by the geomorphological pattern. The influx of nutrients, stratification, **thermal de-stratification** and **retention time** all depend on the lake's geomorphology. The principal forms of hydrographic networks are categorized in several **drainage patterns** important in characterizing the types of regional evolution of the networks of rivers and the interrelationships between climatic factors, rock type, and the nature of terrains. Drainage patterns also provide basic information on the processes of formation of lakes in the regional context

The chemical and biological characteristics of the lake depend on the following:

- Formation
- Basin size and shape
- Topography and chemistry
- Regional climate
- Biological community
- Anthropogenic activity

Lakes are extremely variable in their physical, chemical and biological characteristics. Physically they vary in terms of the level of light, temperature and water currents. Chemically they vary in nutrients, major ions and contaminants, and biologically in terms of biomass, population numbers and growth.

Topic No. 24

Zonation in lakes

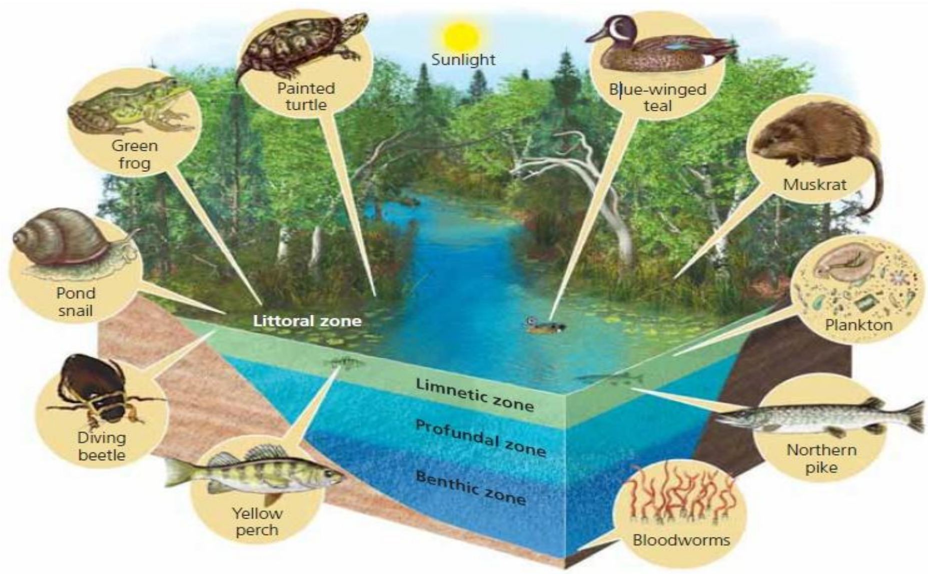
Usually lakes normally consist of four distinct zones

- Littoral zone
- Limnetic zone
- Profundal zone
- Benthic zone

A typical lake has three distinct zones (limnetic, littoral and the benthic zone of biological communities linked to its physical structure. The littoral zone is the near shore area where sunlight penetrates all the way to the sediment and allows aquatic plants (macrophytes) to grow. The 1 % light level defines the euphotic zone of the lake, which is the layer from the surface to the depth where light levels become too low for photosynthesis. In most lakes, sunlit euphotic zone occurs within epilimnion. In transparent lakes, photosynthesis may occur well below the thermocline, into the perennially cold hypolimnion. The higher plants in littoral zone, in addition to being a food source and a substrate for algae and invertebrates, provide habitat for fish and other organisms different from the open waterzones.

The limnetic (pelagic) zone is the open water area where light does not penetrate to the bottom. The third component of the lake habitat is benthic zone (the bottom of the lake), covered by fine layers of mud in which animals live. In the littoral zone, there is enough light for rooted plants to grow, but beyond this zone, there are no rooted plants as the water is too deep for light to reach them. The deepest part of the open water forms profoundal zone, but this is relevant only in extremely deep lakes.

In each community, green plants produce food upon which all aquatic organisms depend. Hence they are called as autotrophs. Animals, which feed on these plants, are called as herbivores and those that eat other animals are called carnivores. Omnivores have a mixed diet and detrivores feed on dead and decayed plant and animal material. All the feeding habits link to form the food-web.



Fish are usually the largest animals in the lake, feeding on most invertebrates; some eat other fish and very few are herbivores. There are more than 20,000 species of fish out of which 7000 live in fresh waters. Fish feed on plankton, plants and invertebrates and are in turn eaten by carnivores such as birds, otters and man. At each step, food is eaten to gain energy and nutrients. Most of the energy generated is used to support daily activity and is dissipated into the environment as heat. Only surplus energy is available for growth and reproduction, such that the energy available for the next link in the food chain is always less than that which entered the present trophic level. Hence, there cannot be more carnivores than herbivores.

Topic No. 25

Penetration of solar energy in water

Light plays an important role in lake ecology and determines the potential rate of photosynthesis, which supplies dissolved oxygen and food in the water. Solar radiation is the major source of heat and determines the wind patterns in the lake basin and water movement. Nearly all energy that controls the metabolism of lakes and streams is derived directly from the solar energy utilized in photosynthesis. That energy stored in photosynthetically formed organic matter is both synthesized within the lake or stream (autochthonous) or within drainage basin and brought to the lake or stream in various forms (allochthonous). Utilization of this energy received within the water or imported from the drainage basin and factors that influence the efficiency of conversion of solar energy to potential chemical energy are fundamental to lake productivity. Light intensity varies with seasons and depth. Deeper the light penetration, higher is the rate of photosynthesis. Photosynthetic organisms include phytoplankton (algae), attached algae (periphyton) and vascular aquatic plants (macrophytes). The rate at which the penetration of light decreases with depth depends on the amount of suspended particles in water. The level of light determines the maximum depth at which algae and macrophytes can grow, which is determined to be the point where available light is reduced to 0.5% - 1% of the amount available on the surface. In a clear lake, the euphotic zone may extend down to 20 m or more but in most of the present day lakes, it is often about 3-5 m or as less as 0.5 m deep. Significant changes in lake transparency are the result of anthropogenic activities in the watershed.

Light and Depth:

When light passes down through a column of water, the amount of light available at any particular depth decreases exponentially, as most of the light is absorbed in the surface waters. The depth of light penetration depends very much on the color and turbidity of the water.

Thus, if there are 100 units of light energy at the surface, they will decrease depending on the water quality and not in a simple linear manner (like 90 at 1m, 80 at 2m and so on).

Nutrient cycling, distribution of dissolved gases and biota, and behavioral adaptations of organisms are all markedly influenced by the thermal structure and stratification patterns. Therefore the optical properties of lakes and reservoirs are important regulatory parameters in the physiology and behavior of aquatic organisms.

Topic No. 26

Physical processes in lakes, reservoirs and rivers

The principal mechanisms and functions of physical force that affect the vertical and horizontal structure of lakes and reservoirs include the following:

External mechanisms

Wind

Barometric pressure

Heat transfer

Intrusion

Downstream flow

Coriolis Effect (from the rotation of the Earth)

Discharges on the surface

Plumes and jets on the surface of lakes and reservoirs

Internal mechanisms

Stratification

Vertical mixing

Selective removal or selective loss downstream

Density currents

Formation of internal waves

These mechanisms drive the processes of vertical organization in lakes and reservoirs, and have fundamental chemical and biological consequences for the functioning of these ecosystems. Both internal and external mechanisms are influenced by climatic and hydrological factors, which are functions of force acting on systems.

The physical processes of stratification and vertical mixing are of fundamental importance for the structure and organization of chemical and biological processes in lakes, reservoirs, rivers and estuaries. In freshwater ecosystems, the processes of stratification and mixing result from the cumulative effects of heat exchange and energy intake; absorption of solar radiation with depth (which depends on the optical conditions of the surface water), the direction and strength of the wind, the kinetic energy of water intakes, and the direction and force of water outlets. Mixing and vertical stratification are dynamic processes. Morphometric characteristics are important in vertical and horizontal mixing: volume, maximum and average depth, and location (latitude, longitude and altitude). The basic mechanisms of generating and dissipating turbulent kinetic energy are the same in lakes and oceans. Differences are caused by density (due to salinity of sea water and effects of the Earth's rotation on oceans or large lakes).

Wind exerts an action of turbulence stress on the water surface. As a consequence, the following phenomena occur:

Surface currents;

Accumulation of water on the surface, in the direction of wind, and an oscillation in the stratified interface;

Turbulence in the surface layers, which can increase during breaking waves.

Topic No. 27

Types of flow

There are in usually three types of fluid flow

- Laminar flow
- Turbulent flow
- Transient flow

Water within streams can come from many different locations, including the ground below the stream, melting snow or rainfall. These different sources can influence how the water flows within the stream, especially the speed of the water. Stream flow can also be influenced by what is physically found within the stream. Objects in the stream can influence the speed and direction of the flowing water. Stream flow is often characterized by the water velocity, which is the speed at which something moves, and the direction of the flow. Based on these characteristics, water in steams can be classified as laminar or turbulent.

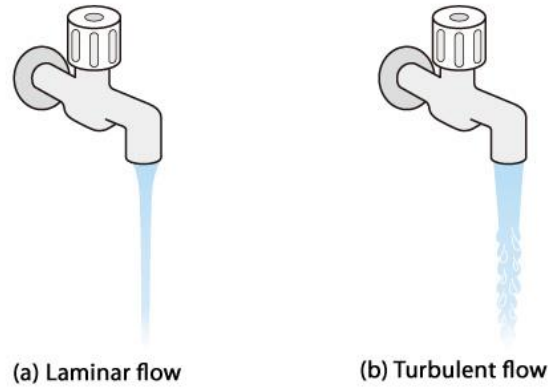
Laminar flow

The more basic type of steam flow is referred to as laminar. A flow with regular, predictable motion is called **laminar flow**. Laminar stream flow is when water is organized in parallel layers and moves in an orderly manner. Water particles stay within their layer and move along the stream at that level. This structure is often possible because there are minimal rocks or other physical barriers in these types of streams.

The orderly manner of the stream results in water moving straight down the stream channel in a line. Due to the straight direction of the water flow, the water often has low velocity and moves very quietly. An example of a stream with laminar stream flow would be a small, meandering waterway. You would not see any visible rocks or barriers, and the water movement would seem gentle and slow.

Turbulent flow

A flow with irregular, unpredictable motion is called **turbulent flow**. The more complex type of steam flow is referred to as turbulent. Turbulent stream flow is when water does not remain within parallel layers and does not move in an orderly manner. Streams with turbulent stream flow have rocks and other physical barriers within the water. When water particles collide with these barriers, they are forced to mix between the parallel layers. Instead of water flowing in a direct line down the stream, the water moves in random and erratic directions.



Transient flow

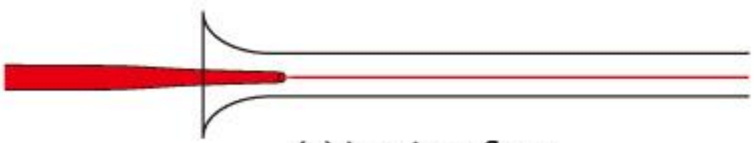
Transient flow is a fluid dynamics condition where the velocity and pressure of a fluid flow change over time due to changes in system status. These changes may be caused by the starting or stopping of a pump, opening or closing of valves, or fluctuations in supply pressure from reservoirs or tanks. It is usually characterized by a powerful pressure wave or waves that may persist for a significant time after the precipitating event has ceased. Transient flow events can be extremely destructive if the magnitude and velocity of the pressure wave exceeds the capacity of the system in which it takes place. Solving recurring transient flow problems is not easy, and is generally only achievable with sophisticated software simulations.

Topic No. 28

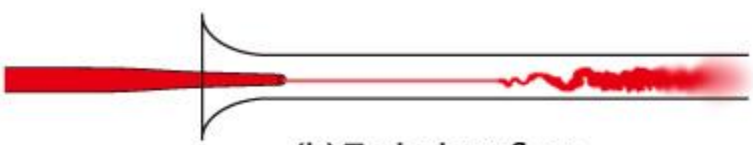
Reynolds Number

The Reynolds number is important in analyzing any type of flow when there is substantial velocity gradient (i.e. shear.) It indicates the relative significance of the viscous effect compared to the inertia effect. The Reynolds number is proportional to inertial force divided by viscous force.

In 1883, a British scientist named Osborne Reynolds (1842-1912) classified flows as either laminar or turbulent from a series of experiments known as the Reynolds' experiment. In the experiment, flows were visualized by pouring a stream of ink into a pipe in which water flows. The result showed that, when the water velocity was low, the ink moved downstream in a continuous straight line as shown in (Fig a). In this case, the flow was laminar. However, when the water velocity was high, the ink started in a straight line but began oscillating and quickly dispersed throughout the pipe. This flow was turbulent (Fig b).



(a) Laminar flow



(b) Turbulent flow

In the experiment, Reynolds discovered a dimensionless number could be used to classify flows as either laminar or turbulent. This number is called the Reynolds number. The Reynolds number Re is defined by the following equation:

$$R_e = \frac{\rho V L}{\mu}$$

- ρ is the density of the fluid
- V is the velocity of the fluid
- μ is the viscosity of fluid
- L is the length or diameter of the fluid.
- It is dimensionless

The Kind of flow depends on value of Re,

If Re < 2000 the flow is Laminar

If Re > 4000 the flow is turbulent

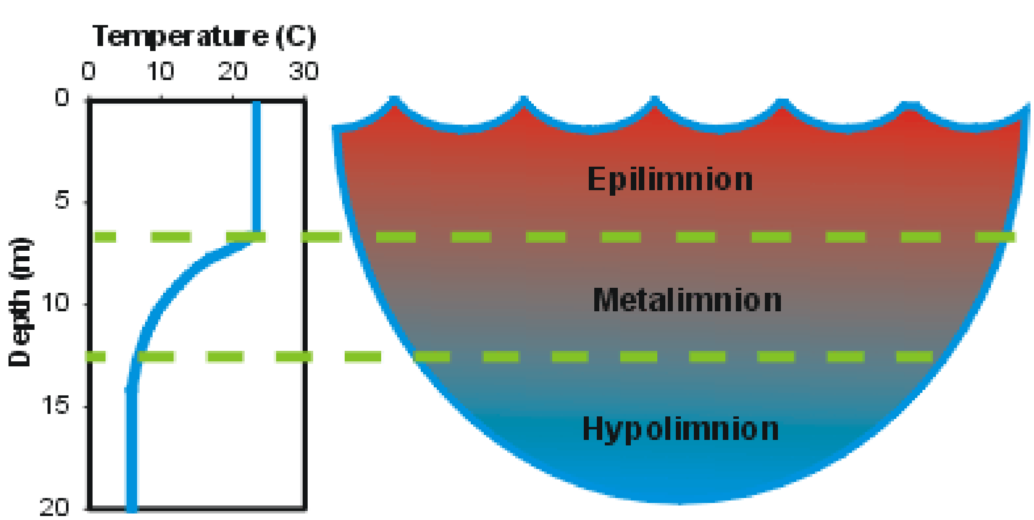
If 2000 < Re < 4000 it is called transition flow.

Topic No. 29

Thermal stratification

Changes in the temperature profile with depth within a lake system are called thermal stratification. This profile changes from one season to the next and creates a cyclical pattern that is repeated from year to year. Let us begin with spring. After the ice melts on a lake, the lake water is generally the same temperature from the surface to the bottom. Wind allows circulation and mixing of the lake water. Surface water can be pushed to the lake bottom and bottom water can rise to the surface. This circulation pattern is very important in that it allows relatively large amounts of oxygen to reach the bottom of the lake. Otherwise, oxygen would have to reach the bottom by the relatively slow process of diffusion. The mixing of the lake water at this time of year is called spring overturn.

As air temperatures rise in late spring, heat from the sun begins to warm the lake. As the amount of solar radiation absorbed decreases with depth, the lake heats from the surface down. The warm water is less dense than the colder water below resulting in a layer of warm water that floats over the cold water. The layer of warm water at the surface of the lake is called the epilimnion. The cold layer below the epilimnion is called the hypolimnion. These two layers are separated by a layer of water which rapidly changes temperature with depth. This is called the thermocline (or metalimnion). The three distinct layers of water, each with a different temperature or range of temperatures, is an excellent example of thermal stratification within a lake system.



During the summer the epilimnion will reach a maximum depth and stratification will be maintained for the remainder of the summer. The warm water, abundant sunlight, and nutrients brought up from the lake bottom during spring overturn provide an ideal environment for algae growth within the epilimnion. Algal blooms tend to give the epilimnion a greenish hue. Stratification during the summer acts as a deterrent to complete lake mixing. Wind circulates the surface water, but the warm water of the epilimnion is unable to drive through the cold, dense water of the hypolimnion. As a result, the water is only mixed in the epilimnion.

Lake stratification in winter

As the winter approaches, the lake gets colder until the water attains a uniform temperature of 4°C at which it has maximal density. As the surface cools below it becomes lighter. Eventually the surface water may freeze at 0°C.

During the winter season, the ice cover forms on the surface and in such ice-bound lakes there exists an inverse stratification of water temperature, with the coldest water (ice) at the surface and the warmest water (4°C) on the bottom.