Ecology and Environment Management

ABIOTIC FACTORS

Laxmi Narula
SGTB Khalsa College
Guru Tegh Bahadur Marg
Delhi – 110 007

Date of Submission 3/15/2008

Contents:

Key Words: Physical factors, climatic regime, sun as major source of energy, limiting factors, laws of limiting factors, optimum range, zone of stress and coma, temperature -variations on land , temperature variations in water, thermocline, ectotherms , endotherms, heterotherms, absolute humidity, relative humidity, precipitation, light - variations on land, extinction of light in water, lunar periodicities , circadian rhythms, diurnal periodicities and seasonal reproductive cycles, edaphic factors, pedon, formation of soil- factors and processes, components, characteristics of soil, soil erosion.

ABIOTIC FACTORS

Introduction

The universe is made up of matter and energy. Matter occupies space and has mass whereas, energy has no mass and does not occupy space. Matter and energy together have created life on the planet earth and are required to sustain it. *Both of them together constitute the non-living components of the ecosystem and are called abiotic factors*. These include all the physical and the chemical conditions around the living beings and are important to support life. These factors can be classified into following types:

1. ***Physical factors:***
   - i) *Climatic regime*: Sun as the main source of energy, the limiting factors are temperature, precipitation, humidity, clouds and light that determine the climatic regime.
   - ii) *Atmosphere:* It is a mixture of air around the earth.
   - iii) *Edaphic factors :* Nature and structure of soil constitute edaphic factors
   - **iv)** *Topographic factors*: They deal with the latitudinal and altitudinal variations on the earth.
2. ***Chemical factors***
   1. *Inorganic substances:* Elements such as carbon, nitrogen, hydrogen, phosphorus, oxygen, sulphur and others.
   2. *Organic substances***:** They are the organic molecules like carbohydrates , proteins, lipids and humus.

Climatic Regime

Climate is the determining factor for the existence of life and distribution of major ecosystems on the biosphere. Climate and weather are quite closely associated terms. *Weather* is the combination of temperature, humidity, precipitation, wind, clouds and other atmospheric conditions at a specific place and specific time. *Climate* is the long term average pattern of weather. Climate can be local, regional or global. The climate of a place is determined by the average temperature, temperature extremes, precipitation, clouds, day length and seasons length. For example we commonly say that the climate of a place is hot and dry or wet and moist. Presently the global climate is changing rapidly due to the various anthropogenic activities. The weather may be temporarily good or bad e.g. when it is raining heavily with a hail storm we say that the weather is bad.

Sun - The inexhaustible source of energy for the planet earth

Solar radiations warm the earth and make all life possible on it. Sun’s warmth not only makes it habitable it is also a source of energy for all the biogeochemical cycles on it. The temperature of earth would approach absolute zero (-273^{o} C) and all the water would be frozen on it without sun. The sun’s energy is the product of a massive nuclear fission and is emitted into the space in the form of electromagnetic radiations as light energy. A very small fraction of the sun’s total production strikes the earth’s atmosphere and of this a tiny tickle of energy per minute part operates the ecosphere. During the day time, 30% of the solar radiation that falls upon the earth is immediately reflected away by the clouds, snow, ice and oceans. The remaining 70% is absorbed by earth.

Distribution of solar radiation determines the climate patterns on the earth through the following processes:

i) warming the planet

ii) running the ocean currents

iii) driving winds

iv) water cycles

v) powering photosynthesis

Ultimately all this energy is lost by continual radiation of long wavelength infrared (heat) into space.

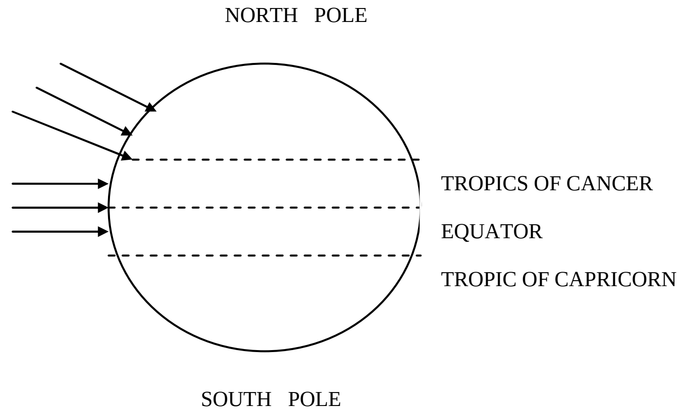

Fig. 1: Solar energy at the equator and the poles.

The most significant local variations in the temperature is produced because the sun's energy doesn't reach uniformly on all parts of the earth's surface. This is because of the two reasons:

1) roughly spherical shape of the earth and

2) the tilt of its axis.

Both the factors produce a great deal of variation on exposure of the earth's surface to the energy delivered by sunlight. The principal effect of the tilt is on the angles, at which the sun's rays strike different areas of the earth at any time. On an average sun's rays hit the earth vertically (90^o) near the equator making the energy more concentrated and producing higher temperature. The rays of light entering the atmosphere obliquely near the poles must pass through a deeper envelope of air than those entering through equator. This causes more sun's energy to be scattered and reflected back into the space which in turn lowers the temperature near the poles. Thus the solar energy that reaches the poles is less concentrated and the temperature is lower.

a) **Seasonal variations in solar energy:** Seasons are determined by the following two main factors:

- the inclination of earth's axis and
- the distance of the earth from the sun, which varies during the year.

The earth's inclination on its axis is always the same 23.5^o, during half of the year from March 21 to September 23, the northern hemisphere tilts towards the sun and during the other half, from September 23 to March 21, it tilts away from the sun. The orientation of southern hemisphere is just opposite at these times.

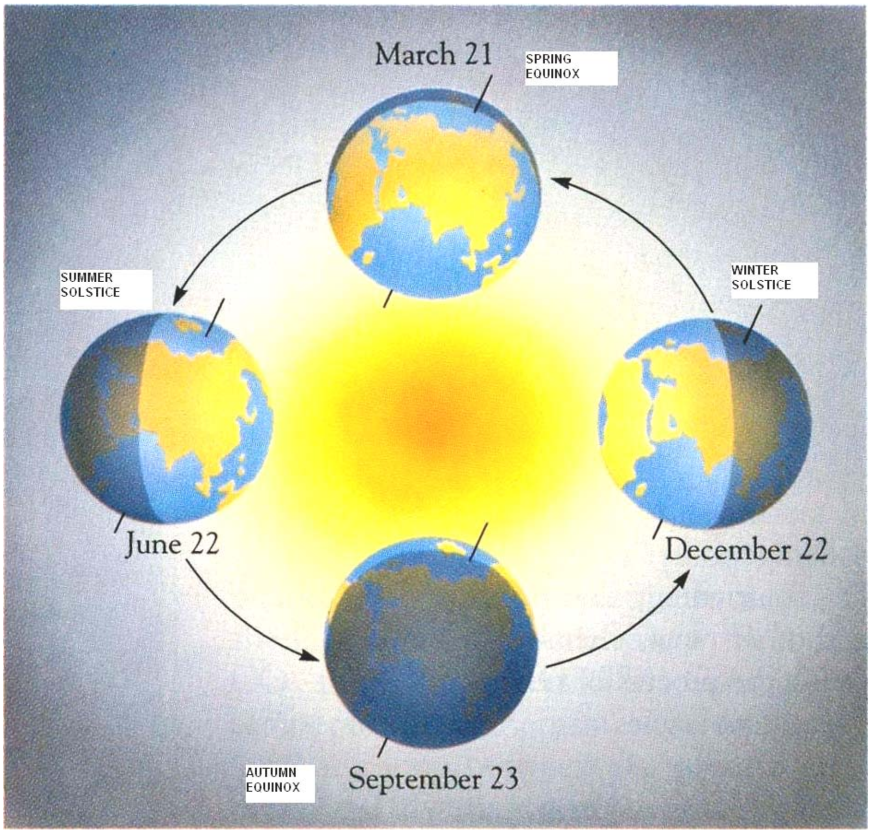

Fig. 2: Seasonal variations in solar intensity on earth. The inclination of the earth's axis remains the same as it travels around the sun. Therefore, the rays hit the northern hemisphere obliquely during winter and directly during summer. The southern hemisphere experiences winter when it is summer on the northern hemisphere and receives the sun's rays obliquely at this time. At the equator sun's rays are nearly vertical through out the year.

b) Global Atmospheric Circulation: The atmospheric circulation also results in variations in the solar energy reaching the surface of the earth. Near the equator the air is heated, it expands and rises. As it cools after going to a certain height, its density increases and it comes down to the surface forming subtropical regions with high density. The air from the high pressure areas either moves again near the place which it left or recirculates forming the *trade winds*. The remaining air flows towards the poles where it is eventually chilled. This air flows as a layer beneath the hot layer from the poles towards the equator. This takes place not only on the equator but at all the latitudes from equator towards poles. *This atmospheric circulation of air helps in creating a moderate temperature on the surface of the earth.*

c) Surface winds: Winds are due to the complex horizontal movements of earth's atmosphere. Since the gases that constitute atmosphere have weight and exert pressure which is 760 mm of mercury at the sea level (14.7 pounds per square inch). This air pressure changes with altitude, temperature and humidity. Winds always flow from the area of high pressure zone to low pressure and the greater the pressure the stronger are the wind currents. The earth's atmosphere has three **prevailing winds** which are the major surface winds that blow more or less continuously they are of three types: i) *Polar easterlies* are the prevailing winds that blow from northeast near the north pole or from the southeast near the south pole, ii) *Westerlies winds* are those which blow in the mid latitude from the south west (in the northern hemisphere) or from the north west (in the southern hemisphere) and iii) *Trade winds* are the tropical winds that blow from the north east (northern hemisphere) or from the south east (southern hemisphere).

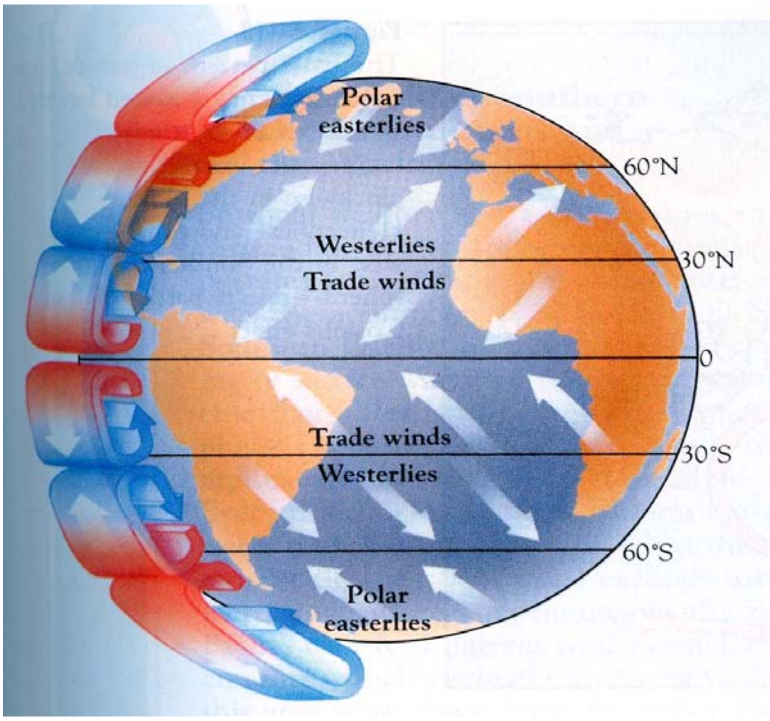

Fig.3: Atmospheric circulation and surface winds.

The earth's rotation also influences the direction of wind. The east- west rotation of earth causes moving air to be deflected from its path and swerve to the right in the northern hemisphere and to the left in the southern hemisphere . This tendency is known as *Coriolis effect*, named after the French Mathematician Gaspard Coriolis (1792- 1843).

Thus the climate of an area is the result of many varying factors that affect the region. The climates can be classified into following five main divisions even though each one of them shows large number of variations:

1) cold
2) cold temperate
3) warm temperate
4) subtropical
5) tropical.

ii) ATMOSPHERE

Atmosphere is the multilayered gaseous envelope surrounding the planet earth. This ocean of air is about 1000 km. above the surface of the earth and blends with the outer space. Atmosphere is a reservoir of several elements essential to life and helps in cycling of these nutrients between the organism and the environment. It also serves many other functions that make life possible on earth, such as filtering of radiant energy from sun, insulations from heat loss at earth's surface and stabilization of weather and climate owing to the heat capacity of air.

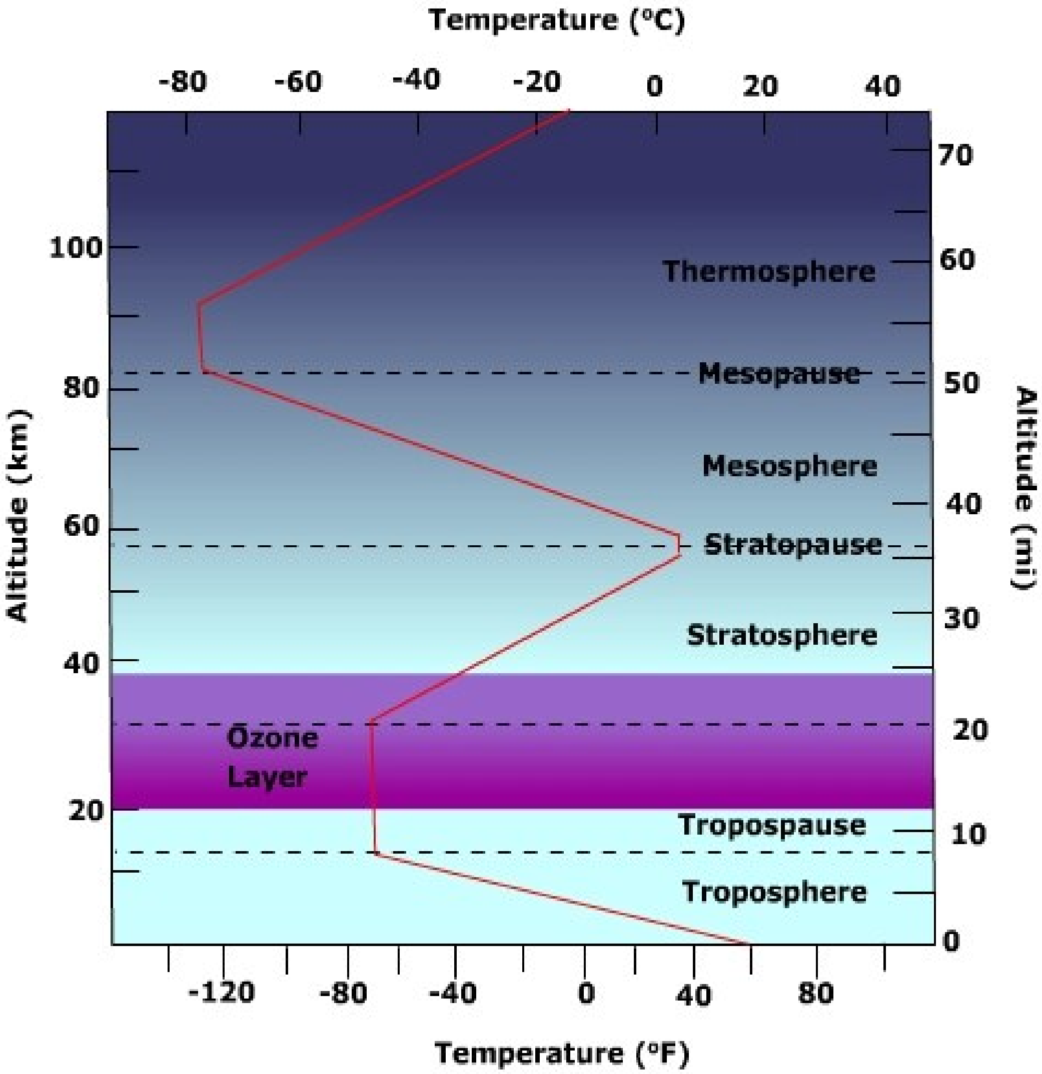

Fig. 4: showing different layers of the atmosphere and temperature changes.

There are five concentric layers wihin the atmosphere, which can be differentiated on the basis of temperature. They are namely, troposphere, stratosphere, mesosphere, thermosphere and exosphere.

Troposphere is the lowest layer of the atmosphere in which human and other organisms live. It is approximately 17 km (11 miles) in thickness. It is slightly thicker on the equator than on the poles. With an increase in altitude from the surface of the earth there is a steady decrease in tropospheric temperature.

Troposphere is a mixture of gases as shown in the table 1.

Name of the gas	percentage
Nitrogen	78. 084
Oxygen	20. 9476
Argon	0. 934
Carbon dioxide	0.0314
Water vapours*	0 to 4
Others	Traces

Table1: Percentage composition of tropospheric air. * Water vapours and dust particles are highly variable and depend on the altitude and temperature.

Troposphere is a locus of weather formation of various ecosystems and shows air movement and cloud formation. The important four constituents of air that is nitrogen, oxygen, carbon and water vapours are continuously cycling in nature between organism and troposphere through biogeochemical cycles.

Stratosphere is the air mass above the troposphere nearly 40 km thick. The temperature in this layer ranges from -55 ^{o} to 5^o C. Its lower layer consists of significant quantities of ozone forming *ozonosphere*. For the ecosystems, ozone layer is an important umbrella that protects them from ultraviolet radiations of sun. Secondly, it also acts like a blanket that reduces the cooling rate of the earth and thus adds to the effect of water. The *mesosphere* which is the next higher layer is characterized by very low temperature and pressure .At about 80 to 90 km above the surface of the earth the temperature is reduced to - 95^o C. Above the mesosphere is *thermosphere* that extends upto 500 km and shows a steady increase in the temperature with the increase in altitude. The molecules are widely spaced and are in the ionized state. The outermost layer of the atmosphere is called *exosphere* . It contains only hydrogen and helium. This layer extends upto 32190 km above the surface of the earth.

Limiting Factors

The existence, survival and sustainable growth of an organism depends on the presence of sum total of all the essential materials and the physical conditions required by it at a given time and place. The basic requirements of an organism change with age and availability of other conditions. These essential materials include chemical factors i.e. all the macronutrients and micronutrients and the physical factors, such as temperature, humidity, light, pressure and topography of a place. All *these factors limit /control the growth of an organism or a population and therefore are called limiting factors.* The concept of the limiting factors was given for the first time by Justus Liebig in 1840. He stated the law of minimum for the *essential chemicals* required for the plant growth. In his studies he found that the substances required by plants in large quantities are not limiting the growth of the plant rather the ones required in small amounts or traces limit the plant growth.

Liebig's law of minimum: It states that *under steady state conditions the essential material available in amounts most closely approaching the critical minimum needed will tend to be the limiting one***.** The law of minimum is less applicable under *transient state* conditions when the requirements are changing rapidly. The transient phase applies here to the phase of growth and reproduction. He found that the yield of the crops was often limited not by the nutrients needed in large quantities such as carbon dioxide and water since these were abundant in the environment but by some raw material like boron. Boron is required in very small quantity by the crop plants but it is very scarce in the soil.

Two important requisitions for the law of minimum are:

i) The law is applicable only under *steady state condition* that is, when the inflow balances the outflow of energy and materials in an organism or population. During growth and reproduction an organism is not in the steady state condition.

ii) *Factor interaction* is also an important consideration for this law of minimum. It states that high concentration or availability of some substance or some factor/ factors other than minimum one may modify the rate of utilization of the latter. Sometimes organisms are able to substitute closely related substances for the one that is deficient in the requirements list. For example strontium can be substituted for calcium by molluscs.

Law of tolerance: The presence and success of an organism depend upon completeness of the complex condition. Absence or failure of an organism can be controlled by the qualitative or quantitative deficiency or excess with respect to any one of the several factors which may approach the limits of tolerance for that organism..

V.E. Shelford in 1913 stated this law of tolerance. According to him, not only minimum of some factor controls growth of an organism rather maximum of the same is also a limiting factor. He carried out several "stress tests" in his laboratory to show that all the organisms have an upper and lower limit of tolerance. Above or below these levels, the organisms are subjected to stress initially and then to "coma" or leading to their complete death. In the zone of stress, their growth rate is reduced and it gradually stops in the zone of coma.

In other words a combined concept of the limiting factor states that *the presence and success of an organism or a group of organisms depends upon a complex of conditions. Any condition which approaches or exceeds the limit of tolerance is said to be a limiting condition or a limiting factor.*

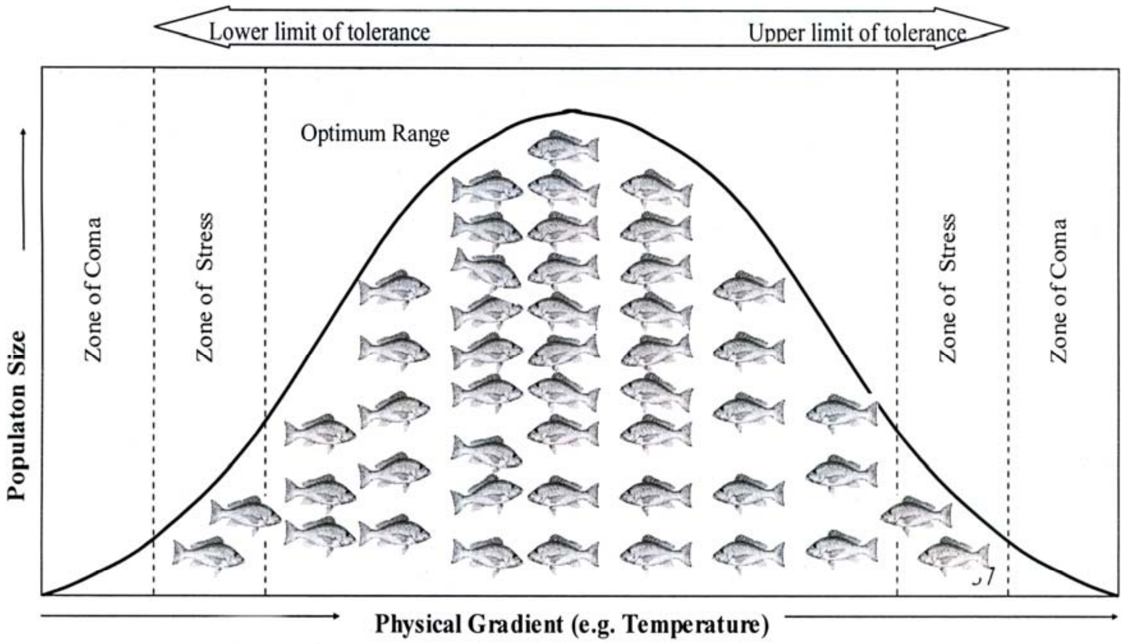

Fig. 4: showing limits of tolerance, zone of stress and zone of coma.

There are some subsidiary principles to these laws of limiting factor which also play an important role in controlling the growth of organisms. These are as follows:

1) An organism may have a wide range of tolerance for one factor and a narrow range for another. The degree of tolerance is expressed in terms of "***steno***" or "***eury***" meaning narrow and wide range of tolerance respectively. They can be used as a prefix to any of the environmental factors required by an organism , such as *stenothermic* : refers to narrow range and *eurythermic to the* wide range of tolerance to temperature.

   Similarly for salinity it can be referred to as stenohaline and euryhaline and for food as stenophagic and euryphagic organisms. For example Antarctic fish *(Trematomus bernacchi)* is stenothermic and has a narrow range of temperature tolerance from -2^0 to $+ 2^0$ C. In contrast the desert fish *(Cyprinodon macularius*) is eurythermic and euryhaline and can tolerate temperature between 10^0 C to 40^0 C and salinity between fresh water to greater than sea water.

2) Organisms with wide range of tolerance for all the factors are more widely distributed than those with the narrow range of tolerance. Species of frogs (*Rana*) and desert fish are widely distributed as they have a wide range of tolerance.

3) When the conditions are not optimum for a species with respect to one ecological factor, the limits of tolerance may be reduced with respect to another ecological factor. For example, the resistance of the grasses to drought is reduced when nitrogen is a limiting factor in the soil. That is, more water is required to prevent wilting at low nitrogen levels.

4) Many a times it is observed that organisms are not actually living under optimum conditions with respect to particular factor. In such cases, some other factor or factors are more important for their growth e.g. tropical orchids grow better in full sunlight than in shade provided they are kept cool. Therefore in nature they are always found in shaded places to avoid the heating effects of direct sunlight.

5) During the reproductive phase, the environmental factors are most likely to become limiting. Eggs, embryos, larvae and seedlings have a narrow range of tolerance for most of the factors. Migratory birds and fishes travel long distances to lay their eggs in those geographical places which are most suitable for their eggs and young ones.

Temperature

In the previous section we have divided climate into five main types for which temperature is the main controlling factor. This determines the distribution of various ecosystems on the earth. *Temperature is the intensity aspect of the heat energy***.** The different media which support life in the biosphere are lithosphere, hydrosphere and atmosphere. They have a different capacity to absorb and transfer heat energy. Even though, the temperature in the universe exists in thousands of degrees but life exists only in a very small range of 300 ^{o} C (between -200^{o} to +100 ^{o} C). In this range also very few species exist at –200^{o} C or +100^{o} C which are considered to be extremes of temperature conditions. The majority of organisms are found in narrow range only within this wide range of temperature.

Temperature variations in water: In open freshwater of pond, the temperature can not drop below the freezing point and in salt water oceans never below -2.5^{o} C. The highest temperature in the oceans is never above 36 $^{o.}$C and in pools or lakes, it may be higher than this depending on the surrounding temperature. This is because of the unique physical properties of water like high latent heat of fusion , latent heat of vapourization and its maximum density at 4 ^{o} C. Water on getting heated up evaporates, and ice melts leading to the cooling effect of water. Both these effects reduce the temperature variations in an aquatic system. In a water body, heat moves down by actual movement of the water by vertical circulation.

Diurnal changes in temperature in any water body are much less than on land. Below a depth of 15 metres, there are virtually no temperature changes. Seasonal variations in temperature are more important for all living beings on land and in water. In the polar and tropical seas these changes may not be more than 5^{o} C where as in temperate seas, changes may be from 10^{o} to 15^{o} C from summer to winter. However, in some regions a difference of 23^{o} C is also observed. Nearly 95% of the oceanic environment does not exhibit seasonal temperature changes that influences the organisms. In the temperate and tropical regions of the seas, there is a permanent thermal gradient. The depth and the extent of zone of relatively rapid temperature change is known as *permanent thermocline layer*. In the ocean from a depth of 2000 m to the bottom the temperature is uniformly 3^{o} C. If you were a fish restricted to a temperature of 3^{o} C you could nonetheless travel over more than 60 % of the globe without being exposed to the significantly different temperature. Seasonal cycles of temperature occur in oceans also but they are superimposed upon the permanent structure as a relatively minor fluctuation. But in the coastal region the water is sufficiently shallow for the seasonal effects to reach the bottom. In winter there is thorough stirring of water which produces uniform temperature through out from top to bottom. In August the relatively thin stratum at the top attains the maximum temperature. Below this layer exists a sharp thermocline (10 to 20 m) followed by the lower layers of the deeper water which are quite cold. During autumn as the solar radiations are reduced and the winds become stronger the surface waters are stirred down and the thermocline is shifted downward into the deeper layers or may be destroyed completely. By November, the whole water column has become mixed and remains uniform as it cools to the minimum in winter.

In freshwater habitat, the seasonal changes are much greater. Seasonal changes in a temperate lake are of great significance for the survival of aquatic fauna and flora of this region under extreme temperature conditions. The maximum density of freshwater is at 4^o. C. Any warmer or colder water will always float on top at this temperature. In winter, as the temperature approaches 0^o C, water that is above 0^o C being heavier would sink down. A distinct density gradient is established from top to bottom, with ice floating on the surface of the lake. The bottom the lake has water at 4^o C. This is known as *winter stratification or winter stagnation.* So the fishes can survive under the extreme conditions of winter in the deeper layers of the lake. During spring as the surface temperature starts rising, the heavy water molecules start moving downward and convection currents are generated. The whole lake water is mixing continuously. This is called *spring overturn***.** With the onset of summer the surface temperature starts going above 4^o C upto 25^o C. This hot water is lighter than water at 4^o C therefore it remains on the surface and once again a density gradient is established. This time the surface has the highest temperature and the bottom is again at 4^o C. This is called *summer stratification.* In deep lakes, the upper the wind stirred largely homogeneous layer is called *epilimnion*. Below this there is a zone of rapid vertical temperature changes termed as *thermoclin***e** (or metalimneon). The layer below the thermocline, where the water is relatively stagnant is known as *hypolimnion.*

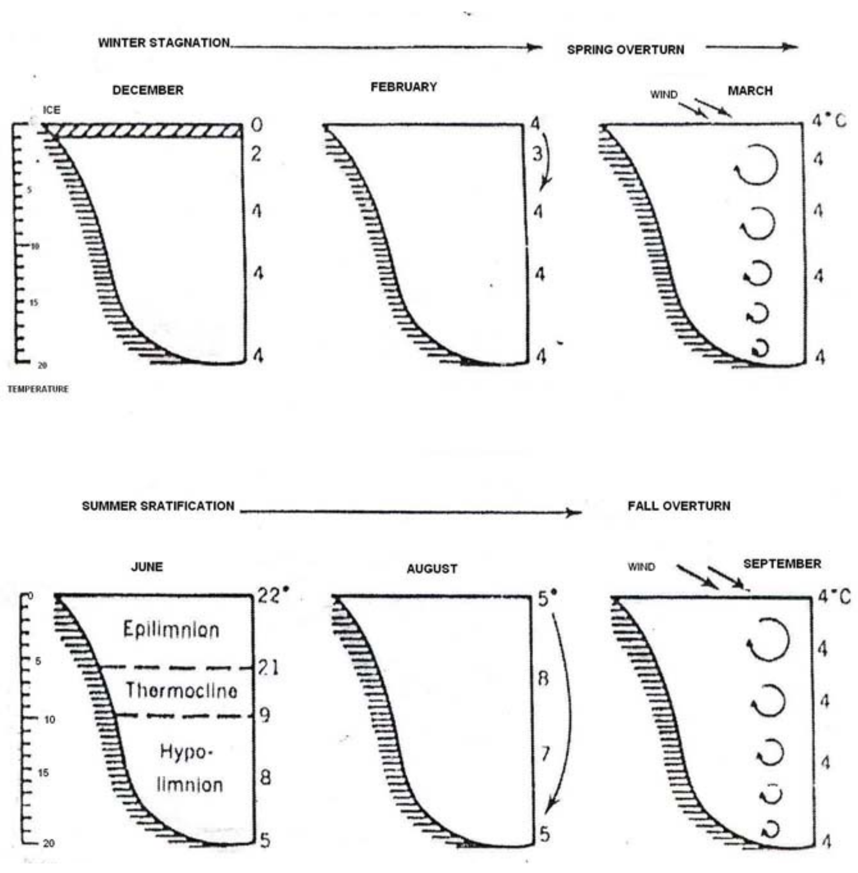

Fig 4: Seasonal temperature changes in a temperate lake.

Thus it is clear that in oceans and lakes the life is much easier than on land for the following reasons

(i) There is no temperature too high or too low for the active life of some forms of aquatic species.

(ii) temperature changes are much less and slower than on the land.

(iii) The organisms can escape from the effect of high or low temperature by making short journeys into the deeper water.

For ages, the oceanic plants and animals are adapted to relatively stable temperature. As a result when an unusual change in temperature occurs it leads to drastic effect on fauna and flora. Many such incidences have occurred in the past.

Temperature changes on land

The regional temperature variations on land are much more severe than in water. On land, the minimum temperature is observed in Siberia -70^o C and the maximum in desert 84 ^{o} C. Animals and plants are also exposed to more severe diurnal and seasonal temperature variations. A great difference in the heat received by a sessile plant or animal may be observed within a short period as the sun changes its position with respect to the earth. It may change from a direct sunlight to a complete shade. The diurnal variation in air temperature near the surface of the land is from 17^{o}C to more than 40^{o}C. The day temperature is higher than the temperature at night. The temperature of air varies widely in a vertical direction according to the local conditions but a decrease of about 1^o C per 150 m altitude is generally found as discussed in the previous section that unequal heating of the air horizontally and vertically causes movements of atmosphere. Air is heated and cooled maximum at its bottom by the solar radiations. This is because air is transparent and the surface of the earth is heated faster during the day and cools by radiation more rapidly at night than the atmosphere. That is why the air near the surface cools faster than the upper strata of the atmosphere.

The progressive changes in temperature and other climatic factors from equator to poles and from sea level to the mountain peaks control the distribution of major vegetation types (Fig.5 altitudinal and latitudinal distribution of life zones). These major vegetation types then allow the growth of certain subordinate plants and animals They can be differentiated as distinct life zones in the following sequence: tropical forests, desert or grasslands deciduous forests, coniferous forests and tundra .(from equator to poles and sea level to high mountain peaks) and ice on the poles and high mountain peaks there may be some variations in these life zones due to other local climatic variations. Besides these distinct life zones there are distinct thermal boundaries that that completely control the growth of certain plants and animals. *Frost line* is a boundary beyond which frost sensitive plants such as palm trees can not live for long. *Tree line* is another such boundary that abruptly changes the fauna and flora at high altitude and latitude. Beyond this line even though there is no sudden change in temperature but the trees disappear above this line. Therefore the associated animals and plants also change.

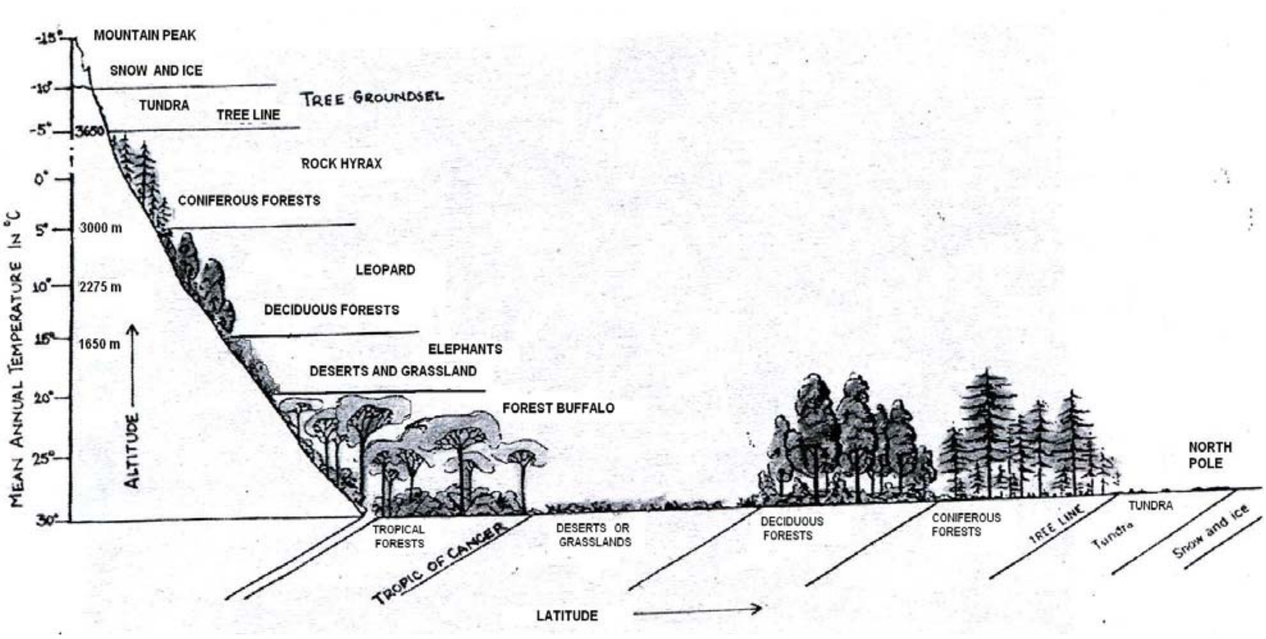

Fig.5: Altitudinal and latitudinal temperature changes

Reduction of temperature also takes place beneath the earth's surface. As shown in the table2,there is a great decrease in temperature(43.6^{o} C) at Tucson desert in Arizona in summer from the surface upto a depth of 45 cm.

Depth	Temperature
Air (maximum)	42.5^{o} C
Surface(maximum)	71.5^{o} C
10 cm below the surface	41.1^{o} C
30 cm below the surface	29.8^{o} C
45 cm below the surface	27.9^{o} C

Table2: Showing temperature changes from the atmospheric air to 45 cm below the earth's surface .

Temperature changes in atmosphere

The atmosphere is stratified and it shows contrasting temperature between different layers mixing between these layers is prevented due to density differences. Weathers on the earth are due to the atmosphere. The layer of the atmosphere near the surface of the earth is *troposphere* which can be differentiated into lower (0 to 8 km) and upper (8 to 13 km) troposphere. Troposphere shows a decrease in temperature with the increase in altitude. It may be reduced to about -50 ^{o} C at tropopauseLife can be supported only by a thin lower layer of the troposphere. Temperature is gradually increasing in the lower troposphere due to global warming. The stratosphere is getting cooled for the same reason. .

Biological Actions Of Temperature

All organisms live in and exchange energy with a thermodynamic environment on the earth. The rate of all the thermodynamic reactions in the biological system such as photosynthesis and transfer of energy through food chain, taking place are directly or indirectly controlled by the intensity of solar radiations (temperature) received by them. The quantitative relationship between the activities of organisms and the temperature has been recognized for centuries. R'eaumaur in 1736 quantitatively estimated the total heat required to produce growth is a constant. Since this time many other investigators also recognized linear relationship between the rate of a biological action and temperature. With the recent advances in physical, chemical and biological sciences, the various biochemical actions are better explained by applying the laws of thermodynamics. The transfer of heat between the organisms and the environment takes place by the following four methods:

- ***Evaporation*****:** Transpiration and perspiration involves conversion of water into its vapours , producing cooling effect.
- ***Conduction****:* The heat is lost or gained by a hot or cold object respectively by conduction into the surroundings. Foe example it is difficult to walk bare footed on the heated road in mid summer due to the conduction of heat from road to the feet.
- ***Convection* :** It is due to the movement of fluid or air molecules. One feels cool in front of a rotating fan.
- ***Thermal radiation* :** One can experience the transfer of heat by standing in front of fire. Similarly the earth experiences the thermal radiations of the sun.

Animal-temperature interactions

The animals can be classified into three main groups on the on the basis of their responses to the environment

1 Ectotherms or poikilotherms
2 Endotherms or homeotherms
3 Heterotherms

1 *Ectotherms or Poikilotherms* - These animals control their body temperature by external means. Their body temperature is variable (" *poikilos*" meaning many fold) depending on the surrounding temperature. They gain heat through exposure to the environmental sources and loose heat to the surrounding by means of conduction, convection or evaporation. These animals are also called cold blooded animals. Invertebrates, protochordates, fishes, amphibians and reptiles are ectothermic animals.

Characteristics of poikilotherms

i) Their metabolic rate and other activities are controlled by the environmental temperature. Their metabolic rate is only 10 to 20% of the warm blooded animals.

ii) Every 10^{o} C rise in the temperature doubles or triples the metabolic rate and other biological processes. This is in accordance with Von't Hoff's Law. For example in the cadence of crickets the frequency of their chirping is higher in the warm weather. A blind astronomer used this parameter to read the temperature by timing the chirps produced by the crickets outside his house and applying the formula :

Number of chirps per 13 sec + 42 = temperature in deg. F

Another example of increase in the speed of reaction is observed in development of cod eggs. From -1^{o} C to + 14^{o} C, there is a direct relationship between the development of eggs and increase in temperature.

iii) Ectotherms become more active when temperature is sufficiently high and lethargic when the temperature is lowered. During the day time they maintain their body temperature higher than the night.

iv) The range of body temperature at which poikilotherms carry out daily activities is known as operative temperature.

v) Poikilotherms have a low metabolic rate and a high thermal conductance between the body and the environment.

vi) Aquatic poikilotherms do not maintain any appreciable difference between their body and temperatrue and surrounding water. They are poorly insulated. Temperature can change the morphology of some poikilotherms according to *Jordan's rule.* Cod fish when hatches at a temperature 4^{o} to 8^{0} C has 56 vertebrae whereas, if it hatches at 10^{0} to 11^{0} C it has 54 vertebrae (Clarke,G.L., 1954).

vii) Poikilotherms do not have the problem of loosing metabolic heat they can occupy the habitat which homeotherms can not .

viii) They produce more energy anaerobically.

ix) **A**nimals living in the colder region are smaller in size as compared to their closely related species in the warmer region to reduce the heat loss from the body surface.

x) Poikilotherms *hibernate* in winter and *aestivate* in summer to escape the extremely cold and hot environmental conditions respectivly. They are also called frequently winter and summer sleep.

2. Endotherms or Homeotherms These animals can maintain their constant internal body temperature , which is independent of outside temperature("*homeo*" means same). Homeothermy allows these animals to remain active even at low temperature at high energy expanse. They are also called warm blooded animals as they are warm to touch Birds and mammals are endothermic animals except humming birds and bats.

Characteristics of homeotherms

i) Homeotherms have a high metabolic rate and a low thermal conductance.

ii) They maintain a high level of aerobic energy production since the efficient cardiovascular system can rapidly provide oxygen to all the tissues .

iii) There is a close relationship between the metabolic rate and body size . It is explained by *Bergmann's principle* which states that "birds and mammals of the same species attain a greater body size in cold region than in the warmer regions and among the closely related species larger ones inhabit the colder climate. The basal metabolic rate (BMR) is proportional to the body mass. As the body weight increases weight specific BMR reduces. Conversely as the body mass decreases weight specific BMR increases. Smaller organisms have a higher metabolic rate than the larger.

In smaller organisms mass per unit surface area is more than in larger

In these three cubes of equal weight mass per unit area is maximum in the first and minimum in the last.

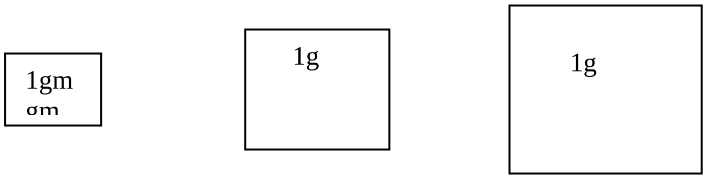

Fig. 6: Showing body size and mass relationship

iv) Homeotherms maintain their internal body temperature by the following processes:

- Increasing their metabolic rate by utilizing more glucose.
- Seasonal changes in the insulation such as the type and thickness of fur, structure of feather and a layer of fat.
- Cooling by perspiration .

v) Birds and mammals have shorter extremities such as legs, tail and ear in the colder climate to avoid the excessive loss of heat through them. As explained by *Allen's rule* that warm blooded animals loose their body heat through the extremities. They tend to be shorter in the colder regions as compared with their relative species in the warmer climatic regions. The reverse holds good for the cold blooded animals.
.

vi) In all homeotherms the enzyme systems in their body show the maximum activity at a constant temperature which is called the *optimum temperature*. For example all mammalian enzymes have their maximum activity at 37^{o} C which is the constant temperature in their body.

vii) Some of the mammals can hibernate during extremely cold. They reduce their body temperature but unlike poikilotherms keep it higher than the surrounding temperature e.g. in case of polar bear there is not much reduction in body temperature. They do not eat, drink and urinate during hibernation but maintain the metabolism near normal . They do so by recycling urea which is completely converted into amino acids which in tern are reconverted into proteins and the energy is conserved to perform essential life processes at a minimum rate.

3. Heterotherms They are in between ectotherms and endotherms as they regulate their body temperature by ectothermy sometimes and by endothermy at other times. The environmental temperature determines the mode of their body temperature regulation Humming birds , bats some insects and bees are heterotherms . Most of the species of insects while flying are heterotrophic Their metabolic rate increases some times it is even higher than that of homeotherms Most of the insects can not fly if the temperature of their thoracic muscle is below 30^{o} or higher than 44^{o} C. Butterflies and dragonflies warm up by orienting their bodies and spreading their wings to the sun.

To reduce the energy expeanditure during the period of inactivity small homeotherms become heterotherms and show *daily torpor* . Daily torpor is the dropping of the body temperature to approximately ambient temperature for a part of each day. Nocturnal animals go into torpor during the day time e.g. bats. Hibernation in poikilotherms is also a *seasonal torpor*

Some of the microorganisms are found surviving at very high temperature in hot springs without being affected these are called *thermophillic* organisms.

Animal Responses to the Extreme Temperature Condition

- *Optimum range:* **A**lthough the actions of temperature extremes may be drastic at times but the plants and animals of any habitat spend most of their lives at intermediate temperature. There is always an optimum range in which a species lives comfortably without being subjected to any constrains. Some animals have a wide range of tolerance to temperature and others have a narrow range. Animals with wide range of temperature tolerance are called *eurythermic* and with narrow range of tolerance are *stenothermic*. Poikilotherms are mostly stenothermic and homeotherms are eurythernic. But the action of temperature on life processes must be considered for each species separately as the behaviour of each species changes with its geographical location as well as with its evolutionary history and adaptations.
- *Minimum effective temperature:* The lowest temperature at which the organism can live indefinitely in an active state is termed as the minimum effective temperature. After a further reduction in temperature the organism goes into chill coma. If organism is not subjected to this low temperature for a long time, it may revive from this chill coma under favourable conditions . Total duration of exposure is very important,e.g. the eggs and the larvae of the fruit fly *Ceratitis caopitata* were killed after 7 days at 7^0 C, in 3 weeks at 4^0. C and in 2weaks at 1^0 C .
- *Maximum effective temperature:* This is the greatest heat intensity at which the species can live indefinitely. At a temperature higher to this the animal goes into heat coma but can recover from it if it is not too long exposure. Exposure time at high and low temperature is also equally important in determining whether the animal would recover from the coma or not. All these thermal relations can be clearly understood from the following study on House fly (Table3)

Death	**46.5^{o}C**	**In few minutes**	**Maximum survival temperature**
Heat coma	44.6^o C		
Excessive activity	40.1^o C		
Rapid movement	27.9^o		Maximum effective temperature
Normal activity	23^o to 15^{o}C		Effective temperature range
Feeble movements	10.8^{o}C		Minimum effective temperature
Begins moving	6.7^o C		
Chill coma	6.0^o C		
Death	-5.0^o C -8.0^o C -12^o C	in 40 minutes in 20 minutes in 5 minutes	Minimum survival temperature

Table: 3 Temperature relations of the house fly *Musca domestica* indicating the range of tolerance, zone of stress and zone of coma. Death occurs with in a few minutes at high temperature and at low temperature, at -5.0 it take 20 minutes, and at -12^o, only 5 minutes**.**

Adaptations of organisms to the extremes of temperature conditions can be behavioral morphological or physiological

1. *Morphological adaptation*: Formation of seeds, spores, cysts , eggs and pupae is a morphological adaptation of the organism to escape from unfavourable temperature. These protective specialized structures protect the whole organism with in them. In some cases only a part of the plant (like stolon and roots of grasses) is resistant to unfavourable temperature and it develops into the whole plant under proper temperature conditions whereas, the rest of the plant disintegrates.
2. *Physiological adaptation*: In some organisms, physiological changes take place in the tissues to prevent their freezing. Some colloids are formed which bind to the water and increase the osmotic concentration , depressing freezing point . Many poikilothermic animals inhabiting arctic and temperate region are exposed at below freezing temperatures for a long periods in winter. They are capable of supercooling their body without allowing their protoplasm to freeze. They have certain solutes like *glycerol* in their body which help in supercooling process. Some desert mammals use hyperthermia to reduce the difference between the body and the environment. They store body heat by day time and at night dissipate it to the cool desert air.
3. *Hibernation:* It is also known as winter sleep in animals. A large number of poikilothernic animals go into hibernation during winter. These animals store sufficient quantities of food as fat in their body so that they can survive through these extreme temperature conditions without spending energy on feeding. These animals go into mud, in crevices or under rocks. They spend very little energy on respiration to keep them alive and suspend all other activities. Homeotherms also undergo hibernation but they slightly lower their body temperature and keep it sufficiently higher than the surrounding temperature. For example, ground squirrel hibernate in burrows made up to a depth of 1 meter in snow and when the surface temperature is – 50 ^{o} C temperature in the burrow is -5 ^{o}C.
4. *Aestivation or dormancy* : This occurs during summer may be in response to high temperature, dryness and short supply of food to animals. It is more common in pokilotherms and is less common amongst homeotherms. This is also known as summer sleep. The animals reduce their activities and remain in their burrows to avoid the heat of the summer.
5. *Insulation:* To reduce the exchange of heat between the body and the environment, homeotherms and some poikilotherms use some form of insulation such as fur, feather or fat on their body. In mammals fur is the major barrier to heat flow. Larger mammals can afford to have more fur but not the smaller ones since it will add to their weight and reduce their mobility. The thickness of the fur also changes with the season. Many mammals have a thick layer of fat as an insulator. Even in some antarctic birds like auklet and penguins there is a thick layer of fat beneath the skin. When insulation fails many animal can produce heat by shivering . *Shivering* is an involuntary muscular activity that produces heat. Small mammals burn their brown fat to generate heat.
6. Migrations: Both poikilotherms and homeotherms resort to behavioural means to regulate their body temperature. They can change their

microclimate by thermal migrations which can be very small that is a few cm to several thousands miles. In winter poikilotherms can move to the warm sunny places during the day and enter into the burrows at night which are warmer. In summer, they spend the day in the shaded places and come out when it cools outside. Ground squirrels in south western United State hardly ever experiences the extremes of desert temperature because of these thermal migrations. Crocodiles, turtles, frogs and many other amphibians can move in and out of water in response to temperature changes. Many birds mammals and insects make very long journeys to escape the summer heat or winter . Arctic tern makes the longest migrations of 18000 km every year. They have their feeding grounds in the antarctic and the breeding grounds in the north arctic zone. Similarly there are large number of migratory birds that have their breeding grounds in the northern temperate zone and feeding grounds in the tropical regions. Cranes, coots, many species of ducks, storks and flamingoes are well known migratory birds of the wetlands. Many of them come to India from Siberia. In summer northern regions are their breeding places and in winter southern tropical regions are their feeding grounds. Bear, deer and other game animals descend from the mountain peaks into the sheltered valley in winter. Many mammals like caribou and bison also migrate long distances to avoid extremes of temperature as well as in search of food.

Humidity

Humidity is the amount of water vapours in the atmosphere. The water vapours get into the air by evaporation from water bodies, moist surfaces and transpiration from the plants. Like other gases in the atmosphere, water vapours act as independent gas and exert their own pressure called *water vapour pressure*.

The actual amount of water in the air can be expressed as weight of water per unit of air and is referred to as *absolute humidity*. When volume of the air holds all the water vapours it can hold, and it is completely saturated the pressure exerted by water vapours at saturation is called *saturation vapour pressure.* The amount of water vapour air can hold varies with temperature and pressure. At higher temperature and lower pressure air can hold more water vapours. The lower the air pressure more is the capacity of air to hold water vapours at the same temperature. For ecologists *relative humidity* is more significant than absolute humidity. *Relative humidity is the percentage of water vapours actually present in the air as compared to saturation under the existing conditions of temperature and pressure.* At saturation vapour pressure relative humidity is 100 %. If relative humidity is 60% means the air has 60 percent of the water vapours with respect to its total water holding capacity. A reduction in the temperature decreases the capacity of air to hold moisture, for example if relative humidity is 30% at 25^0 it may be increased to 40% at 20^0 C with the same amount of water vapours. In a given volume of air, there is an inverse relationship between temperature and humidity. Relative humidity of a place is affected by the following conditions:

- Relative humidity shows diurnal variations. It is higher at night and early morning when the temperature is lower and lower during the day time when the temperature is higher.
- . In the mountainous countries the variations in humidity are more pronounced. Relative humidity decreases as the altitude increase due to a decrease in the pressure but simultaneously there is a decrease in the

temperature that results in increased relative humidity. The diurnal variation of humidity is greater in valleys than at higher elevations.

- Wind along with temperature has a great influence on the evaporation and humidity. Wind mixes the moisture laden air with the drier air above and as a result the vapour pressure of the air is reduced and evaporation from the surface increases and an increase in humidity.

An instrument called *psychrometer* is used to determine the humidity of a place. It is also called dry and wet thermometer as it consist of a dry and a wet bulb thermometer. The difference in the reading on the two scale is recorded by continuously revolving it in the air for 10 minutes This difference in reading is used to calculate the relative humidity.

Vapour pressure deficit: It is converse of relative humidity and is the amount of water vapours required to saturate the air It can be obtained as a difference of partial pressure of water vapour at saturation and the actual vapour pressure. For example if relative humidity is 30%, vapour pressure deficit is 70 %.

Dew point: This is also used to measure moisture in the air. When the air is cooled the water in it condenses to form water droplets. *The dew point is the temperature at which the condensation of water vapours in air begins.*

Adaptations to drought (arid conditions)

i) *Impervious skin*: To prevent the loss of water from the surface of the body animals living in arid zones have thick skin. Generally the skin is also covered with spines for the same purpose.

ii) *Dormancy*: During extreme summer conditions, many animals become dormant and undergo summer sleep. This process is known as *aestivation which is in response to both the increased temperature and reduced moisture in air.* Some insects under go *diapause* a stage of arrested growth in development and hatch out only under favourable conditions.

iii) *Metabolic water* : Water available in food and metabolic water produced within the body is retained and used as and when required.

iv) *Reducing the respiratory water loss*: Many species of rodents remain active during dry season by reducing respiratory water loss. Small desert rodents lower the temperature of the air they breath out. The moist air from the lungs passes over the cooled nasal membranes leaving condensed water on the walls and as they inhale the warm dry air it is humidified and cooled by this water. In ungulates the respiratory mechanism is more efficient and they have a low rate of respiration to reduce the respiratory loss of water.

v) *Suppressing the sweating*: Some of the desert ungulates reduce loss of water through sweating by becoming hyperthermic during the daytime. At night these ungulates reduce the rate of evaporation by lowering the body temperature.

vi) *Production of concentrated urine* : Most of the animals living in arid conditions produce concentrated urine and dry faeces

vii) *Ability to withstand dehydration:* Desert rabbit can withstand dehydration up to 50% and camel up to 27% of their body weight.

viii) *Migration*: Many animals which have no means to conserve their body water migrate to the new localities where it is available in plenty, In Africa, many large ungulates avoid drought by leaving the area during the dry season. The spade foot toad makes small migrations and becomes underground during the dry conditions and it emerges only during the rainy periods.

ix) *Nocturnal behaviour*: The temperature is high and relative humidity is low during the day time on the surface, therefore many animals become nocturnal in habit. They spend the day in the burrow and come out at night.

Precipitation

Freshwater on land and in air exists in three principle forms - atmospheric moisture, precipitation and soil water. Atmospheric water is present as invisible vapours called humidity and also as visible vapours known as *fog* or *clouds* . Precipitation occurs as a result of cooling and condensation of water vapours at high altitude because of fall in temperature, the air gets saturated and looses its water holding capacity and the condensed water vapours start falling as rain due to gravity. Precipitation includes all the moisture that comes to the earth in the form of rain, snow, hail and dew. It is the chief source of soil water. There is a continuous interchange of water between the earth's surface and the atmosphere forming the water *or hydrologialc cycle.* The process of precipitation depends on evaporation from the moist and wet surfaces of the water bodies (like rivers, ponds , lakes, ocean etc.), transpiration from the leaf surface, condensation at high altitude and the gravitational pull of the earth. When the moisture is in the form of minute drops it is called *drizzle***.** *Snow* moisture in the solid form**.** Condensation of moisture directly on an object is known as a *dew* or *frost***.** Rain is the drop of water which is larger and heavier than drizzle and is most important form of precipitation.

Rain is the most important source of soil water. And affects the humidity of the atmosphere. Rains in India are caused by monsoon. Nearly 45% of water available during the annual precipitation flows into rivers. 20% percolates into ground. And the remaining 35% is lost by evaporation.The growth of animals and plants is greatly influenced by the annual rainfall. Not only the regional distribution of rainfall is important in determining the distribution of life forms but the different seasons of the year also control the regional distribution of vegetation. For example, the evergreen forests are found in the tropical areas with heavy rainfall through out the year. In the regions of heavy rainfall during winter and low during summer only the sclerophyllous trees can grow. Grasslands are generally characterized by moderate in summer and a very low rainfall during winter.

Light

Light is the driving force of life on earth. It is captured by the green plants and converted into food (potential energy) which can be used by the other living organisms of the biosphere. Light controls the distribution of animals and plants on earth. It also plays an important role in controlling the various rhythms in all the living organisms through day and night cycles. In case of animals, it is associated with their visibility. The main source of light on earth is sun during the day and moon and stars at night . For some animals in deep sea as well as at night where sun / moon light is not available, light of biological origin that is *bioluminescence* is the source of light to perform their activities.

Light is a directional and is highly variable factor with time and space as compared to temperature. The magnitude of the solar radiation as it reaches the outer atmosphere is called *solar constant* and it is 1.9 g- cal./cm ^{2} / min. Light intensity at the sea level is 1.5 g-cal /cm.^{2}/ min. Of the total range of solar radiations reaching the earth's atmosphere, the wavelength of only approximately 360 to 760 nanometer (3600 to 7600 A^o) make up the visible light. Collectively these wave lengths are known as *photosynthetically active radiations* (PAR), because they are used by plants for photosynthesis. Light of wave length less than 3600 A^o is ultraviolet and is bad for life. The radiations of higher wavelength i.e. larger than 7600 A^o are called infrared. Inferared radiations have high penetrating capacity because of their large wavelength. Nearly half the solar radiations are visible light and the remaining half is infrared.

Intensity and duration of light on land

The intensity of light reaching the earth's surface varies with angle of incidence and the amount of absorption by the atmosphere. Changes in the sun's altitude (that change in the angle of incidence) are due to differences in - i) latitude ii) season iii) time of the day. An increase in the altitude decreases the angle of incidence and the light has to pass through a longer distance to reach the surface of the earth. This reduces the intensity of light. The greatest intensity of sunlight occurs when the sun is most over head. At higher latitudes, the intensity of light is reduced as the angle of incidence decreases. On the equator, the day length is always 12 hours but with the change in latitude it increases or decreases with the season. In spring, as we move from equator towards pole the day length increases and this effect is accelerated at higher latitudes. In summer the day length increases to 24 hours on the poles on June 22. This is called *summer solstice* for the northern hemisphere when north pole experiences a day length of 24 hours and there is 24 hour night on south pole. Conversely, on *winter solstice* that is 22 December, south pole has 24 hour day and north pole has 24 hour night. At higher latitudes the intensity of light is reduced. At 50^o north latitudes on the day of E*quinox* that is when the day and night are equal on March 21 and September 23, the intensity of light is only half of what it is on the equator and goes on reducing towards the poles (Fig.2).
Thus latitude has a definite effect on the amount of light available on the surface of the earth, but other factors also play an equally important influence on the availability of light to the biosphere. Moisture, clouds and dust particles in the atmosphere have a profound and irregular influence on light reaching the surface of the earth. In case of forests light is obstructed from reaching the forest floor by the tall trees. This effect is seen quite variable in different forests depending on the type of trees growing in them. The day length and intensity of light may change with altitude, time of the day or season or with other conditions but it is observed that sufficient light is received by all parts of the biosphere to support some form of life.

Intensity of Light in Water

The sunlight available to the plants and animals in the aquatic environment, enters the water from air. Therefore, first it is subjected to all the changes imposed by the conditions above the surface. Nearly 10 % of the light is reflected back by the water surface. As the light enters into water which is a different medium from air, it is modified with respect to its intensity (due to dispersion of light in water), spectral composition, angular and time distribution. Intensity of light is reduced both by absorption and scattering. The light intensity can be measured with the help of a photometer (luxmeter) placed in a water tight case. This process of reduction of different spectra (light of different wavelength) of light at different depth is referred to *as extinction of light in water*. Orange and yellow components are reduced more rapidly with increasing depth. At a depth of about 70 meters blue light is reduced to about 70% of its intensity at the surface whereas, the yellow light is reduced to 6%. At a depth of 100 meter or slightly deeper blue light becomes completely dominant.

In all natural bodies of water suspended particles, dissolved materials and fauna and flora causes further alteration in the transparency and spectral composition of light. In temperate and costal seas and in majority of inland lakes, fine particles or stains are present that tend to absorb or scatter blue light more strongly than others in pure waters. As a result of this, the green component of the sunlight is usually most penetrating giving the water a characteristic emerald colour.

Biological Effects of Light

Light influences photosynthesis, pigmentation, growth , reproduction, locomotion and many other activities in animals and plants.

1. *Photosynthesis:* One of the most important life process which cannot be performed without light by the green plants is photosynthesis. So light is an essential ecological factor to perform a life support function of the biosphere

2. *Effect on pigmentation* : Light affects pigmentation in both animals and plants. Among green plants light is required for the production of chlorophyll in chloroplasts. Plants growing under insufficient light are not able to synthesize sufficient amount of pigment and their leaves become *etiolated*. Excess of illumination also causes destruction of chlorophyll. In some plants, the excessive penetration of light is prevented by the screening action of the chloroplasts. In the presence of bright light the chloroplasts line up one behind the other so that a larger proportion of the radiation passes through the leaf in between the chloroplasts. When the light becomes weak the chloroplasts spread out and absorb a maximum percentage of the incident illumination.

   In animals light influences pigmentation in several different ways. Cave animals, blind amphibians and certain aquatic fishes which lack pigmentation normally (as they live in dark), if exposed to light develop pigmentation. The abundance of pigment in the chromatophores is sometimes directly controlled by the intensity of light. The pigmentation in animals is their adaptation to local conditions and helps them in several ways. In some animal groups pigmentation helps in protecting them from their predators. A fish is generally darker in colour on the dorsal side than on the ventral side. When a predatory bird looks at it from the top, its colour merges with the dark background in water and when large predatory fish looks at it from the lower side, it merges with the light above the water column. This type of protective colouration is also commonly observed in terrestrial animals. In some animals colour may be changed very fast, within a few minutes to fool the enemy and escape e.g. colour changes in chamaeleon are known to everyone. They match their colour with the background to escape the sight of their predator. Another example is mimicry in insects. They adapt themselves to the surrounding environmental conditions. Evidences indicate that pale or dark colouration has evolved in many species as a result of selective survival value as influenced by their conspicuousness against the background. A common example is of industrial melanism in moth in England. The moths relied upon camouflage to protect themselves from being eaten by insectivorous birds. As long as the bark of the trees on which they rested was pale, it was advantageous for the moth to be pale. But as the industrialization proceeded and the bark of the trees near the cities was blackened by soot, pale moths became more conspicuous. In 1848 for the first time the dark moth or the melanic moth appeared and over a period of 100 years it became more common and the pale form was rare exception. Dark winged moths were produced from the light winged moth by the process of mutations.

In some cases pigment may be produced as a metabolic by-product and may not have any ecological significance. Deep sea animals are dark in colour e.g. a species of shrimp is red coloured which has no ecological significance. In many birds and reptiles bright colouration is also to attract their mate.

3. *Vision and movements :* In higher forms light is perceived by vision. All the organisms who can perceive may not have visual organs. Their sensitivity to light is expressed by their behaviour and movements as given below:

   a. *Phototropism:* Orientation of the sessile organisms in response to light is called phototropism. If an organism bends or grows in the direction of light it is positive phototropism and if it is away from the source of light it is negative phototropism. It is more common in plants and in a few sessile animals. It is brought about by a differential growth or turgor movement of the plant. Some times it is due to the combined effect of gravity and light. The tips of the green plants grow towards the light and are positive phototropic while the roots are negative phototropic.

   b. *Phototaxis:* This is the orientation of the motile organisms towards (positive) or away (negative) from the direction of light. Many flagellates , zoospores and gametes of plants exhibit phototaxis.

   c. *Photokinesis* : Light controls the locomotor activity of many lower organisms by a direct action on their speed. This is known as photokinesis. The increase in the light intensity increases the speed of locomotion and a reduction in the same lowers the speed. This is positive photokinesis and conversely in negative photokinesis an increase in light intensity reduces the speed of locomotion.

4. *Periodicity* : It is a common observation that the onset of winter in India brings the migratory birds from extreme north and in spring the flowering plants are in full bloom. The songs of the birds signal the arrival of dawn. At dusk the water lilies fold, the birds back into their nests and one feel tired after the whole day's activity period. What controls day and night or summer and spring on earth? Light controls a large number of such rhythms in animals and plants. *Rhythms are activities of the organisms which are repeated at regular intervals*. These rhythms are driven by daily rotation of the earth on its axis and its revolution around the sun. Therefore a rhythm can be completed in 24 hours (circadian) or in 365 days (annually). Moon completes its one revolution around the earth in one month therefore, the rhythms controlled by moon light are of one month duration. Biological rhythm can be classified into the following types :

   i) Diurnal and circadian

   ii) Seasonal

   iii) Lunar.

i) **Diurnal Rhythms** : The word "diurnal" means around the day. These rhythms exhibit a 24 hour cycle. The word diurnal is also used for the animals active during the day in contrast to "nocturnal" that is active at night. Photosynthesis is a diurnal rhythm in plants. In animals almost all the activities are controlled by day and night cycles. The vertical migrations in the zooplanktons in seas and lakes are common example of diurnal rhythm. The flying squirrels- *Glaucomys volans* shows a day to day activity that conforms with 24 hour cycle. Sunset stimulates the "onset" of activity period of this animal. Light has a direct or indirect regulatory effect on their diurnal rhythm. In the laboratory when these animals are subjected to artificial day and night of 16 hours light and 8 hours dark or vice versa , their activity always begins with the onset of dark period. This behaviour indicates only response to a night fall or day break(dusk and dawn). However, if this squirrel is kept in constant darkness, instead of remaining active through out it shows a pattern of activity and inactivity cycle without any environmental factor acting to trigger it but its activity rhythm deviates from the normal 24 hour cycle and on an average it become shorter than 24 hours. If on the other hand it is kept under constant light conditions, the on set of activity period is delayed and cycle becomes longer than 24 hours. The innate rhythms of active and inactive phases are approximately of 24 hour duration. All living organisms except the bacteria exhibit these rhythms. These rhythms match the period of earth's rotation on its axis therefore they are called *circadian rhythms* which in Latin means about the day. ("*circa*" is about and "*dies*" means day). This is like even on a dark cloudy day you wakeup in the morning at the same time when you do so on other days. Circadian rhythms exhibit a self sustained oscillations under constant conditions of light or dark. *The period of a free running circadian cycle is the number of hours from the beginning of the cycle on one day to its beginning of the next cycle under constant conditions.* Thus an organism is subjected to an external rhythm of 24 hours controlled by day and night cycle and an internal circadian rhythm of *approximately* 24 hours. That is the biological clock. Circadian rhythms are inherited in populations e.g. human beings are active during the day time. These rhythms control not only the physical activity of the organism but they also influence the physiological processes and metabolic activities.

The circadian rhythm and its sensitivity to light and dark are the major mechanisms that operate the biological clock. They are the time keeper of physical and physiological activities of plants and animals. In unicellular organisms, there are photosensitive chemicals that act as biological clock. In multicellular animals the cock is present in brain or may be connected to brain. Reptiles, birds and mammals have a light sensitive pineal gland. This is commonly called the third eye of lord Shiva in reptiles. In mammals it is located in the hypothalamus above the optic chiasmata (where the optic nerves cross over each other). During the dark period a hormone called *melatonin* is synthesized by the pineal gland which operates the clock. More the concentration of melatonin, longer is the dark period and less concentration means long light period in these animals. Like melatonin plants have a protein pigment called *phytochrome* which can detect the light.

Biological clock runs continuously and recurring environmental signals should reset it. The study of biological clocks remains incomplete without mentioning the name of Bunning. He proposed two models. The first model states that the fist half (12 hours) of the cycle requires light and the second half requires darkness. When the light extends into the dark period it triggers long day to induce or inhibit flowering in plants. The second model is a two oscillator model. One oscillation is regulated by dawn and the other by dusk.

Biological clocks are of great significance to the organisms. They prepare the organism for a periodical change in time ahead. They also provide the organism with time dependent mechanisms for reproduction, preying, reducing competition and escaping from their enemies.

ii) **Seasonal** : The effect of season on animals and plants is exhibited more in the middle and upper latitudes as the daily periods of light and dark change with the season.

Seasonal periodicities in animals and plants are not only in repose to light and dark cycles but are equally influenced by temperature, precipitation and availability of food .Nevertheless, light plays a very important role. The responses of organisms in day length is known as *photoperiodism.* The most striking manifestation of photoperiodism is the control of reproductive cycles in animals and plants.

Photoperiodism was first discovered in plants. The species of plants which flower only during summer are called *long day plants* and those which flower during winter are known as *short day plants* . Plants in which day length has no effect and flowering occurs through out the year are the *day neutral plants.* Some familiar examples of the long day plants are Trillium , Violets radish, iris, red clover, evening primrose, spinach and smaller cereals. Short day plants are tobacco, aster, dahlia, ragweed and chrysanthemum. It has been observed that the dark period (night) plays a more important role in triggering its stimulatory effect. If the dark period of the subjective night of circadian rhythm is interrupted, each plant responds as if it had been exposed to a long day. *The modern ecologists call them as long night and short night plants.*

In most of the seasonally breeding birds and mammals, day length is crucial in determining their reproductive cycles. For the long day breeders, increasing day length during spring stimulate their gonadal growth. Indian weaver bird , *Ploceus philippinus* , commonly called Baya. Is a good example to demonstrate this phenomenon. Its reproductive cycle clearly shows the direct effect of day length on the growth of testis in male birds. In female the ovaries do not undergo any such variation and maintain the same size and weight throughout the year. The reproductive cycle is divided into four phases namely

1) Progressive

2) Breeding

3) Regressive

4) Nonbreeding.

The progressive phase begins with the increasing day length of spring in March and continues till May. From June to August the birds are in their breeding phase and gonads are fully developed and active. Male birds show beautiful *nuptial* plumage at this time to attract the female. Their beak becomes black and there is golden yellow colour on head and neck. They also make well designed retort shaped pendant nests on date palm or babool tree. Breeding period is followed by the regressive phase in which the testis start regressing in September and October when the day length is decreasing. During this period the nuptial plumage gradually fades. In winter months (November and February) , the birds are in their nonbreeding phase.

iii) **Lunar**: The reproductive cycles of many animals are controlled by moon. These are called *lunar periodicities*. Most of the organisms exhibiting lunar periodicities are marine. They are greatly affected by the high and low tides. It is even stated the 28 day menstrual cycle in women recall an earlier period our marine ancestors.

Some example of lunar periodicity are

i) The marine alga ,*Dictyota*, produces gametes at the full moon spring tide.

ii) Enlargement of gonads in sea urchin in Red Sea during full moon. Sea urchin gonads are food for the local populations.

iii) Palolo worm is a marine polychaete found in the waters near the south pacific islands. They are bioluminescent. These worms come to the surface in great number during the last quarter of the moon in October and November to discharge eggs and sperms and swim in small circles in dense masses giving the sea an appearance of a spaghetti soup. The sea shore populations collect the worms and celebrate the occasion with religious rites and feast.

iv) Bermuda fire worms also displays a similar firework in the shallow waters at the time of full moon in the evening. They began their spawning and luminescence at about 55 minutes after the sunset. These worms are very accurate in calculating their time.

v) Grunion smelt (fish) found on the beaches of southern California is another fascinating example of lunar periodicity. Three or four days after the spring tide from April to June the fish swims to the beach to lay its eggs and sperms in sand and it is carried back to the sea by the waves of the spring tide. The eggs remain undisturbed in the sand under warm and moist conditions till the next spring tide when they hatch out into larvae and move into the sea with the adults.

Pressure

Pressure is defined as a force per unit area applied by a fluid or gas against a surface. The pressure changes with the increasing altitude in the atmosphere and increasing depth in the water. It decreases with the increasing altitude on mountains and increases with the increasing depth in water bodies. On the surface of the earth at sea level, the pressure is 760 mm Hg. and this is called as one atmospheric temperature. Above the surface of the earth for every 300m (1000 feet) rise in the altitude results in the reduction of pressure by 25 mm Hg. In contrast, for every 10 m (33 feet) increase in the depth in water the pressure rises by 1 atmosphere. (760 mm Hg.) This is because of the density difference between air and water. For this reason, it is easy to explore atmosphere than to explore deep sea.

Pressure reduction with altitude : Reduction in pressure has little effect on plants, invertebrates and lower vertebrates. Their reduction at high altitude is primarily due to other limiting factors such as temperature and light. But for the warm blooded animals reduction in pressure with altitude becomes very important. At high altitudes , the layer of air becomes very thin thus rendering the flying more difficult for birds. The most adverse effect at high altitude are due to short supply of oxygen that impairs the respiration in animals. The highest permanent human settlements are found upto only 5000 meter in Tibet. At this altitude and slightly higher, very few highly adapted specie of animals like wild sheep and ibex are found. At 4800 m altitude the pressure is reduced to 413 mm Hg.

Altitude in meters	Pressure in mm Hg	Significance
Sea level	760	Surface of the earth
4860	413	Highest human settlement
5800	367	Wild sheep and ibex
7000	310	Vultures and eagle
8840(29000 ft)	235	Mt Everest
22000	22	Stratosphere balloon
254000	-	Rocket powered plane

Table 3: Showing the fall in temperature with increasing altitude.

Pressure increase with depth: The rate of change of pressure with increasing depth is much more than that of increase in altitude, therefore the distribution of life in the ocean is limited. Deep sea forms if brought to the surface would die because of a sudden change in pressure. The average depth of the oceans is 3700 m at which the pressure is increased to 370 atmosphere. Surprisingly, it is observed that some crustaceans, bivalves (Molluscs) , sea cucumber (echinoderms) and sea anemones(coelenterates were found at a depth of 10500 m (oceanic trench) of the Philippine Islands. The pressure at this depth was 1050 atmosphere. The body of these animals does not have any air spaces rather it is filled up with the fluid. This is an adaptation which prevents their deformation under high pressure in deep sea.

Edaphic Factors

Edaphic factors include structure, physical and chemical composition of the soil. Soil is the foundation upon which all terrestrial life and much of the freshwater aquatic life depends. It is an integral part of the biosphere. It is essential for the biological cycling of nutrients and is a main reservoir for the minerals. Soil system make substrate for the roots of the plants. The biomass of the living organisms below the surface of earth is less than that above it in a given area. Although it is difficult to define soil, It may be defined as the weathered superficial layer of the earth's crust in which the living organisms grow and also release the products of their activities, death and decay. *Pedon* is the basic unit of soil. Soil is not merely an abiotic factor as it is impregnated with millions of minute bacteria fungi and small animals. The components of soil are studied as follows:

Components of soil

a. *The fauna and flora.:* It is difficult to distinguish between fauna and flora of the soil since representatives of most of the major groups of organisms spend a part of their life cycle on the earth. The major groups of living organisms are bacteria, actinomycetes, fungi, algae, protozoa, rotifers, nematods and earthworms .

b. *Organic matter:* Most of the organic component of the soil is formed from the dead and decomposed living organisms. It makes up very small portion of the soil (only 5% of the dry weight). *Humus* is dark brown to black product formed from the bacterial decomposition of dead animals and plants.

c. *The inorganic matter*: The mineral matter constitutes about 38 to 47 % of the soil's 'wet weight and 97 % by oven dry weight. It includes all the minerals present in the soil.

d. *The soil solutions*: Water is the major nutrient solvent in the soil. Minerals dissolved in nutrients solvent make soil solutions.

e. The soil atmosphere: The amount of air in the soil varies inversely with that of water. Maximum aeration is observed in soil at conditions which cause wilting of plants.

Formation of Soil :

A. Factors involved in the formation of soil.

Formation of soil involves five interdependent factors as given below:

i) *Parent material* :It is the unconsolidated mass from which the soil forms. It is derived from the parent rock or from the transported material. It is important in determining the chemical composition of the soil depending upon whether it is derived from an igneous , sedimentary or metamorphic rock.

ii) *Climate:* It affects the development of the soil. Temperature and rainfall determine the weathering of rock, decomposition of minerals, organic matter and leaching of materials.

iii) *Biotic factors:* Plants, animals, bacteria and fungi contribute to the formation of soil. Vegetation gives colour to the soil and prevents its erosion. Animals, bacteria and fungi decompose organic matter, mix it with mineral matter and help in the aeration of soil and percolation of water.

iv) *Topography:* Formation of soil also depends on the topography of a place. The contour of the land determines the amount of water that enters into the soil. Less water is retained on the steep slopes than on a flat surface. Therefore, the soil is less developed on the slopes.

B. The process of formation of soil:

It begins with the weathering of rocks and their minerals. Weathering includes two steps :

a) *Mechanical breakdown:* The rock material is mechanically broken into smaller particles by the combined action of water, wind and temperature. It sloughs off the surface layer of the rock and creates crevices into which water seeps in. Alternate cooling and freezing of water cracks the rock into smaller pieces. Materials transported by wind, water and glaciers are added to it. The soil may consist of slightly weathered material with fresh primary minerals or it may be intensely weathered and consist of highly resistant minerals such as quartz.

b) *Chemical modification* : The new secondary minerals are brought about by the activities of soil organisms such as lichens and mosses and the acids produced by them, are added to the primary rock minerals. This activity continuously keeps adding more and more organic matter, and the rain water added to it brings them into solution. This triggers a chain of complex chemical reactions resulting in the conversion of many primary minerals into secondary minerals particularly clay. Iron in this way gets oxidized to red ferric state or it may be reduced to gray ferrous state. Percolating rain water carries carbonates of calcium and potassium along with other soluble salts into deeper layers.

Because of the slope, climate and native vegetation different soils may develop from the same parent material.

Soil Profile

If the soil is cut vertically the soil profile can be distinguished in to five horizontal layers. They are called **horizons** O,A,E,B, and C. 'O' is the organic layer and others are mineral layers. Below these five layers lies a non-soil 'R' horizon. In some of the soils all the horizons are very distinct but in others they appear to form a continuum as the boundaries are not clear.

'O' horizon is formed by partially decomposed material and can be subdivided in to two layers as O_1 or the litter layer, and O_2 is the humus layer. O_1 layer shows seasonal variations in its thickness. In the temperate zones it is thickest in autumn and thinnest in winter. It is usually absent in the cultivated ecosystems.

Soil Layer	**Composition**
O_1 O_2	Litter layer Humus layer
A	Upper mineral layer rich in Organic matter
E	Zone of maximum leaching consisting of suspended and dissolved materials (Granular layer).
B	Zone of illuviation, rich in clay, Iron,,aluminium, and humus
C	Weathered Materials.
R	Unweathered Materials, or the parent Rock Material

Table 4: Composition of the various soil layers.

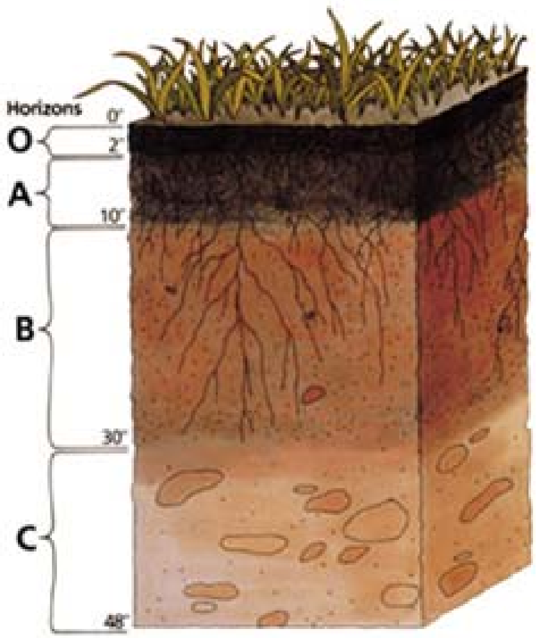

Fig 7: A generalized profile of the soil .In between each horizon there is a transitional zone of the two adjoining horizons. 'E' zone is merged with the a zone.

The 'A' horizon is characterized by an accumulation of organic matter, clay, inorganic minerals and some dissolved salts. This is the zone with maximum biological activity. The 'E' horizon has granular appearance and is whitish in colour. This is the zone of eluviation or maximum leaching. The downward movement of water, suspended particles and dissolved materials make it granular in appearance. 'B' horizon accumulates silicates, clay, iron aluminium and humus and is also known as zone of illuviation. Below this zone some times *clay pans* are formed by the downward leaked out clay. This interferes with the penetration of roots and water. 'C' horizon contains the weathered material and 'R' unweathered or parent material.

Physical characteristics of soil:

Soil colour: Type of soil can be some times identified from its colour as well as their functions and composition. For example, brownish black or dark brown colour indicates large quantities of humus in the soil. Red and yellow soil derive their colour from the presence of iron oxide in them. Quartz, kaolin, carbonates of calcium and magnesium, gypsum and various salts of iron give whitish and grayish colour to the soil.

Soil texture: Texture of the soil is partly due to the parent material and partly it is a result of soil forming processes. On the basis of the particle size the soils are classified into four main types as shown in the table 5.

Type of Soil	**Particle Size**
Gravel	Greater than 2 mm
Sand	0.05 to 2 mm
Silt	0.05 to 0.002 mm
Clay	Less than 0.002 mm

Table 5: Soil type and their particle size.

Gravel and sand particle can be seen with the naked eye but not the silt or clay. Clay controls the most important properties of soil. *The soil texture is the percentage (by weight) of sand, silt, clay .* Based on the proportion of these components the soils are divided into *texture classes* namely - sandy soil, loam and clay. Laom is an ideal agricultural soil and has approximately equal portions of sand, silt and clay.

Soil Texture Type

Soil Property	**Sandy Soil**	**Loam**	**Clay**
Aeration	Excellent	Good	Poor
Drainage	Excellent	Good	Poor
Nutrient holding capacity	Low	Medium	High
Water holding capacity	Low	Medium	High
Workability (tillage)	Easy	Moderate	Difficult

Table 6: Depiction of The effects of Soil Texture on Soil Properties.

Pore space: Soil texture affects the pore space in soil and controls the movement of air and water in the soil. Coarse textured soil has more pore spaces and water flows down rapidly. On the contrary, finer textured soil has small pores with greater availability of water and chemical activities. Very fine soils such as clay are poorly aerated and difficult for roots to penetrate.

Soil depth: It varies with the landscape depending on the slope, weathering parent material and vegetation.

Soil Erosion

Depletion of the top layers of the soil from the land is called *soil erosion* . Water, wind, ice and anthropogenic activities are the main agents of soil erosion. Deforestation, industrialization, urbanization, roads and railway tract construction and poor agricultural practices are the anthropogenic activities that accelerate this process and make the land unfit for the growth of natural ecosystems as well as for cultivation.

Consequeces of soil erosion

- It reduces the productivity of land by reducing its fertility.
- Economy of the country is affected.
- It also affects the other natural resources as the sediment gets into the streams rivers and lakes; the aquatic habitat is affected resulting in reduced aquatic food production.
- Natural ecosystems are destroyed leading to ecological imbalance.

Topographic Factors

They are the surface features of a region such as the presence or absence of mountains and valleys. They are also known as physiographic factors. Topographic factors are concerned with the geography of the earth of a particular area that area as it show several irregularities. The chief topographic factors are: direction of mountains and valleys and the steepness of slope. For example , south facing slopes of the mountains receive the most solar energy , which is maximum when the slope grade equals the sun's angle from the zenith point. North facing slopes receive the least energy especially when the slope grade equals or exceeds the angle of sun rays inflection. The climate ranges from warm xeric condition with wide extremes on south pole to cooler, less variable more mesic conditions on north slopes. Consequently, the western or southern and eastern or northern slopes exhibit different distribution patterns of plants.

With the rise in altitude, temperature decreases, rainfall increases and the wind velocity also increases. This results in increased organic matter of the soil at high altitude and causes increase in nitrogen content of the soil with a fall in pH.

GLOSSARY

Weather: It is the combination of temperature , humidity,precipitation, wind, cloudiness and other atmospheric conditions at a specific place and time.

Climate: Long term average pattern of local, regional or global weather is called climate of a place.

Equinox : When the day and night are equal in length ,that is March 21 and September 23.

Summer solstice: on the northern hemisphere, it is the longest day and shortest night, June 21.

Winter solstice: This is the shortest day and longest night on the northern hemisphere, December 22.

Prevailing Winds: These are the major surface winds that blow more or less continuously and are of three types:polar easterlies.westerlies and trade winds.

Polar easterlies: T**hese** are the prevailing winds that blow from northeast near the north pole or from the southeast near the south pole.

Westerlies winds: In the northern hemisphere these winds blow in the mid latitude from the south west and in the southern hemisphere, from the north west

Trade winds :They are the tropical winds that blow from the north east (northern hemisphere) or from the south east (southern hemisphere).

Liebig's law of minimum: It states that *under steady state conditions the essential material available in amounts most closely approaching the critical minimum needed will tend to be the limiting one*

Shelford'sLaw of tolerance*: The presence and success of an organism depend upon completeness of the complex condition. Absence or failure of an organism can be controlled by the qualitative or quantitative deficiency or excess with respect to any one of the several factors which may approach the limits of tolerance for that organism.*

Stenohaline: Organisms that have a narrow range of tolerance to salinity are called stenohaline.

Ectotherms : Animals that change their body temperature with the surrounding environmental conditions. They are also called cold blooded animals.

Endotherms: Animals that can regulate their internal body temperature, by internal heat production. They are also called endotherms.

Bergmann's Rule: It states that "birds and mammals of the same species attain a greater body size in cold region than in the warmer regions and among the closely related species larger ones inhabit the colder climate.

Thermocline: In a thermally stratified body of water ,the layer showing rapid change in temperature is called thermocline It Is also known as metalimneon.

Minimum effective temperature: The lowest temperature at which the organism can live indefinitely in an active state.

Maximum effective temperature: This is the greatest heat intensity at which the species can live indefinitely.

Absolute Humidity: The actual amount of water in the air can be expressed as weight of water per unit of air and is referred to as *absolute humidity*.

Relative humidity *:* It is the percentage of water vapours actually present in the air as compared to saturation under the existing conditions of temperature and pressure.

Dormancy: The state of cessation of growth and suspended biological activity in a living organism is known as dormancy.

Photoperiodism: Responses of the plants and animals to the changes in the relative duration of light and dark.

Periodicity: These rhythms are driven by daily rotation of the earth on its axis and its revolution around the sun. Therefore a rhythm can be completed in 24 hours (circadian) or in 365 days(annually).

Photoropism : It is the orientation by growth or turgor movement in sessile organisms in response to light.

Phototaxis: This is the orientation of the motile organisms towards (positive) or away (negative) from the direction of light. Many flagellates, zoospores and gametes of plants exhibit phototaxis.

Photokinesis: Increase or decrease in the locomotor activity of the motile organisms in response to light is called phototaxis.

Circadian Rhythms: They are the endogenous rhythms of physiological or behavioral activity which are completed in approximately 24 hours. Circadian rhythms are the inherent biological clock of the animals and plants.

Phytoplanktons: These are small floating plants in in abody of water. They move with the currents of water.

Soil Eosion: Depletion of the top layers of the soil from the land is called is soil erosion . Water, wind, ice and anthropogenic activities are the main agents of soil erosion.

Nuptial Plumage: Colourful plumage at the mating time to attract the mate It I stimulated by the sex hormones

Humus: Humus is dark brown to black product formed from the bacterial decomposition of dead animals and plants.

Suggested readings:

1. Elements of Eecology By Robert Leo Smith and Thomas M. Smith, Forth edition Pub: Benjamin/Cumming publishing company Inc.
2. Ecology and Field Biology by Robert Leo Smith (Third edition), 1980 Pub: Harper and Row, New York
3. Ecology by G.L. Clarke John, Pub: Wiley and Sons, Inc. (NY,London, Sydney).
4. Fundamentals of Ecology by E.P.Odum Pub: W.B.Saunder's Company Ltd.
5. Environmental Science by William.P.Cunningham and Barbara Woodworth Saigo Pub: McGraw Hills.
6. Comprehensive Environmental Studies by J.P.Sharma Pub: Laxmi Publications(P) Ltd.
7. Environmental Science , Towards A Sustainable Future,.Eighth Edtion, 2002, Richard T. Wright and Bernard J Nebel. Pub: Prentice Hall of India Private Limited. New Delhi - 110001.
8. Environmental Science by G.J.Miller Jr. Tenth edition, 2004, Pub: Thomson Brooks /Cole.
9. Environment , International edition by Peter H. Raven, Linda R. Berg,andGeorge B.Johnson.Pub: Saunders College Publishing.
10. Ecology and Environment by P.D. Sharma, Pub :Rastogi Publications.
11. Essentials of Ecology and Environmental science by S.V.S. Rana Prentice- Hall of India ,2005.
12. Fundamentals of Ecology by M.C. Dash, Second edition

    Tata McGraw Hill Publishing company Ltd, New Delhi