Advanced Biology

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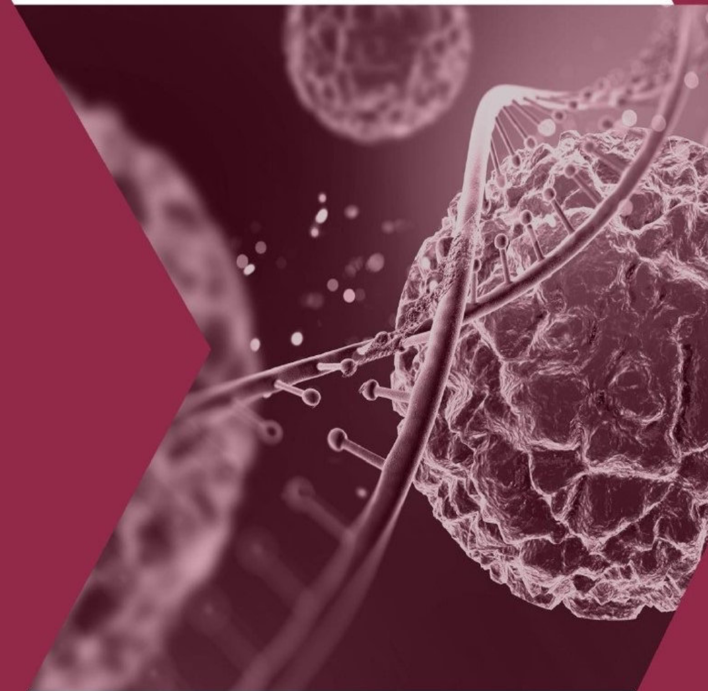

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Dr. P. Muthukumaran

Dr. R. Sakthivel

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AUTHORS INFORMATION:

Dr. P. Muthukumaran., M.Sc., M.Phil., Ph.D.,
Senior Lecturer
Department of Biology
DMI – St. Eugene University
P.O.Box: 330081, Chibombo
Zambia.

Dr. R. Sakthivel., M.Sc., M.Phil ., M.Ed., Ph.D.,
Associate Professor
Department of Biology
DMI – St. Eugene University
P.O.Box: 330081, Chibombo
Zambia.

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#987, Medical College Road
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Phone: +918300123232
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From the desk of
Dr. T. X. A. ANANTH, BBA, MSW, MBA, MPhil, PhD,
President – University Council

Dear Learner,

Welcome to DMI – St. Eugene University!

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I am happy at the efforts taken by the University in publishing this book not only in printed format, but also in PDF format in the Internet.

With warm regards

Dr. T. X. A. ANANTH
President – University Council

CHAPTER I

What is a Cell?

A cell is the structural and fundamental unit of life. The study of cells from its basic structure to the functions of every cell organelle is called Cell Biology. Robert Hooke was the first Biologist who discovered cells.

All organisms are made up of cells. They may be made up of a single cell (unicellular), or many cells (multicellular). Mycoplasmas are the smallest known cells. Cells are the building blocks of all living beings. They provide structure to the body and convert the nutrients taken from the food into energy.

Cells are complex, and their components perform various functions in an organism. They are of different shapes and sizes, pretty much like bricks of the buildings. Our body is made up of cells of different shapes and sizes.

Cells are the lowest level of organisation in every life form. From organism to organism, the count of cells may vary. Humans have the number of cells compared to that of bacteria.

Cells comprise several cell organelles that perform specialised functions to carry out life processes. Every organelle has a specific structure. The hereditary material of the organisms is also present in the cells.

Discovery of Cells

Discovery of cells is one of the remarkable advancements in the field of science. It helped us know that all the organisms are made up of cells, and these cells help in carrying out various life processes. The structure and functions of cells helped us to understand life in a better way.

Who discovered cells?

Robert Hooke discovered the cell in 1665. Robert Hooke observed a piece of bottle cork under a compound microscope and noticed minuscule structures that reminded him of small rooms. Consequently, he named these "rooms" as cells. However, his compound microscope had limited magnification, and hence, he could not see any details in the structure. Because of this limitation, Hooke concluded that these were non-living entities.

Later Anton Van Leeuwenhoek observed cells under another compound microscope with higher magnification. This time, he had noted that the cells exhibited some form of movement (motility). As a result, Leeuwenhoek concluded that these microscopic entities were "alive." Eventually, after a host of other observations, these entities were named as animalcules.

In 1883, Robert Brown, a Scottish botanist, provided the very first insights into the cell structure. He was able to describe the nucleus present in the cells of orchids.

Characteristics of Cells

Following are the various essential characteristics of cells:

- Cells provide structure and support to the body of an organism.
- The cell interior is organised into different individual organelles surrounded by a separate membrane.
- The nucleus(major organelle) holds genetic information necessary for reproduction and cell growth.
- Every cell has one nucleus and membrane-bound organelles in the cytoplasm.
- Mitochondria, a double membrane-bound organelle is mainly responsible for the energy transactions vital for the survival of the cell.
- Lysosomes digest unwanted materials in the cell.
- Endoplasmic reticulum plays a significant role in the internal organisation of the cell by synthesising selective molecules and processing, directing and sorting them to their appropriate locations.

Types of Cells

Cells are similar to factories with different labourers and departments that work towards a common objective. Various types of cells perform different functions. Based on cellular structure, there are two types of cells:

- Prokaryotes
- Eukaryotes

Prokaryotic Cells

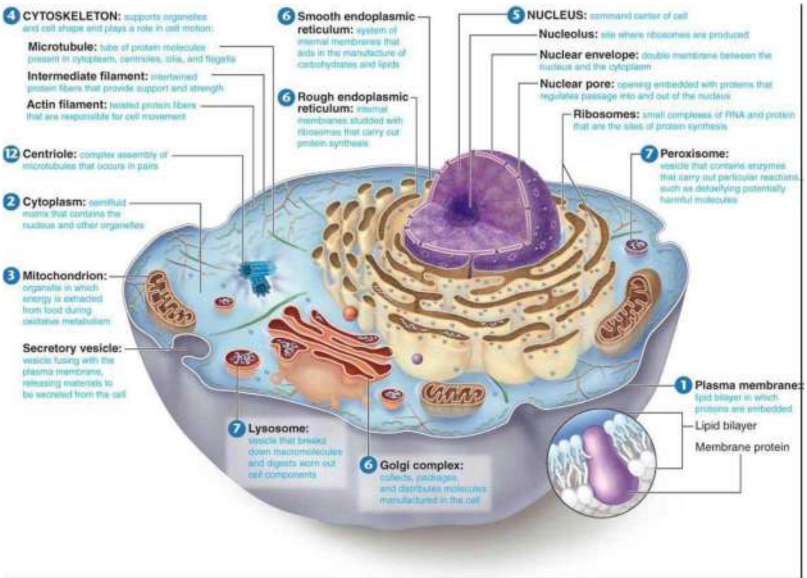
1. Prokaryotic cells have no nucleus. Instead, some prokaryotes such as bacteria have a region within the cell where the genetic material is freely suspended. This region is called the nucleoid.
2. They all are single-celled microorganisms. Examples include archaea, bacteria, and cyanobacteria.
3. The cell size ranges from 0.1 to 0.5 μm in diameter.
4. The hereditary material can either be DNA or RNA.
5. Prokaryotes reproduce by binary fission, a form of sexual reproduction.

Eukaryotic Cells

1. Eukaryotic cells are characterised by a true nucleus.
2. The size of the cells ranges between 10–100 μm in diameter.
3. This broad category involves plants, fungi, protozoans, and animals.
4. The plasma membrane is responsible for monitoring the transport of nutrients and electrolytes in and out of the cells. It is also responsible for cell to cell communication.
5. They reproduce sexually as well as asexually.
6. There are some contrasting features between plant and animal cells. For eg., the plant cell contains chloroplast, central vacuoles, and other plastids, whereas the animal cells do not.

Cell Structure

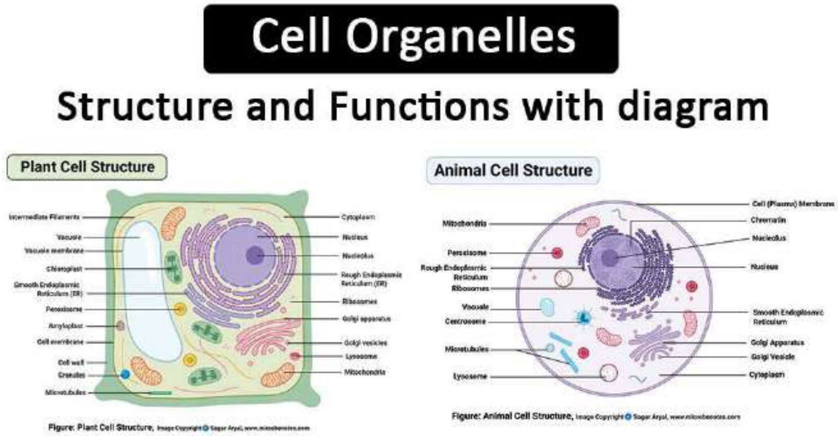
The cell structure comprises individual components with specific functions essential to carry out life's processes. These components include- cell wall, cell membrane, cytoplasm, nucleus, and cell organelles. Read on to explore more insights on cell structure and function



The number of cells in an individual may range from one (bacteria, protozoa etc.) through 6*1012 (human beings) to even a larger number in animals like whales and elephants. The following structures are visible in a ell with the aid of light microscope: cell wall, cytoplasm, nucleus, chloroplast and mitochondria. However, studies with electron microscope have revealed many more structures within a eukaryotic cell. The various structures seen in plant cells are

1. Cell wall
2. Plasma lemma
3. Endoplasmic reticulum (ER)
4. Ribosomes
5. Golgi bodies
6. Lysosomes
7. Spherosomes
8. Chloroplasts
9. Mitochondria etc. and
10. Nucleus

Animal cells lack cell wall and chloroplasts, while centrioles are not found in plant cells. Further, RBCs in animals are devoid of nuclei.



]Cell membrane (Plasma membrane/ Plasma lemma)

- A plasma membrane is composed of lipids and proteins where the composition might fluctuate based on fluidity, external environment, and the different stages of development of the cell.

Structure

- Structurally, it consists of a phospholipid bilayer along with two types of proteins viz. embedded proteins and peripheral proteins that function in providing shape and allowing the movement of particles in and out of the cell.
- The most abundant lipid which is present in the cell membrane is a phospholipid which contains a polar head group attached to two hydrophobic fatty acid tails.
- The embedded proteins act as channels for the transfer of particles across the cell with some proteins acting as receptors for the binding of various components.
- The peripheral proteins function as to provide fluidity as well as mechanical support to the structure of the cell.

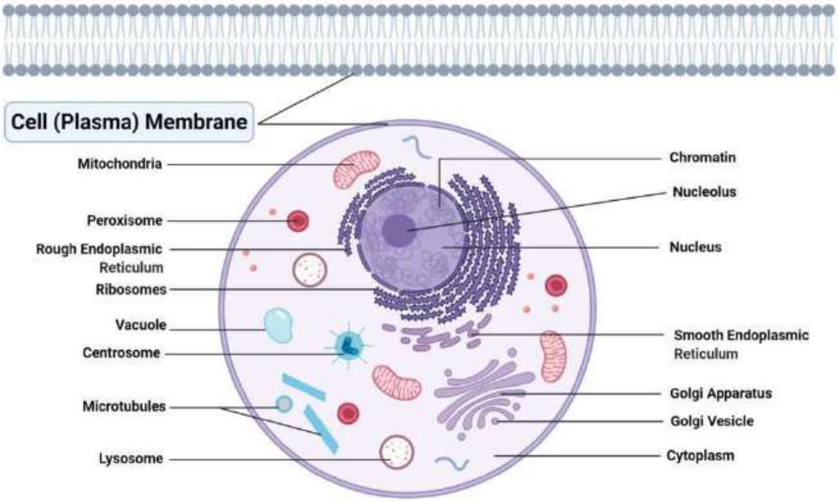


Figure: Animal Cell Structure with Cell (Plasma) Membrane, Image Copyright © Sagar Aryal, www.microbenotes.com

Functions

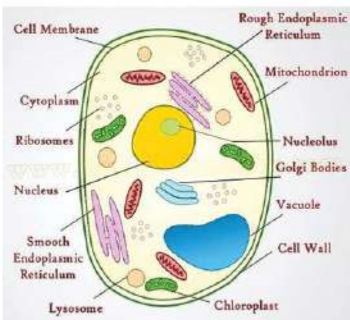
- The cell membrane provides mechanical support that facilities the shape of the cell while enclosing the cell and its components from the external environment.
- It regulates what can be allowed to enter and exit the cell through channels, acting as a semi-permeable membrane, which facilities the exchange of essential compounds required for the survival of the cell.
- It generates and distributes signals in and outside of the cell for the proper functioning of the cell and all the organelles.
- It allows the interaction between cells required during tissue formation and cell fusion.

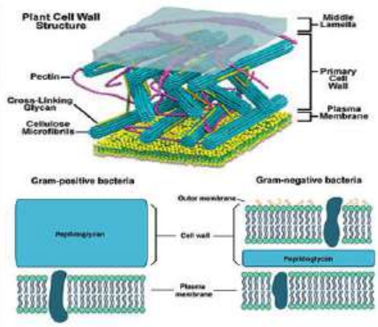
Cell Wall

- An additional non-living layer present outside the cell membrane in some cells that provides structure, protection, and filtering mechanism to the cell is the cell wall.

Structure

- In a plant cell, the cell wall is made up of cellulose, hemicellulose, and proteins while in a fungal cell, it is composed of chitin.
- A cell wall is multilayered with a middle lamina, a primary cell wall, and a secondary cell wall.
- Middle lamina contains polysaccharides that provide adhesion and allows binding of the cells to one another.
- After middle lamina is the primary cell wall which is composed of cellulose. The last layer, which is not always present, is the secondary cell wall made of cellulose and hemicellulose.





Functions

- The critical function of the cell wall is protecting and maintaining the shape of the cell. It also helps the cell withstand the turgor pressure of the cell.
- It initiates cell division by providing signals to the cell and allows the passage of some molecules into the cell while blocking others.

Centriole

- Centrioles are tubular structures mostly found in eukaryotic cells which are composed mainly of the protein tubulin.

Structure

- A centriole consists of a cylindrical structure made with nine triplets microtubules that surround the periphery of the centriole while the center has a Y-shaped linker and a barrel-like structure that stabilizes the centriole.

- Another structure called cartwheel is present in a centriole which is made up of a central hub with nine spokes/filaments radiating from it. Each of these filaments/spokes is connected to the microtubules through a pinhead.

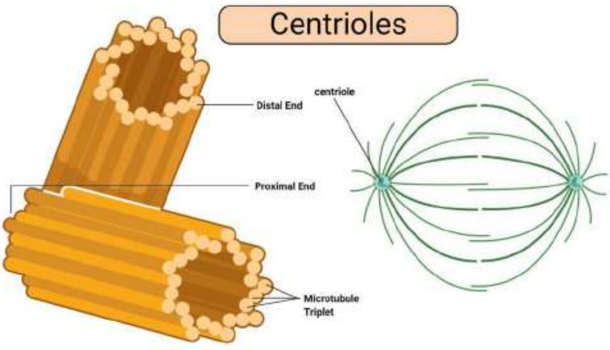


Figure: Centrioles, Image Copyright © Sagar Aryal, www.microbenotes.com

Functions

- During cell division, centrioles have a crucial role in forming spindle fibers which assist the movement of chromatids towards their respective sides.
- They are involved in the formation of cilia and flagella.

Cilia and Flagella

- Cilia and Flagella are tiny hair-like projections from the cell made of microtubules and covered by the plasma membrane.

Structure

- Cilia are hair-like projections that have a 9+2 arrangement of microtubules with a radial pattern of 9 outer microtubule doublet that surrounds two singlet microtubules. This arrangement is attached to the bottom with a basal body.

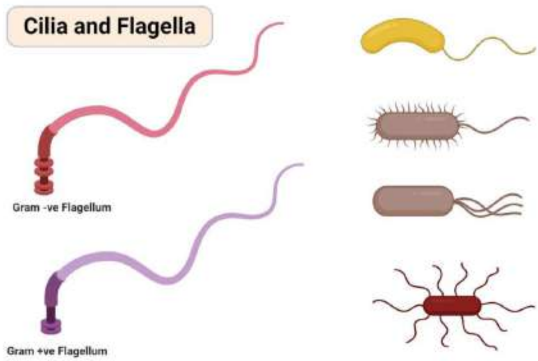


Figure: Cilia and Flagella, Image Copyright © Sagar Aryal, www.microbenotes.com

- Flagella is a filamentous organelle, the structure of which, is different in prokaryotes and eukaryotes.
- In prokaryotes, it is made up of the protein called flagellin wrapped around in a helical manner creating a hollow structure at the center throughout the length.
- In eukaryotes, however, the protein is absent and the structure is replaced with microtubules.

Functions

- The most critical role of cilia and flagella is movement. These are responsible for the movement of the organisms as well as for the movement of various particles present around the organisms.
- Some cilia present in some particular organs may have the function of sense. The cilium in the blood vessels, which helps in controlling the flow of blood is an example.

Chloroplast

- A chloroplast is a type of plastic that is involved in photosynthesis in plants and algae.
- Chloroplast contains an essential pigment called chlorophyll necessary to trap sunlight for the production of glucose.

Structure

- It is a double-membraned structure with its own DNA which is inherited from the previous chloroplast.

- These are usually lens-shaped with shape and number varying according to cells. They have an outer membrane, an inner membrane, and a thylakoid membrane that enclosed the gel-like matric called the stroma.

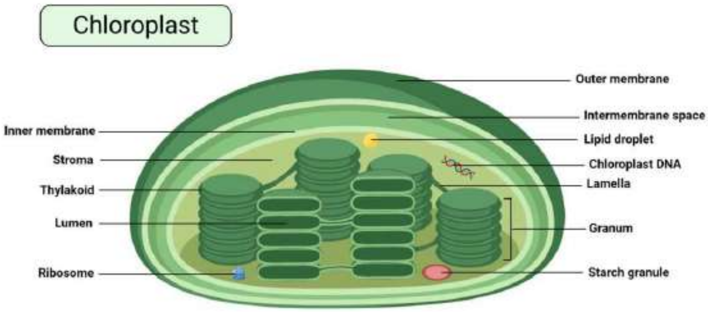


Figure: Chloroplast, Image Copyright © Sagar Aryal, www.microbenotes.com

- The outer and inner membrane is porous and allows transport of materials while the stroma contains DNA, chloroplast ribosomes, proteins, and starch granules.

Functions

- The chloroplast is the primary center for light-dependent and light-independent reactions during photosynthesis.
- Different proteins present in chlorophyll are involved in the regulation of photorespiration.

Cytoplasm

- Cytoplasm refers to everything present inside the cell except the nucleus.

Structure

- The cytoplasm consists of a cytosol; a gel-like substance that contains other matter; cell organelles; smaller cell-like bodies bound by separate membranes; and cytoplasmic inclusions; insoluble molecules that store energy and are not surrounded by any layer.
- The cytoplasm is colorless and has about 80% water along with various nutrients required for the cell.

- It is known to have the properties of both viscous matters as well as elastic matter. Under its elasticity, cytoplasm helps in the movement of materials inside the cell by a process termed cytoplasmic streaming

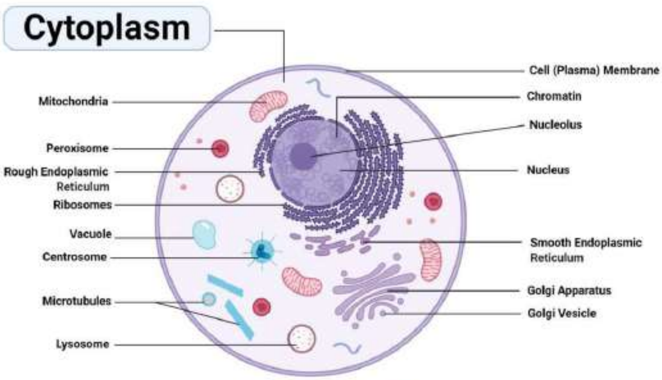


Figure: Animal Cell Structure with Cytoplasm, Image Copyright © Sagar Aryal, www.microbenotes.com

Functions

- Most of the vital cellular and enzymatic reactions like cellular respiration and translation of mRNA into proteins occur in the cytoplasm.
- It acts as a buffer and protects genetic materials as well as other organelles from damage due to collision or change in the pH of the cytosol.
- The process called cytoplasmic streaming helps in the distribution of various nutrients and facilitates the movement of cell organelles within the cell.

Cytoskeleton

- A number of fibrous structures are present in the cytosol that helps give shape to the cell while supporting cellular transport.

Structure

- Around three different classes of fibers make up the cytoskeleton which is: microtubules, microfilaments, and intermediate filaments.

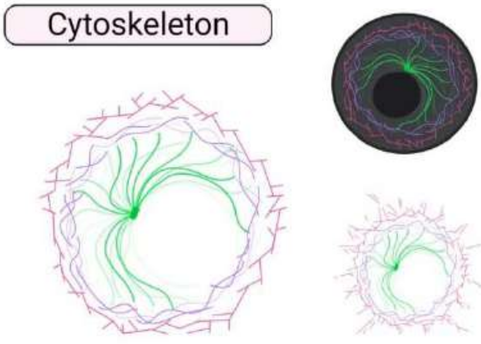


Figure: Cytoskeleton, Image Copyright © Sagar Aryal, www.microbenotes.com

- These are separated based on a protein present in them.

Functions

- The critical function of the cytoskeleton is to provide shape and mechanical support to the cell against deformation.
- It allows the expansion and contraction of the cell which assists in the movement of the cell.
- It is also involved in intracellular and extracellular transport of materials.

Endoplasmic Reticulum (ER)

- Endoplasmic Reticulum (ER) is present as an interconnection of tubules that are connected to the nuclear membrane in eukaryotic cells.
- There are two types of ER based on the presence or absence of ribosomes on them:
    - Rough ER (RER) with ribosomes attached on the cytosolic face of Endoplasmic Reticulum and thus is involved in protein synthesis
    - Smooth ER (SER)which lacks ribosomes and has a function during lipid synthesis.

Structure

- Endoplasmic Reticulum exists in three forms viz. cisternae, vesicles, and tubules.

- Cisternae are sac-like flattened, unbranched structures that remain stacked one on top of another.
- Vesicles are spherical structures that carry proteins throughout the cell.
- Tubules are tubular branched structures forming a connection between cisternae and vesicles.

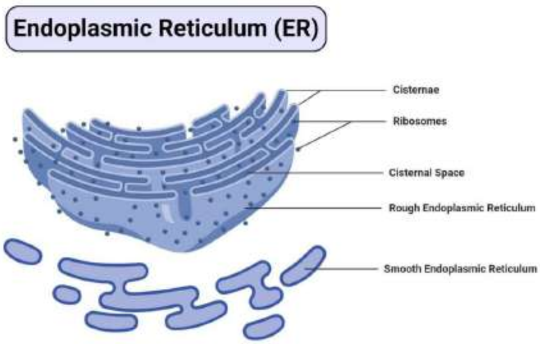


Figure: Endoplasmic Reticulum (ER), Image Copyright © Sagar Aryal, www.microbenotes.com

Functions of Endoplasmic Reticulum (ER)

- Manufacturing, processing and transporting proteins for cell utilization both in and out of the cell. This is because it is directly connected to the nuclear membrane providing a passage between the nucleus and the cytoplasm.
- The ER has more than half the membranous cell content, hence it has a large surface area where chemical reactions take place. They also contain the enzymes for almost all the cell lipid synthesis hence they are the site for lipid synthesis.

The variation in physical and functional characteristics differentiate the ER into two types i.e Rough endoplasmic reticulum and Smooth endoplasmic reticulum.

Types of Endoplasmic Reticulum

1. **Rough Endoplasmic Reticulum (Rough ER)** – Rough ER is called "rough" because there surface is covered with ribosomes, giving it a rough appearance. The function of the ribosomes on rough ER is to synthesis proteins and they have a signaling sequence, directing them to the endoplasmic reticulum for processing. Rough ER transports

the proteins and lipids through the cell into the cristae. They are then sent into the Golgi bodies or inserted into the cell membrane.

2. **Smooth Endoplasmic Reticulum (Smooth ER) –** Smooth ER is not associated with ribosomes and their unction is different from that of the rough endoplasmic reticulum, despite lying adjacent to the rough endoplasmic reticulum. Its function is to synthesis lipids (cholesterol and phospholipids) that are utilized for producing new cellular membranes. They are also involved in the synthesis of steroid hormones from cholesterol for certain cell types. It also contributes to the detoxification of the liver after the intake of drugs and toxic chemicals.

- There is also a specialized type of smooth ER known as the **sarcoplasmic reticulum.** Its function is to regulate the concentration of Calcium ions in the muscle cell cytoplasm.

Endosomes

- Endosomes are membrane-bound compartments within a cell originating from the Golgi network

Structure

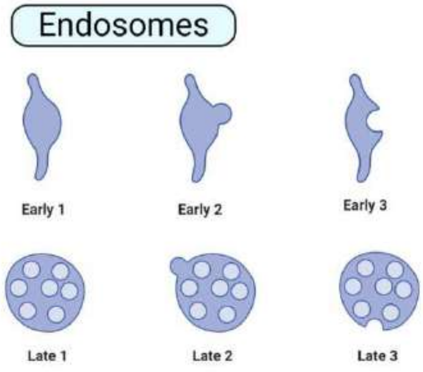


Figure: Endosomes, Image Copyright © Sagar Aryal, www.microbenotes.com

- There are different types of endosomes based on morphology and the time it takes for the endocytosed materials to reach them.

- The early endosomes are made with the tubular-vesicular network while the late endosomes lack tubules but contain many close-packed intraluminal vesicles. The recycling endosomes are found with microtubules and are mainly composed of tubular structures.

Functions

- Endosomes allow the sorting and delivery of internalized materials from the cell surface and transport of materials to the Golgi or the lysosomes.

Golgi Apparatus/ Golgi Complex/ Golgi Body

- The Golgi Apparatus is the cell organelle mostly present in eukaryotic cells which is responsible for the packaging of macromolecules into vesicles so that they can be sent out to their site of action.

Structure

- The structure of the Golgi Complex is pleomorphic; however, it typically exists in three forms, i.e. cisternae, vesicles, and tubules.
- The cisternae, which is the smallest unit of Golgi Complex, has a flattened sac-like structure which is arranged in bundles in a parallel fashion.
- Tubules are present as tubular and branched structures that radiate from the cisternae and are fenestrated at the periphery.
- Vesicles are spherical bodies that are divided into three groups as transitional vesicles, secretory vesicles, and clathrin-coated vesicles.

Functions of Golgi apparatus (Golgi bodies)

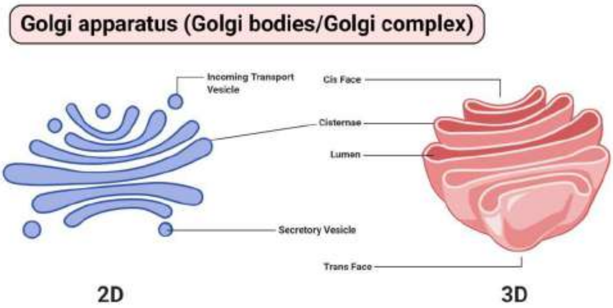


Figure: Golgi apparatus (Golgi bodies/Golgi complex), Image Copyright © Sagar Aryal, www.microbenotes.com

ary function is to transport, modify and pack proteins and lipids into the Golgi vesicles to deliver them to their target sites. Animal cells contain one or more Golgi bodies while plants have a few hundred.

- Cis and trans Golgi network make up the outer layer of cisternae at the cis and trans face and they are responsible for sorting proteins and lipids received at the cis face and released by the trans face, by the Golgi bodies.
- The cis face collects the proteins and lipids, of fused vesicles in clusters. The fused vesicles move along the microtubules through a specialized compartment known as the **vesicular-tubular cluster**. This compartment is found between the endoplasmic reticulum and the Golgi apparatus.
- The vesicle clusters fuse with the cis Golgi network, delivering the proteins and lipids into the cis face cisternae and as they move from the cis face to the trans face, they get **modified** to functional units. These functional units get delivered to intracellular and extracellular components of the cell.
  - Modification mechanisms include:
  - Cleaving of oligosaccharides chains
  - Attachment of sugar moieties of different side chains
- Adding fatty acids and/or phosphate groups by phosphorylation, and/or removing monosaccharides e.g. the removal of the mannose moieties takes place in the cis

and the medial cisternae while adding of galactose takes place in the trans cisternae.

- Sorting of the modified proteins and lipids occurs in the trans-Golgi network and packed into the trans vesicles, which then delivers them to the lysosomes or sometimes to the cell membrane for exocytosis. Assisted by ligands bound to receptors triggering fusion and protein secretion.

Intermediate Filaments

- The third class of filament that makes up the cytoskeleton are the intermediate filaments.
- They are designated at intermediate filaments because of the intermediate diameter of the filaments as compared to microfilaments and myosin proteins.

Structure

- Intermediate filaments contain a family of related proteins.
- The individual filaments are coiled around each other in a helical structure called coiled-coil structure.

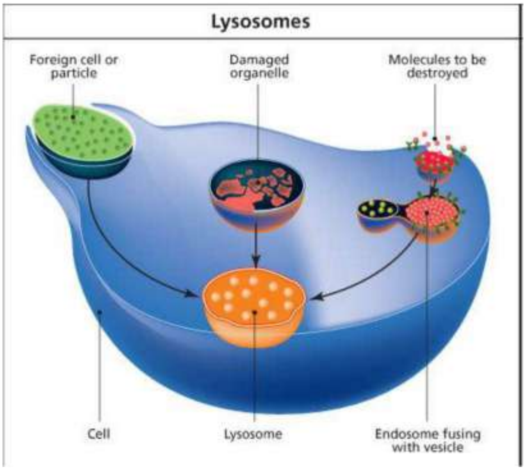
Functions

- Intermediate filaments contribute to the structural integrity of a cell while playing a crucial role in holding tissues of various organs like the skin.

Lysozyme

- Lysozymes are membrane-bound organelles that occur in the cytoplasm of animal cells.
- These organelles contain an array of hydrolytic enzymes required for the degradation of various macromolecules.
- There are two types of lysozymes:
  - Primary lysosome containing hydrolytic enzymes like lipases, amylases, proteases, and nucleases.
  - Secondary lysozyme formed by the fusion of primary lysozymes containing engulfed molecules or organelles.

Structure



- The shape of lysozymes is irregular or pleomorphic; however, mostly, they are found in the spherical or granular structure.
- Lysozymes are surrounded by a lysosomal membrane that contains the enzymes within the lysosome and protects the cytosol with the rest of the cell from the harmful action of the enzymes.

Lysosomes are of the following two types:

1) primary and
2) Secondary lysosomes.

Primary lysosomes

Primary lysosomes are produced by Golgi bodies and contain hydrolytic enzymes only. They fuse with food vacuoles produced through phagocytosis and pinocytosis to generate secondary lysosomes.

Secondary lysosomes

Secondary lysosomes contain both hydrolytic enzymes as well as food materials. The food particles are ultimately digested by the hydrolytic enzymes and absorbed into the hyaloplasm, while the undigested portion of food materials remains in the secondary lysosomes; such lysosomes are known as residual bodies.

The enzymes present in the lysosomes are capable of digesting any living organism. When a white blood cell (WBC) ingests (by phagocytosis) a bacterium or some I some other organism, all the lysosomes of the WBC fuse with the food vacuole thus produced. As a result, the bacterium as well as the WBC itself is lysed. In some situations, the enzymes present in lysosomes are released into the cytoplasm, which leads to the lysis of concerned cell **(autolysis).** Thus the function of lysosomes is digestion (lysis) of food particles and microorganisms ingested by a cell and also to cause autolysis of the cell, if required.

Functions

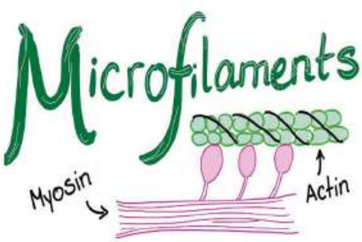
- These organelles are responsible for intracellular digestion where the larger macromolecules are degraded into smaller molecules with the help of enzymes present in them.
- Lysozymes also perform the critical function of the autolysis of unwanted organelles within the cytoplasm.
- Besides these, the lysosome is involved in various cellular processes, including secretion, plasma membrane repair, cell signaling, and energy metabolism.

Microfilaments

- Microfilaments are a part of the cytoskeleton of a cell made up of actin protein in the form of parallel polymers.
- These are the smallest filaments of the cytoskeleton with high rigidity and flexibility, providing strength and movement to the cell.

Structure

- The filaments are present either in cross-linked forming networks or as bundles. The chains of protein remain twisted around each other in a helical arrangement.



- One of the polar ends of the filament is positively charged and barbed, whereas the other end is negatively charged and pointed.

Functions

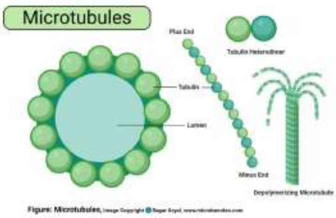
- It generates the strength for the structure and movement of the cell in association with myosin protein.
- They help in cell division and are involved in the products of various cell surface projecti

Microtubules

- Microtubules are also a part of the cytoskeleton differing from microfilaments in the presence of tubulin protein

Structure

- They are long hollow, beaded tubular structure of diameter of about 24nm.
- The wall of the microtubules consists of globular subunits present at a helical array of a and b tubulin.
- Similar to microfilaments, the ends of microtubules also have a defined polarity with one end being positively charged while the other being negatively charged.



Functions

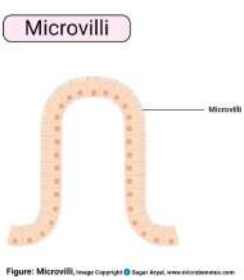
- As a part of the cytoskeleton, they provide shape and movement to the cell.
- Microtubules facilitate the movement of other cell organelles within the cell through binding proteins.

Microvilli

- Microvilli are tiny finger-like structures that project on or out of the cells. These exist either on their own or in conjunction with villi.

Structure

- Microvilli are bundles of protuberances loosely arranged on the surface of the cell with little or no cellular organelles.
- These are surrounded by a plasma membrane enclosing



cytoplasm and microfilaments.

- These are bundles of actin filaments bound by fimbrin, villin, and epsin.

Functions

- Microvilli increase the surface area of the cell, thus, enhancing the absorption and secretion functions.
- The membrane of microvilli is packed with enzymes that allow the break down of larger molecules into smaller allowing more effective absorption.
- Microvilli act as an anchoring agent in white blood cells and in sperms during fertilization.

Mitochondria

- Mitochondria are double membrane-bound cell organelles responsible for the supply and storage of energy for the cell.
- The oxidation of various substrates in the cell to release energy in the form of ATP (Adenosine Triphosphate) is the primary purpose of mitochondria.

Structure

- A mitochondrion contains two membranes with the outer layer being smooth while the inner layer is marked with folding and finger-like structures called cristae.
- The inner mitochondrial membrane contains various enzymes, coenzymes, and components of multiple cycles along with pores for the transport of substrates, ATP, and phosphate molecules.
- Within the membranes is a matrix that contains various enzymes of metabolic processes like Kreb's cycle.
- In addition to these enzymes, mitochondria are also home to single or double-stranded DNA called mtDNA that is capable of producing 10% of the proteins present in the mitochondria.

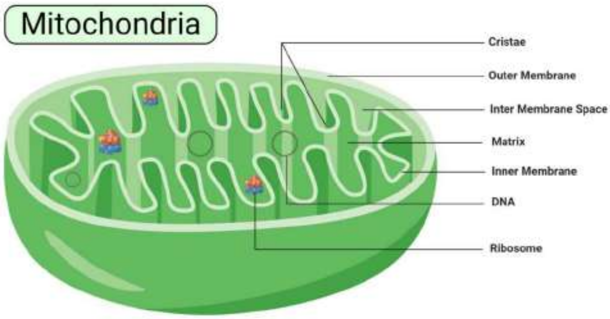


Figure: Mitochondria, Image Copyright Sagar Aryal, www.microbenotes.com

Functions of Mitochondria

- Their primary function is to generate energy for the cell i.e they are the power generators, producing energy in form of Adenosine Tri-phosphate (ATP), by converting nutrients and oxygen into energy enabling the cell to perform its function and to also release excess energy from the cell.
- Mitochondria also store calcium which assists in cell signaling activity, generating cellular and mechanical heat and mediating cellular growth and death.
- The outer membrane is permeable, allowing the transport of small molecules and a special channel to transport large molecules.
- The inner mitochondrial membrane is less permeable thus allowing very small molecules into the mitochondrial gel-matrix in the central mass. The gel matrix is composed of the mitochondria DNA and enzymes for the Tricarboxylic Acid (TCA) cycle or the Kreb's Cycle.
- The TCA cycle uses up the nutrients, converting them into by-products that the mitochondria use for producing energy. These processes take place in the inner membrane because the membrane bends into folds called the **cristae**, where the protein components used for the main energy production system cells, known as the Electron Transport Chain (ETC). ETC is the main source of ATP production in the body.

- The ETC involves several sequences of oxidation-reduction reactions to transport electrons from one protein component to another, thus producing energy that is used for phosphorylation of ADP (Adenosine diphosphate) to ATP. This process is called the **chemiosmotic coupling of oxidative phosphorylation.** This mechanism gives energy to most cellular activities including muscle movement and they power up the general brain function.
- Some if not all proteins and molecules that make up the mitochondria come from the cell nucleus. The mitochondrial nucleus genome has 37 genes of which 13 of these genes produce most of the components of the ETC. However, the mitochondrial DNA is very vulnerable to mutations because they don't possess a large DNA repair mechanism, a common element found in other nuclear DNAs.
- Moreover, **Reactive Oxygen Species** ((ROS)) also called **free radicals** are produced in the mitochondrion, because of the preference for abnormal production of free electrons. These electrons are neutralized by antioxidant proteins in the mitochondrion. However, some of the free radicals can damage mitochondrial DNA (mtDNA).
- Equally, consumption of alcohol can cause damage to the mtDNA because excess ethanol in the body causes saturation of the detoxifying enzymes leading to the production and leakage of highly reactive electrons into the cytoplasmic membrane and into the mitochondrial matrix, combining with other cellular molecules forming numerous radicals that significantly cause cell damage.
- Most organisms inherit the mtDNA from their mother. This is because the maternal egg donates most of the cytoplasm to the embryo while the mitochondria inherited from the father's sperm is destroyed. This causes the origin of inherited and acquired mitochondrial diseases due to mutations transmitted into the embryo from the maternal and paternal DNA or maternal mtDNA. Such diseases include Alzheimer's disease and Parkinson's disease. When

mutated mtDNA accumulates over time has been linked to aging and the development of certain cancers and diseases.

- Naturally, mitochondria play a major role in programmed cell death (apoptosis) and due to mutations in the mtDNA can inhibit cell death-causing the development of cancer.

Nucleus

- The nucleus is a double membrane-bound structure responsible for controlling all cellular activities as well as a center for genetic materials, and it's transferring.
- It is one of the large cell organelles occupying 10% of total space in the cell.
- It is often termed the "brain of the cell" as it provides commands for the proper functioning of other cell organelles.
- A nucleus is clearly defined in the case of a eukaryotic cell; however, it is absent in prokaryotic organisms with the genetic material distributed in the cytoplasm.

Structure

- Structurally, the nucleus consists of a nuclear envelope, chromatin, and nucleolus.
- The nuclear envelope is similar to the cell membrane in structure and composition. It has pores that allow the movement of proteins and RNA in and outside the nucleus. It enables the interaction with other cell organelles while keeping nucleoplasm and chromatin within the envelope.
- The chromatin in the nucleus contains RNA or DNA along with nuclear proteins, as genetic material that is responsible for carrying the genetic information from one generation to another. It is present in a sense and compact structure which might be visible as chromosome under powerful magnification.
- The nucleolus is like a nucleus within the nucleus. It is a membrane-less organelle that is responsible for the synthesis of rRNA and assembly of ribosomes required for protein synthesis.

Functions of Nucleus

- The primary role of the nucleus is to control and regulate cell activities of growth and maintain cell metabolisms.

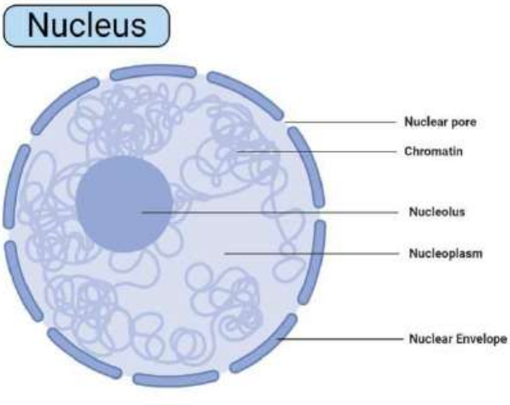


Figure: Nucleus, Image Copyright © Sagar Aryal, www.microbenotes.com

- It also carries the genes that have hereditary information of the cell.
- The chromosomal DNA and genetic materials, which are made up of genetic coded ultimately make up their proteins' amino acid sequences for use by the cell.
- Therefore, the nucleus is the information center.
- It is the site for Transcription (formation of mRNA from DNA) and the mRNA is transported to the nuclear envelope.

Peroxisomes

- Peroxisomes are oxidative membrane-bound organelles found in the cytoplasm of all eukaryotes.
- The name is accredited due to their hydrogen peroxide generating and removing activities.

Structure

- Peroxisome consists of a single membrane and granular matrix scattered in the cytoplasm.
- They exist either in the form of interconnected tubules or as individual peroxisomes.

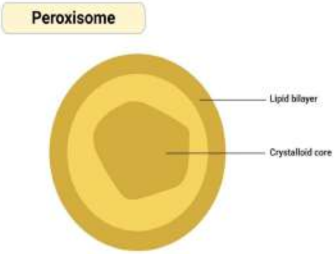


Figure: Peroxisome, Image Copyright © Sagar Aryal, www.microbenotes.com

- The compartments within every peroxisome allow the creation of optimized conditions for different metabolic activities.
- They consist of several types of enzymes with major groups being urate oxidase, D-amino acid oxidase, and catalase.

Functions

- Peroxisomes are involved in the production and elimination of hydrogen peroxide during biochemical processes.
- Oxidation of fatty acids takes place within peroxisomes.
- Additionally, peroxisomes are also involved in the synthesis of lipid-like cholesterol and plasmalogens.

Plasmodesmata

- Plasmodesmata are tiny passages or channels that allow the transfer of material and communication between different cells.

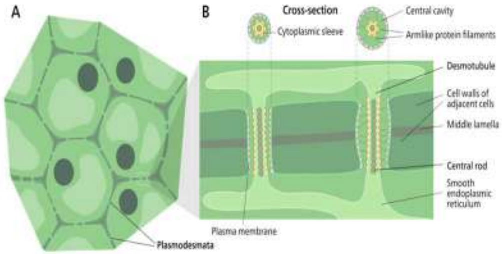
Structure

- There are 103 – 105 number of plasmodesmata connecting two adjacent cells with 50-60 nm in diameter.
- A plasmodesma has three layers:
    - The plasma membrane is continuous with the plasma membrane of the cell and has the same phospholipid bilayer.
    - The cytoplasmic sleeve that is continuous with the cytosol that allows the exchange of materials between two cells.
    - Desmotubule which is a part of the endoplasmic reticulum that provides a network between two cells and allows the transport of some molecules.

Functions

- Plasmodesmata are the primary site for the communication of two cells. It allows the transfer of molecules like proteins, RNA, and viral genomes.

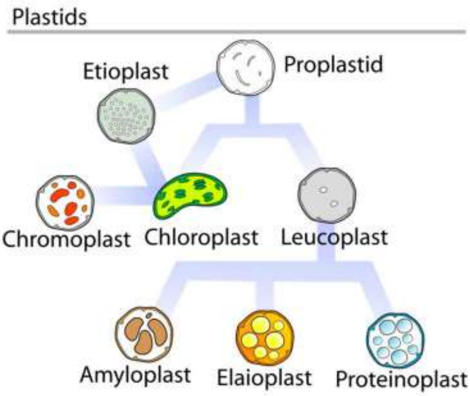
Plastids



- Plastids are double membrane-bound structures present in plants and other eukaryotes involved in the synthesis and storage of food.

Structure

- Plastids are usually oval or spherical with an outer and an inner membrane between which lies the intermembrane space.
- The inner membrane enclosed a matrix called stroma that contains small structures called grana.
- Each granum consists of several sac-like thylakoids piled one on the other and connected by stroma lamellae.
- Plastids contain DNA and RNA that allows it to synthesize necessary proteins for different processes.



Functions

- Chloroplasts are the center for many metabolic activities, including photosynthesis as it contains enzymes and other components required for it.
- They are also involved in the storage of food, primarily starch.

Ribosomes

- Ribosomes are ribonucleoprotein containing equal parts RNA and proteins along with an array of other essential components required for protein synthesis.

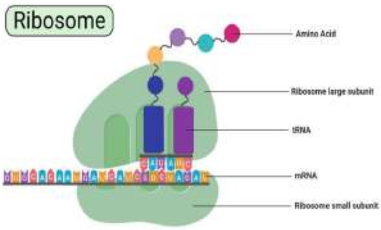


Figure: Ribosome,

- In prokaryotes, they exist freely while in eukaryotes, they are found either free or attached to the endoplasmic reticulum.

Structure

- The ribonucleoprotein consists of two subunits.
- In the case of prokaryotic cells, the ribosomes are of the 70S with the larger subunit of 50S and the smaller one of 30S.
- Eukaryotic cells have 80S ribosomes with 60S larger subunit and 40S smaller subunit.
- Ribosomes are short-lived as after the protein synthesis, the subunits split up and can be either reused or remain broken up.

Functions of Ribosomes

- Ribosomes that occur as free particles are attached to the endoplasmic reticulum membrane occurring in large numbers accounting for about a quarter of the cell organelles. A single replicated cell has about 10 million ribosomes.
- The ribosomal subunits are the site for genetic coding into proteins. On the ribosomes, the mRNA helps determine the coding for Transfer RNA (tRNA) which also determines the

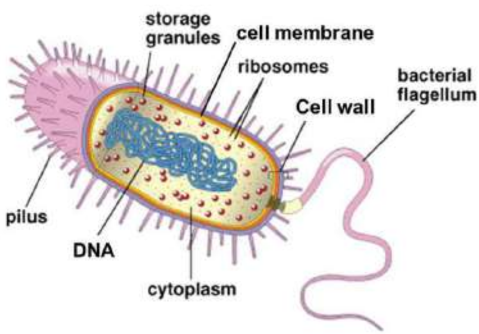
protein amino acid sequences. This leads to the formation of the rRNA which are involved in the catalyzation of peptidyl transferase creating the peptide bond found between the amino acid sequences that develop the proteins. The formed proteins then detach from the ribosomes, migrating to other cell parts for utilization by the cell.

Storage granules

- Storage granules are membrane-bound organelles, also called zymogen granules storing cell's energy reserve and other metabolites.

Structure

- T



ules are surrounded by a lipid bilayer and are composed mostly of phosphorus and oxygen.

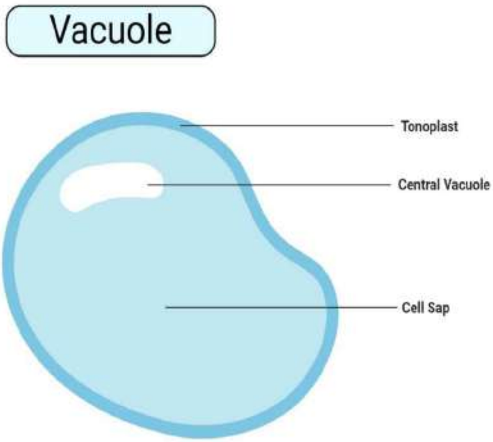
- The components inside these storage granules depend on their location in the body with some even containing degradative enzymes yet to participate in digestive activities.

Functions

- Many prokaryotes and eukaryotes store nutrients and reserves in the form of storage granules in the cytoplasm.
- Sulfur granules are characteristic of prokaryotes that utilize hydrogen sulfide as a source of energy.

Vacuoles

- Vacuoles are membrane-bound structures varying in size in cells of different organisms.



Structure

- The vacuole is surrounded by a membrane called tonoplast, which encloses fluid containing inorganic materials like water and organic materials like nutrients and even enzymes.
- These are formed by the fusion of various vesicles, so vacuoles are very similar to vesicles in structure.

Functions

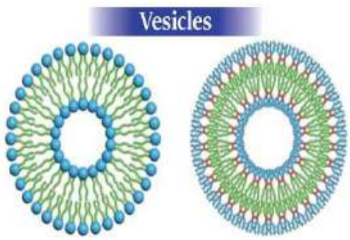
- Vacuoles act as a storage for nutrients as well as waste materials to protect the cell for toxicity.
- They have an essential function of homeostasis as it allows the balance of pH of the cell by influx and outflow of H+ ions to the cytoplasm.
- Vacuoles contain enzymes that play an important role in different metabolic processes.

Vesicles

- Vesicles are structures present inside the cell which are either formed naturally during processes like exocytosis, endocytosis or transport of materials throughout the cell, or they might form artificially, which are called liposomes.

- There are different types of vesicles like vacuoles, secretory and transport vesicles based on their function

Structure



- A vesicle is a structure containing liquid or cytosol which is enclosed by a lipid bilayer.
- The outer layer enclosing the liquid is called a lamellar phase which is similar to the plasma membrane. One end of the lipid bilayer it hydrophobic whereas the other end is hydrophilic.

Functions

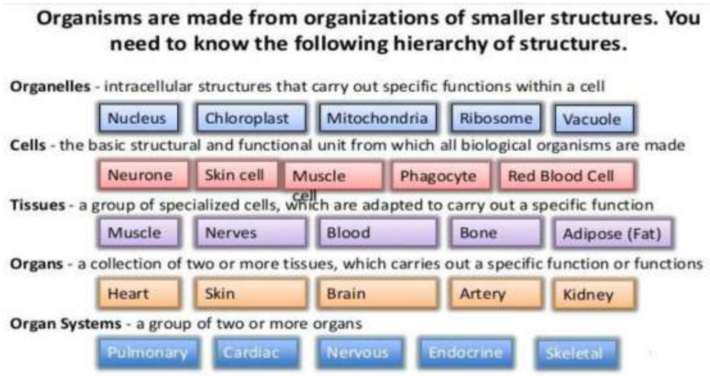
- Vesicles facilitate the storage and transport of materials in and outside the cell. It even allows the exchange of molecules between two cells.
- Because vesicles are enclosed inside a lipid bilayer, vesicles also function in metabolism and enzyme storage.
- They allow temporary storage of food and also control the buoyancy of the cell.

Organization of Living Things.

What does this mean?

We know it all starts with the **cell**. And for some species it ends with the cell. But for others, the cells come together to form tissues, tissues form organs, organs form **organ** systems, and organ systems combine to form an **organism**

There are also levels of organization above the individual organism. These levels are illustrated in the table below:



Having learnt the multi complex organization of a living organism, it is to realised that organisms of many different species form the biological world. The set facts to be understood as below:

Organisms of the same species that live in the same area make up a **population**. For example, all of the human living in the same area makes up a human population.

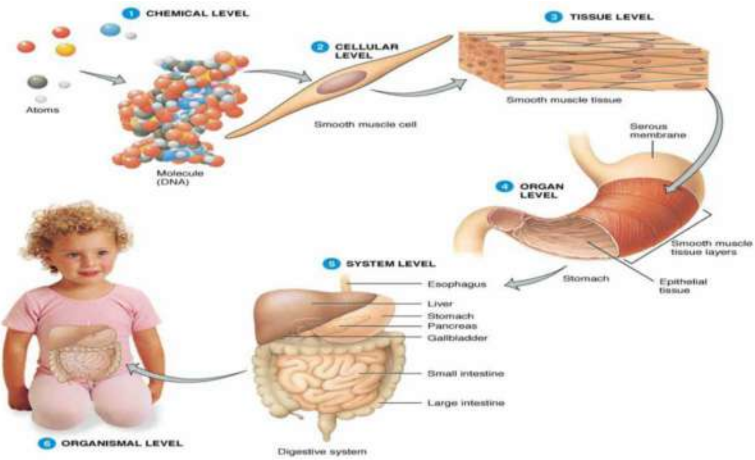
 All of the populations that live in the same area make up a **community**. The community that includes the human population also includes the populations of other organisms.

 An **ecosystem** consists of all the living things (**biotic factors**) in a given area, together with the nonliving environment (**abiotic factors**). The nonliving environment includes water, sunlight, soil, and other physical factors.

 A group of similar ecosystems with the same general type of physical environment is called a **biome**.

The **biosphere** is the part of Earth where all life exists, including all the land, water, and air where living things can be found. The biosphere consists of many different biomes. These basic analysis leads to a well knit organization of organisms in an ecosystem.

A picture presentation of an organizational level in a human body:



An exception to note: Colonial organisms are made of cells living closely together in a connected group but without tissues and organs (e.g. Volvox)

Tissues: Plant and Animal Tissues

Plant tissues are characterized and classified according to their structure and function. The organs that they form will be organized into patterns within a plant which will aid in further classifying the plant.

Plants have specialized tissues and organs different from animals

1. Dermal tissue forms the outer covering of plants
2. Ground tissue makes up roots and stems
3. Vascular tissue transports food and water
4. The four plant organs are the root, stem, leaf and flower

Plant tissues can be grouped into two principal types:

(a) Meristematic tissues and

(b) Permanent tissues

Meristematic (growth) tissues: They are found in those regions of the plant which grow continuously as long as the plant lives. Example: Root tip, shoot tip and cambium. Meristems consist of thin-walled undifferentiated and actively diiding cells and help in increasing girth and length of the plant.

They are characterized by dividing cells.

1.1 Permanent tissues: They are composed of grouped of cells which are derived from the meristematic tissues but have lost their ability to divide and become differentiated to make permanent tissues. These tissues can als be called as non-meristematic tissues.

1.2 **Meristematic Tissues:** Tissues where cells are constantly dividing are called meristems or meristematic tissues. These regions produce new cells. These new cells are generally small, six-sided box-like structures (hexagonal) with a number of tiny vacuoles and a large nucleus, by comparison. Sometimes there are no vacuoles at all. As the cells mature the vacuoles will grow to many different shapes and sizes, depending on the needs of the cell. It is possible that the vacuole may fill 95% or more of the cell's total volume.

There are **three** types of meristems:

1. Apical Meristems
2. Lateral Meristems
3. Intercalary Meristems

Apical meristems are located at or near the tips of roots and shoots. As new cells form in the meristems, the roots and shoots will increase in length. This vertical growth is also known as primary growth. A good example would be the growth of a tree in height.

Each apical meristem will produce embryo leaves and buds as well as three types of primary meristems:

- Protoderm,
- Ground meristems, and
- Procambium.

These primary meristems will produce the cells that will form the primary tissues.

Lateral meristems account for secondary growth in plants. Secondary growth is generally horizontal growth. A good example would be the growth of a tree trunk in girth.

There are two types of lateral meristems to be aware of in the study of plants.

The **vascular cambium,** the first type of lateral meristem, is sometimes just called the cambium. The cambium is a thin, branching cylinder that, except for the tips where the apical meristems are located, runs the length of the roots and stems of most perennial plants and many herbaceous annuals. The cambium is responsible for the production of cells and tissues that increase the thickness, or girth, of the plant.

The **cork cambium**, the second type of lateral meristem, is much like the vascular cambium in that it is also a thin cylinder that runs the length of roots and stems. The difference is that it is only found in woody plants, as it will produce the outer bark.

Both the vascular cambium and the cork cambium will begin to produce cells and tissues only after the primary tissues produced by the apical meristems have begun to mature.

Intercalary meristems are found in grasses and related plants that do not have a vascular cambium or a cork cambium, as they do not increase in girth. These plants do have apical meristems and in areas of leaf attachment, called nodes, they have the third type of meristematic tissue.

This meristem will also actively produce new cells and is responsible for increases in length. The intercalary meristem is responsible for the re-growth of cut grass.

Permanent tissue in detail:

There are other tissues in plants that do not actively produce new cells. These tissues are called non-meristematic tissues or permanent tissues. Non-meristematic tissues are made of cells that are produced by the meristems and are formed of various shapes and sizes depending on their intended function in the plant. Sometimes the tissues are composed of the same type of cells throughout, or sometimes they are mixed. There are simple tissues and complex tissues forming protective tissues, supporting tissues and conducting tissues. These tissues may be living or dead in plant body and are useful to them.

i) **Protective tissue**: It is made up of cells with thick walls are found on the surface of roots, stems and leaves. Example: epidermis of leaves secretes a waxy water proof material; the cork cells in the bark contain another strong water-proof material.

ii) **Supporting tissues**: These tissues are of many types. The most important ones are

(a) Parenchyma,

(b) Collenchymas and

(c) Sclerenchyma.

iii) **Conducting tissue**: These types of tissues consist of permanent complex tissues. They form passages for water and dissolved materials in water to move up and down the plant body. They form the vascular tissue of the plant which are the xylem and phloem units.

Simple Tissues

There are three basic types, named for the type of cell that makes up their composition.

1. **Parenchyma** cells form parenchyma tissue. Parenchyma cells are the most abundant of cell types and are found in almost all major parts of higher plants. These cells are basically sphere shaped when they are first made. However, these cells have thin walls usually with a single large nucleus, the walls of the cells flatten at the points of contact when many cells are packed together.

These cells have large vacuoles and may contain various secretions including starch, oils, tannins, and crystals. Some parenchyma cells have many chloroplasts and form the tissues found in leaves. This type of tissue is called **chlorenchyma**. The chief function of this type of tissue is photosynthesis, while parenchyma tissues without chloroplasts are generally used for food or water storage.

Additionally, some groups of cells are loosely packed together with connected air spaces, such as in water lilies, this tissue is called **aerenchyma** tissue. These type of cells can also develop irregular extensions of the inner wall which increases overall surface area of the plasma membrane and facilitates transferring of dissolved substances between adjacent cells.

2. **Collenchyma** cells form collenchyma tissue. These cells have a living protoplasm, like parenchyma cells, and may also stay alive for a long period of time. Their main distinguishing difference from parenchyma cells is the increased thickness of their walls. In cross section, the walls look uneven. Collenchyma cells are found just beneath the epidermis and generally they are elongated and their walls are pliable in addition to being strong. As a plant grows these cells and the tissues they form, provide flexible support for organs such as leaves and flower parts. Good examples of collenchyma plant cells are the ‗strings' from celery that get stuck in our teeth.
Parenchyma cells can divide if they are mature, and this is vital in repairing damage to plant tissues. Parenchyma cells and tissues comprise most of the edible portions of fruit. It is considered fundamental (ground) tissue.
3. **Sclerenchyma** cells form sclerenchyma tissue (scleros means hard). These cells have thick, tough secondary walls that are imbedded with lignin. At maturity, most sclerenchyma cells are dead and function in structure and support. Sclerenchyma cells can occur in two forms:

- Sclereids are sclerenchyma cells that are randomly distributed throughout other tissues. Sometimes they are grouped within other tissues in specific zones or regions. They are generally as long as they are wide. An example, would be the gritty texture in some types of pears. The grittiness is due to groups of sclereid cells. Sclereids are sometimes called stone cells.
- Fibers are sometimes found in association with a wide variety of tissues in roots, stems, leaves and fruits. Usually fiber cells are much longer than they are wide and have a very tiny cavity in the center of the cell.

Currently, fibers from over 40 different plant families are used in the manufacture of textiles, ropes, string and canvas goods to name a few.

Permanent Complex Tissues:

Tissues composed of more than one cell type are generically referred to as complex tissues. Xylem and phloem are the two most important complex tissues in a plant, as their primary functions include the transport of water, ions and soluble food substances throughout the plant. While some complex tissues are produced by apical meristems, most in woody plants are produced by the vascular cambium and is often referenced as vascular tissue.

Other complex tissues include the epidermis and the periderm. The epidermis consists primarily of parenchyma-like cells and forms a protective covering for all plant organs. The epidermis includes specialized cells that allow for the movement of water and gases in and out of the plant, secretory glands, various hairs, cells in which crystals are accumulated and isolated, and other cells that increase absorption in the roots. The periderm is mostly cork cells and therefore forms the outer bark of woody plants. It is considered to be a complex tissue because of the pockets of parenchyma cells scattered throughout.

Xylem

Xylem is an important plant tissue as it is part of the ‗plumbing' of a plant. Think of bundles of pipes running along the main axis of stems and roots. It carries water and dissolved substances throughout and consists of a combination of parenchyma cells, fibers, vessels, tracheids and ray cells.

Long tubes made up of individual cells are the vessels, while vessel members are open at each end.

Internally, there may be bars of wall material extending across the open space. These cells are joined end to end to form long tubes. Vessel members and tracheids are dead at maturity. Tracheids have thick secondary cell walls and are tapered at the ends. They do not have end openings such as the vessels. The tracheids ends overlap with each other, with pairs of pits present. The pit pairs allow water to pass from cell to cell. While most conduction in the xylem is up and down, there is some side-to-side or lateral conduction via rays. Rays are horizontal rows of long-living parenchyma cells that arise out of the vascular cambium. In trees, and other woody plants, ray will radiate out from the center of stems and roots and in cross-section will look like the spokes of a wheel.

Phloem

Phloem is an equally important plant tissue as it also is part of the ‗plumbing' of a plant. Primarily, phloem carries dissolved food substances throughout the plant. This conduction system is composed of sieve-tube member and companion cells that are without secondary walls. The parent cells of the vascular cambium produce both xylem and phloem. This usually also includes fibers, parenchyma and ray cells.

Sieve tubes are formed from sieve-tube members laid end to end. The end walls, unlike vessel members in xylem, do not have openings. The end walls, however, are full of small pores where cytoplasm extends from cell to cell. These porous connections are called sieve plates. In spite of the fact that their cytoplasm is actively involved in the conduction of food materials, sieve-tube members do not have nuclei at maturity It is the companion cells that are nestled between sieve-tube members that function in some manner bringing about the conduction of food.

Protective tissues: Two types as below

i) Epidermis

The epidermis is also a complex plant tissue, and an interesting one at that. The epidermis is the outermost layer of cells on all plant organs (roots, stems, leaves).

The epidermis is in direct contact with the environment and therefore is subject to environmental conditions and constraints. Generally, the epidermis is one cell layer thick; however there are exceptions such as tropical plants where the layer may be several cells thick and thus acts as a sponge. Cutin, a fatty substance secreted by most epidermal cells, forms a waxy protective layer called the cuticle.

The thickness of the cuticle is one of the main determiners of how much water is lost by evaporation. Additionally, at no extra charge, the cuticle provides some resistance to bacteria and other disease organisms. Some plants, such as the wax palm, produce enough cuticles to have commercial value: carnauba wax. Other wax products are used as polishes, candles and even phonographic records.

Epidermal cells are important for increasing absorptive surface area in root hairs. Root hairs are essentially tubular extensions of the main root body composed entirely of epidermal cells. Leaves are not left out. They have many small pores called stomata that are surrounded by pairs of specialized epidermal cells called guard cells. Guard cells are unique epidermal cells because they are of a different shape and contain chloroplasts..

There are other modified epidermal cells that may be glands or hairs that repel insects or reduce water loss.

ii) Periderm or Cork cells:

In woody plants, when the cork cambium begins to produce new tissues to increase the girth of the stem or root the epidermis is sloughed off and replaced by a periderm. The periderm is made of semi-rectangular and box-like cork cells. This will be the outermost layer of bark. These cells are dead at maturity.

However, before the cells die, the protoplasm secretes a fatty substance called suberin into the cell walls. Suberin makes the cork cells waterproof and aids in protecting tissues beneath the bark. There are parts of the cork cambium that produce pockets of loosely packed cork cells. These cork cells do not have suberin imbedded in their cell walls. These loose areas are extended through the surface of the periderm and are called lenticels (lateral openings). Lenticels function in gas exchange between the air and the stem interior.

Animal tissues:

In animals organs are made up of four basic types of tissues epithelial tissue, connective tissue, muscle tissue and nerve tissue. These tissues have distinctive features and specific functions which combine to form functioning organs. Generally animals are said to be made up of these basic four types of tissues, but the presence of these tissues may differ, depending on the type of organism. The origin of the cells of a type of tissues may differ in development stages in different classification of animals

Basic understanding to animal tissues: Types	**Function**	**Example**
Epithelial	Protection	Skin
Connective	Support	Bones
Muscular	Movement	Skeletal
Nervous	Communication	Brain

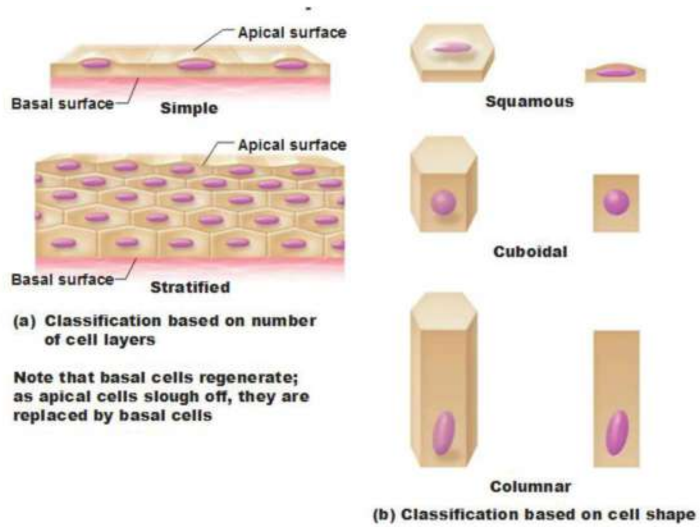
1) Epithelial Tissue

Epithelial tissue is commonly referred to as epithelium.

Special features of Epithelial Tissue:

- The epithelial tissue forms the outer covering or lining for some part of the body.
- It is composed of closely packed cells, arranged in flat sheets.
- Epithelial tissues form the surface of the skin, lines many cavities of the body and cover the internal organs.
- Cells of lowermost layer always rest on a non-living basement membrane, otherwise called basal lamina.
- Cells may originate from any primary germ layer, example epidermis of skin from ectoderm; Coelomic epithelium from mesoderm; and mid-gut epithelium from endoderm.
- These epithelial cells are non-vascular and are dependent upon the underlying connective tissue for nutrients.
- These cells have the power of division and regeneration throughout life.

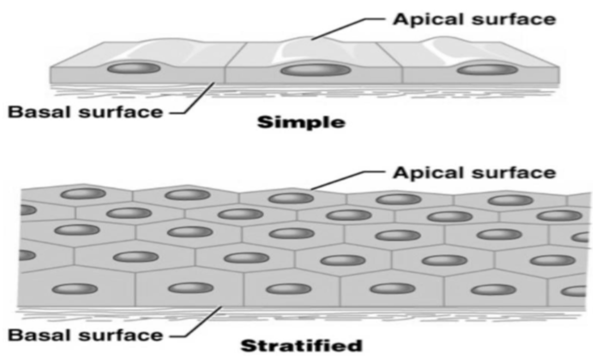
The free surface of the cells may be smooth, or may have fine hair-like cilia or microvilli.



There are two types of epithelial tissues depending on the number of layers of cells. They are:

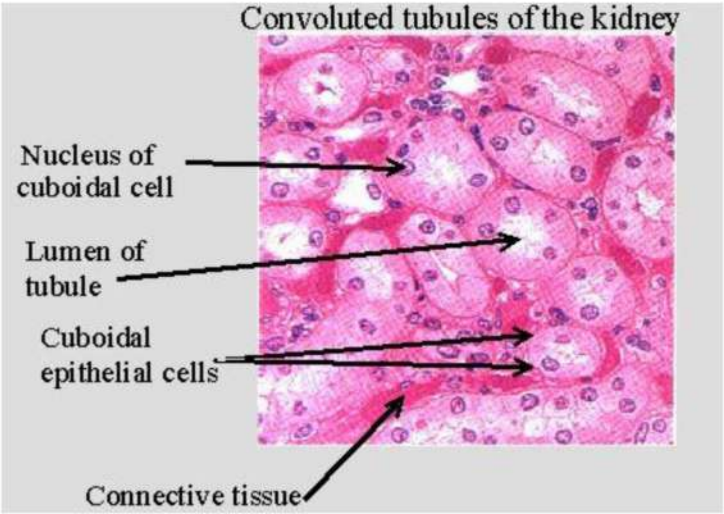
Simple Epithelium or Unstratified epithelium and Compound Epithelium or Stratified epithelium.

Simple epithelium is composed of single layer of cells. It functions as a lining of cavities of body, ducts and tubes. These cover the areas with less wear and tear. The apical surface is exposed to the body cavity or exterior, while the basal surface is adjacent to the underlying tissue.



Compound or stratified epithelium is made up of many layers of cells stacked one over the other on a common basal membrane. The younger layer of cells is seen towards the basement membrane while the older layer of cells are pushed towards the periphery.
All epithelial cells have six sides but they vary in height. For this reason, there are three ways to describe the shape and height of epithelial cells.
1. **Squamous cells**– are flat and scale-like.
2. **Cuboidal cells**– are box-like (same height and width).
3. **Columnar cells**– are tall (column shaped).

Simple squamous epithelium cells are close fitting and flattened laterally. They are found where filtration occurs (kidneys, lungs) and they resemble the look of a fried egg. Two simple squamous epithelia in the body have special names reflecting their location.
 Endothelium– provides a friction-reducing ling in lymphatic vessels and all hollow organs of the cardiovascular system (heart, blood vessels, capillaries).
 Mesothelium– is the epithelium found in serous membranes (membranes lining the ventral body cavity and covering the organs within it).



Simple cuboidal epithelium– consists of a single layer of cells with the same height and width. Functions include secretion and absorption (located in small ducts of glands and kidney tubules)

Simple columnar epithelium– is a single layer of tall, closely packed cells that line the digestive tract from the stomach to the rectum. Functions include absorption and secretion. They contain dense microvilli on their apical surface. Additionally, some simple columnar epithelia may display cilia on their free surface also.

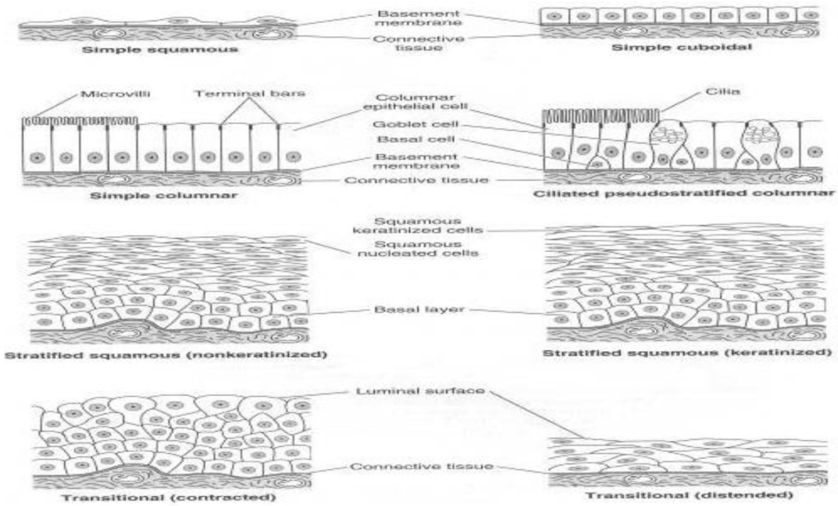
Pseudo stratified columnar epithelium– vary in height. All of their cells rest on the basement membrane and only the tallest reach the apical surface. When viewing pseudo stratified epithelium it may look like there are several layers of cells, but this is not the case. (Because the cells have different heights, it gives the illusion of multiple cell layers). Most pseudo stratified epithelia contain cilia on their apical surface and line the respiratory tract.

Stratified squamous epithelium– is the most widespread stratified epithelia. It's composed of several layers and is perfect for its protective role. Its apical surface cells are squamous and cells of the deeper layer are either cuboidal or columnar. Stratified squamous forms the external part of the skin and extends into body opening that's continuous with the skin. The outer layer of the skin (epidermis) is *keratinized* (contains *keratin*, a protective protein). Other stratified squamous in the body is non-keratinized.

Stratified cuboidal epithelium

Stratified cuboidal epithelium– is somewhat rare in the human body. It's mainly found in the ducts of glands (sweat glands, mammary glands) and is typically has two layers of cuboidal cells.

Stratified columnar epithelium– is also rare in the human body. Small amounts are found in the pharynx, male urethra, and lining of some glandular ducts. Stratified columnar epithelium occurs in transition areas (junctions) between other epithelial types

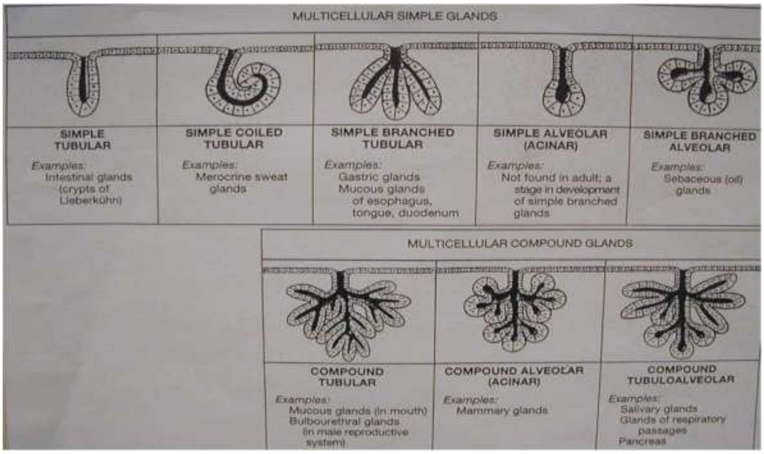


Transitional epithelium– forms the lining of hollow urinary organs, which stretch as they fill with urine. Cells in the basal layer are cuboidal or columnar. Cells by the apical surface vary in appearance depending if the organ is stretched at the time. Transitional cells have the ability to change their shape which allows more urine to flow through.

Glandular Epithelium:

It is modified column epithelium that form glands that secrete chemicals. Modification may be single cell becoming large and goblet shaped or several cells, such as epithelial tissue folding inwards to form alveolar (flask shaped) or tubular glands.

A **gland** is one or more cells that produce and secrete a specific product. The product is always a water-based fluid (aqueous) and usually contains proteins (the product is referred to as a **secretion**). Secretion is considered an active process. Glandular cells obtain substances needed from blood and transform them (chemically) into a product that's discharged from the cell.



Connective Tissue: tabulated details on types of tissue

Connective tissue type and characteristics	Functions	Locations
Areolar (loose) connective tissue. Loose array of random fibers with a wide variety of cell types	Nourishes and cushions epithelia, provides arena for immune defense against infection, binds organs together, allows passage for nerves and blood vessels through other tissues	Under all epithelia; outer coverings of blood vessels, nerves, esophagus, and other organs; fascia between muscles; pleural and pericardial sacs
Adipose tissue (fat). Large fat-filled adipocytes and scanty extracellular matrix.	Stores energy, conserves body heat, cushions and protects many organs, fills space, shapes body	Beneath skin; around kidneys, heart, and eyes; breast; abdominal membranes (mesenteries)

Dense irregular connective tissue. Densely spaced, randomly arranged fibers and fibroblasts.	Toughness; protects organs from injury; provides protective capsules around many organs	Dermis of skin; capsules around liver, spleen, and other organs; fibrous sheath around bones
Dense regular connective tissue. Densely spaced, parallel collagen fibers and fibroblasts.	Binds bones together and attaches muscle to bone; transfers force from muscle to bone	Tendons and ligaments
Cartilage (gristle). Widely spaced cells in small cavities (lacunae); rubbery matrix.	Eases joint movements; resists compression at joints; holds airway open; shapes outer ear; moves vocal cords; forerunner of fetal skeleton; growth zone of children's bones	External ear, larynx, rings around trachea, joint surfaces and growth zones of bones, between ribs and sternum, intervertebral discs
Bone (osseous tissue). Widely spaced cells in lacunae; much of matrix in concentric onion like layers; hard mineralized matrix.	Physically supports body, provides movement, encloses and protects soft organs, stores and releases calcium and phosphorus	Skeleton

Blood. Erythrocytes, leukocytes, and platelets Lymph	Transports nutrients, gases, wastes, hormones. Concerned with immune system	Circulates in cardiovascular system Fluid enclosing body cells.

Connective tissue is specialized for connecting different tissues and organs. It is also supporting them in order to them in their proper location. Loose areolar, fibres, cartilages and bones are some examples of connective tissues in animals.

Loose areolar connective tissue: It occurs all over the body and below the skin. It unites organs together to fill the space and acts as packing tissue. It consists of fine bundles of fibres in the matrix that contain fibroblasts, mast cells, amoebocytes, lymphoid cells and mesenchyme cells etc. Areolar tissue protects organs.

Fibrous connective tissue: It serves for packing and binding most of the organs. The tendons which connect muscles to bones and the ligaments which connect two bones at joints together have fibres in them. The fascia binds our skin to the underlying structures. Fibrous connective tissue covers bones, cartilage, kidneys and blood vessels.

The adipose tissue: It is a fibrous tissue whose cells are filled with oil. The main function of adipose tissue is storing fat and serves as an insulator for the body. It provides a cushion to the body and protects against an injury or fall.

Cartilage: It is a non-porous tissue called cristle. It has a thickened intercellular substance known as the matrix. These are not blood vessels or nerves. The cartilage is semi-transparent elastic. Cartilages occur in the nose, ears, rings of trachea tube, bronchial tubes, between vertebrae and also at the end of long bones such as ribs. Elastic cartilage is found in pinna (external ear). Cartilage tissue smoothes surface at the joints prevents collapse of the trachea (wind-pipe).

Bone: It is a hard porous tissue. It is a skeletal tissue. Bone has a good supply of blood vessels and nerves. This consists of both living cells and the rigid mass of inorganic salts mostly calcium and phosphorous. Bones form the skeleton and support the organs of the body-frame work of the body.

Fluid connective tissue: It is composed of blood and lymph. This is made of both cellular and liquid parts. The liquid part of the blood is called plasma and the cellular part consists of the corpuscles-red blood corpuscles, white blood corpuscles and the platelets. Lymph also forms the part of the fluid connective tissue. The main function of this tissue is to carry nutrients to different parts of the body and protect the body against diseases by giving immunity to the body.

Muscular tissue: It forms the muscles of the body and is present all over it. The muscles contract and relax. Therefore, this tissue helps the body for all its movements. It consists of cells in the form of fibres.

Three distinct types of muscles are:

- Striated –skeletal/striped/voluntary muscles
- Unstraited –smooth/unstriped/involuntary muscles.
- Heart –cardiac muscles/involuntary

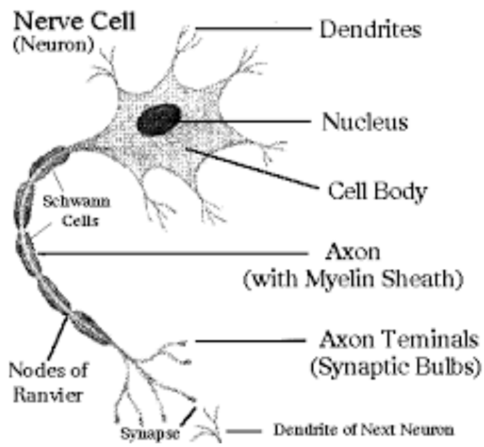
Straited muscle tissue: It is under the control of the will of an individual, hence called voluntary muscle. The muscles in our arms are moved only when you desire. Straited muscles constitute about 50% of the body weight. They occur in groups of fibres. Muscles of arms and legs are striated and so are the muscles of the body wall, face, neck and diaphragm. The striated muscles provide the force for locomotion and all other voluntary movements of the body but get fatigued easily.

Unstraited muscle tissue: It is not under the direct control of our will. Movements of passage of food in intestine or peristalsis and motility are due to the contraction of the unstraited muscles in the intestinal walls. Such muscles are composed of elongated, slender, tapering cells and are called visceral muscles. Muscles of the iris of the eye and those of the skin are also smooth muscles. Some other examples of smooth muscles are those found in the dermis of skin, lining of blood vessels, urinary bladder and wall of the uterus.

Cardiac muscle tissue: it is involuntary. The cells if it are striated and comparatively short and branched. It occurs only in the heart.

Cardiac muscles can contract without outside stimulation and does not get tired soon.

Nerve Tissue: It constitutes the nervous system. It is made up of elongated cells, called neurons or nerve cells. Each nerve cell is made up of a cell body called the cyton. Each cyton contains a nucleus and one or more elongated hair-like extensions all around the outer surface called as dendrons. Each Dendron breaks into many dendrites. The axon may be very long, sometimes as long as one meter in humans or even three meters as in an elephant. Axons bundle together to form a nerve. Nerve tissue is capable of perception and responses of body in animals



CHAPTER II

Definition and Scope of Ecology

Man has been interested in ecology in a practical sort of way since early in his history. In primitive society every individual, to survive, need to have definite knowledge of his environment, i.e., of the force of nature and of the plants and animals around him. Ecology is one of the popular areas of sciences in biology.

It is a pluralistic science in the sense that it depends on a wide variety of methods and approaches rather than on a limited range of techniques and concepts. Even if, it is thought as part of biology, one important way in which ecology differs from most other branches of biology is that it can be properly appreciated or studied only through a multidisciplinary approach involving close cooperation from expertise in several disciplines.

The word 'Ecology' was coined from the Greek word 'oikos' meaning 'house' or ' a place to live' to designate the study of organisms in their natural homes. Specially, it means the study of interactions of organisms with one another and with the physical and chemical environment. The term "logy" is to mean study. Another way of defining Ecology is to look at the levels of biological organizations.

The molecules of life are organized in specific ways to form cells; cells are grouped in to tissues; and tissues are arranged to produce functional organs. The body organs are integrated to produce organ system, and the entire array of these systems constitutes an organism. Organisms exist not just as a single individual, but in-groups called population.

The various populations of organisms that interact with one another to form a community; interdependent communities of organisms interact with the physical environment to compose an ecosystem. Finally, all the ecosystems of the planet are combined to produce a level of organization known as the biosphere.

Ecology is concerned with the levels of organization beyond that of individual organism; i.e. population, community, ecosystem, and biosphere.

Scope

Whether we are talking about humans or any other kind of organisms, certain principles govern the growth and stability of their populations over time. These principles influence the pattern of relationships of organisms with one another and their environment. These patterns, in all their varied forms, are the focuses of ecology. As a science, ecology seeks to treat the world of nature including its human component with a single set of concepts and principles.

Ecology deals with such questions as:

- Why natural communities are composed of certain organisms and not others;
- How the various organisms interact with each other and with the physical environment; and
- How we can control and maintain these natural communities.

Human Activities Affecting Health and the Environment

Human activities in an ecosystem have many drawbacks, unless we are approaching it in an environmental friendly way. The atmosphere, fertile soils, freshwater resources, the oceans and the ecosystems they support, play a key role in providing humans with shelter, food, safe water and the capacity to recycle most wastes.

However, pressures exerted by humans, on the environment, in the form of pollution, resource depletion, land use changes and others affect environmental quality. Degradation of environmental quality can, in turn, lead to adverse human exposures and eventual health effects.

The pressures excreted by the driving forces are in many instances increasing. They relate to household wastes, freshwater use, land use and agricultural development, industrialization and energy use.

Household wastes

Gaseous household wastes arise mainly from heating and cooking. They contribute substantially to both outdoor and indoor air pollution. Liquid wastes are the by-products of domestic activities. In most areas of developing countries, feces are recycled for use in agriculture or deposited on land without prior destruction of pathogens. Not surprisingly, infectious disease such as diarrhoeal diseases, schistosomiasis and hepatitis are endemic, and some times epidemic, in such areas. Solid waste can also create environmental health problems.

It consists mainly of non-hazardous materials such as paper and plastic packaging material, glass, food scraps and other residues. However, it generally also contains small quantities of hazardous substances such as paints, medicines, solvents, cleaning materials and batteries, leading to potential chemical exposures. Production of household and municipal solid waste continues to increase worldwide, both in absolute and per capita terms.

Fresh Water For a large percentage of the world's population, water supplies are neither safe nor adequate. Currently, over 1000 million people do not have access to an adequate supply of safe water for household consumption. Moreover, the world's freshwater resources are limited and unevenly distributed over the global land mass.

Demand for water is nevertheless increasing in several sectors: for drinking water (domestic needs), food production (agriculture) and product manufacturing (industry). Global freshwater resources are threatened not only by overexploitation, however, but also by poor management and ecological degradation. Untreated sewage is discharged into rivers and lakes; industrial wastes are dumped into water bodies; and runoff from agricultural fields treated with herbicides and pesticides is leading to water contamination. Industrial development, the exponential growth of human settlements and the ever-increasing use of synthetic organic substances are also having serious adverse impacts on freshwater bodies. Many surface and ground waters are now contaminated with nutrients, heavy metals and persistent organic pollutants.

For instance, the River Awetu has been degraded by untreated liquid and solid waste discharge from Jimma Town, southwestern Ethiopia. The water is pungent and turns black just before the confluence point with the River Gilgel Gibe and no macroinvertebrates were found at this site

Land use and agricultural development Competition for land appears to be intensifying between sectors and production systems. Agriculture, in particular, can be expected to become an even more dominant form of land use. Population increases and the finite extent, to which further land can be converted to agricultural uses, mean that per capita arable land availability is becoming an issue.

Agricultural production carries several risks. Thus extension and intensification of agricultural production systems, together with fluctuation in the supply of and demand for agricultural produce are causing shifts in the environmental determinants of the health status of local communities.

Erosion Perhaps the worst erosion problem in the world, per ha of farmland, is in Ethiopia. Although Ethiopia has only 1/100 as much cropland in cultivation as the United States, it is thought to lose 2 billion metric tons of soil each year to erosion.

Haitit is another country with severely degraded soil once covered with lush tropical forest; the land has been denuded for firewood and cropland. Erosion has been so bad that some experts now say the country has absolutely top soil, and poor peasant farmers have difficulty raising any crop at all. Economist Lester Brown of World Watch Institute warns that the country may never recover from this eco-disaster.

Industrialization Industrialization is central to economic development and improved prospects for human well-being. But, if proper abatement technology is not used, industry becomes a major source of air, water and soil pollution, hazardous wastes and noise. Industrial workers are often at highest risk of health impacts.

Furthermore, developed countries have exacerbated the environmental problems now being experienced by developing countries through transfer of hazardous wastes industries and technologies. Major industrial impacts also arise from small-scale industry. In developing countries, small-scale industry contributes substantially to economic development, but can create problems for environment and health if environmental safeguards are not used.

Energy

Energy plays a critical role in basic human survival. Energy has important implications for health. Energy is also crucial to transportation and industrial processes. However, production and use of energy, if not properly controlled may be accompanied by adverse health and environment impacts. In developing countries, biomass accounts for about one-third of all energy use, and in some of least-developed countries, for as much as two-thirds. Open fires impair indoor air quality, add to the risk of accidents and jeopardize food hygiene. In general, the adverse effects on the environment of human activities are many and appear to be growing in intensity, and affecting larger and larger areas. Current and future potential pressures on the environment have major implication for health.

Environmental Threats to Human

Health Environmental threats to human health are numerous. These threats can be divided in to two:

a. Traditional hazard; i.e. associated with lack of development. Traditional hazards related to poverty and "insufficient" development are wide-ranging and include: lack of access to safe drinking-water; inadequate basic sanitation in the household and the community; indoor air pollution from cooking and heating using coal or biomass fuel and inadequate solid waste disposal.

b. Modern hazard, i.e. associated with unsustainable development. Modern hazards are related to development that lacks health- and environment safeguards, and to unsustainable consumption of natural resources. They include: water pollution from populated areas, industry and intensive agriculture; urban air pollution from motor cars, coal power stations and industry resulting in climate change, stratospheric ozone depletion and trans-boundary pollution. Polluted air and water, excessive levels of noise, nuclear weapons fall-out, over crowded slums, toxic waste dumps, inadequate or overly adequate diet, stress, food contaminants, medical X-rays, drugs, cigarettes, unsafe working conditions and other can be regarded as causative agents of environmental diseases. In short environmental diseases are those diseases that are introduced to the environment by man due to his careless behavior. Most environmentally induced diseases, unlike those caused by bacteria or other pathogens, are difficult to cure but theoretically simple to prevent. Remove the adverse environmental influence and the ailment will disappear. This is simply to say that by:

- Preventing discharges of poisonous pollutants into water and food
- Avoiding exposure to radiation
- Keeping away from cigarette smoke
– Avoiding synthetic food coloring or material

One of the problems with environmental health concern is our limited knowledge on those toxic agents that are actually distributed over our earth, due to different activities by man in the ecosystem. For example, world wide, there are about 10 million chemical compounds that have been synthesized thus far. But only one percent is produced commercially and is regulated.

Biotic and Abiotic Factors

The main aim of ecology is to understand the distribution of biotic and abiotic factors of living things in the environment. The biotic and abiotic factors include the living and non-living factors and their interaction with the environment.

Biotic components

Biotic components are living factors of an ecosystem. A few examples of biotic components include bacteria, animals, birds, fungi, plants, etc.

Abiotic components

Abiotic components are non-living chemical and physical factors of an ecosystem. These components could be acquired from the atmosphere, lithosphere, and hydrosphere. A few examples of abiotic components include sunlight, soil, air, moisture minerals, and more.

Living organisms are grouped into biotic components whereas non-living components like sunlight, water, topography are listed under abiotic components.

Types of Ecology

Ecology can be classified into different types. The different types of ecology are given below:

Global Ecology

It is the study of interactions among earth's ecosystems, atmosphere, land, and oceans. It helps in understanding the large-scale interactions and their influence on the planet.

Landscape Ecology

It is the study of the exchange of energy, organisms, materials and other products of ecosystems. Landscape ecology throws light on the role of human impacts on the landscape structures and functions.

Ecosystem Ecology

It is the study of the entire ecosystem which includes the study of living and non-living components and their relationship with the environment. This science research how ecosystems work, their interactions, etc.

Community Ecology

It is the study of how community structure is changed by interactions among living organisms. Ecology community is made up of two or more populations of different species living in a particular geographic area.

Population Ecology

It is the study of factors that change and impact the size and genetic composition of the population of organisms. Ecologists are interested in fluctuations in the size of a population, the growth of a population and any other interactions with the population.

In biology, a population can be defined as a set of individuals of the same species living in a given place at a given time. Births and immigration are the main factors that increase the population and death and emigration are the main factors that decrease the population.

Population ecology examines population distribution and density. Population density is the number of individuals in a given volume or area. This helps in determining whether particular species is in endanger or its number is to be controlled and resources to be replenished.

Organismal Ecology

Organismal ecology is the study of an individual organism's behaviour, morphology, physiology, etc. in response to environmental challenges. It looks at how individual organisms interact with biotic and abiotic components. Ecologists research how organisms are adapted to these nonliving and living components of their surroundings.

Individual species are related to various adaptations like physiological adaptation, morphological adaptation, and behavioural adaptation.

Molecular Ecology

The study of ecology focuses on the production of proteins and how these proteins affect the organisms and their environment. This happens at the molecular level.

DNA forms the proteins that interact with each other and the environment. These interactions give rise to some complex organisms.

Importance of Ecology

The following reasons explain the importance of ecology:

Conservation of Environment

Ecology helps us to understand how our actions affect the environment. It shows the individuals the extent of damage we cause to the environment.

Lack of understanding of ecology has led to the degradation of land and the environment. It has also led to the extinction and endangerment of certain species. For eg., dinosaurs, white shark, mammoths, etc. Thus the study of the environment and organisms helps us to protect them from any damage and danger.

Resource Allocation

With the knowledge of ecology, we are able to know which resources are necessary for the survival of different organisms. Lack of ecological knowledge has led to scarcity and deprivation of these resources, leading to competition.

Energy Conservation

All organisms require energy for their growth and development. Lack of ecological understanding leads to the over-exploitation of energy resources such as light, nutrition, and radiation, leading to its depletion.

Proper knowledge of ecological requirements prevents the unnecessary wastage of energy resources, thereby, conserving energy for future purposes.

Eco-Friendliness

Ecology encourages harmonious living within the species and the adoption of a lifestyle that protects the ecology of life.

Examples of Ecology

Following are a few examples of ecology:

Human Ecology

It focuses on the relationship between humans and the environment. It emphasizes the impact human beings have on the environment and gives knowledge on how we can improve ourselves for the betterment of humans and the environment.

Niche Construction

It deals with the study of how organisms alter the environment for the benefit of themselves and other living beings. For eg, termites create a 6 feet tall mound and at the same time feed and protect their entire population.

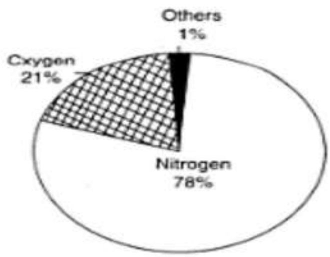
What are the resources on earth?

Life exists only on the planet Earth. Earth can be divided into three components: the land (lithosphere), water (hydrosphere) and air (atmosphere). The unique combination of these elements sustains life on earth. The life zones of the earth, where atmosphere, hydrosphere and lithosphere meet, interact and make life possible, is known as Biosphere.

The abiotic or physical environment of all organisms existing on Earth includes the atmosphere the lithosphere and the hydrosphere, besides a variety of other physical factors like temperature, sunlight and pH (a measure of acidity and alkalinity). The biotic part of environment consists of all living organisms like plants and animals including human beings. All these components of the environment work together, interacting with and modifying the effects on each other.

Air is an inexhaustible natural resource and an important factor for our survival on earth. Air consists of a mixture of gases including, Nitrogen (78%) and Oxygen (21%). The other gases present in air are Carbon-di-oxide (CO_2), Ammonia (NH_3), Ozone (O_3), noble gases like Helium, Argon and Water vapour.

The Oxygen in the air is utilized by the cells (eukaryotic and many prokaryotic cells) for aerobic respiration. Oxygen helps break down the glucose molecules and release energy for the activities of the organisms. CO2 is formed in the process and expelled out into the atmosphere.



Percentage composition of air

Air is also needed for combustion. Combustible substances make use of Oxygen present in the air while burning, and give out Carbon di oxide. The CO2 is released into the environment (atmosphere). Forest fires also release CO2 into the atmosphere.

Despite the release of CO2through respiration and combustion, it is present only in low concentrations in the atmosphere, as it is ‗fixed' in two ways: (1) photosynthetic processes of the green plants utilize the CO2 in the presence of sunlight, chlorophyll and water for the synthesis of glucose and (ii) marine animals utilize the carbonates present in the sea for the production of shells.

The role of the Atmosphere in Climate Control:

Every organism has its own fixed body temperature range which varies between 5oC to 40oC. To ensure survival of organisms this temperature range needs to be maintained on Earth.Air moderates the temperature in the environment by interacting with water vapour or moisture present in the atmosphere.

There are four different temperature zones on the Earth's surface, namely Tropical, Subtropical, Temperate and Arctic zones. The atmosphere retains an average, steady temperature during the day and even throughout the year in these climatic zones. During the night, atmospheric gases slow down the escape of the heat from the atmosphere.

This is because air is a bad conductor of heat. Thus, there is a relatively steady temperature range on earth that is suited to organisms. On Moon, which is approximately the same distance from the sun as the earth, with no atmosphere prevailing in it, and the temperature ranges from – 110oC to 130oC .

Movement of Air: Movement of air is caused by temperature or pressure differences and is experienced as wind. Where there are differences of pressure between two places, a pressure gradient exists, across which air moves: from the high-pressure region to the low-pressure region. This movement of air however, does not follow the quickest straight-line path. In fact, the air moving from high to low pressure follows a spiraling route, outwards from high pressure and inwards towards low pressure.

This is due to the rotation of the Earth beneath the moving air, which causes an apparent deflection of the wind to the right in the Northern Hemisphere, and to the left in the Southern Hemisphere. The deflection of air is caused by the Coriolis force. Consequently, air blows anticlockwise around a low-pressure centre (depression) and clockwise around a high-pressure centre (anticyclone) in the Northern Hemisphere. This situation is reversed in the Southern Hemisphere.

Wind caused by differences in temperature is known as convection or advection. In the atmosphere, convection and advection transfer heat energy from warmer regions to colder regions, either at the Earth surface or higher up in the atmosphere. Small-scale air movement of this nature is observed during the formation of sea and land breezes, due to temperature differences between seawater and land. At a much larger scale, temperature differences across the Earth generatethe development of the major wind belts. Such wind belts, to some degree, define the climate zones of the world.

Air temperature is generally higher at ground level due to heating by the Sun, and decreases with increasing altitude. This vertical temperature difference creates a significant uplift of air, since warmer air nearer the surface is lighter than colder air above it. This vertical uplift of air can generate clouds and rain. Sometimes air from warmer regions of the world collides with air from colder regions. This air mass convergence occurs in the mid-latitudes, where the warm air is forced to rise above the colder air, generating fronts and depressions.

The clouds that are generated by these differences in temperature and pressure, cause rainfall or precipitation. The rainfall may be convectional rainfall, relief rainfall and frontal rainfall. Certain times when the pressure difference is very low may lead to cyclonic storms and hurricanes. The cooling of water vapour in clouds and their fall to earth is called precipitation.

Different forms of precipitation are:

- Rain is the shower of liquid water, as droplets.
- Drizzle is a light shower.
- Snow is water vapour condensed to solid state
- Dew and frost are formed due to condensation of moisture directly on the surface of objects like plants or the earth's surface.
- Sleet is in the form of small grains of ice.
- Hail consists of balls or lumps of ice.

Thus the air plays a major role in patterning the climatic zones and rainfall patterns throughout the world.

Air, water and soil pollution

Our environment (air, water and land) were clean, clear and pristine. In other words, they were "without contamination or pollution". Our use of the environment changed all these. Any portion of the environment that man enters is transformed, changed or to put it precisely, polluted.

How did we do it?

Our activities - industrial, agricultural, recreational, domestic - introduce "contaminants" into the environment. These activities impact our air, water and our land.

Air pollution: Exhausts to the atmosphere from airplanes, vehicles and industrial plants; open burning; gaseous (e.g. methane) releases from open dumps etc. Since our atmosphere is universal, it can be concluded that our Earth's Air Medium is universally contaminated, albeit, to varying degrees. For more detailed account follow the link to the left on Air Pollution.

Water pollution: - Most of our water bodies have been impacted through our water transportation activities; heavy oil spills and leaks to water bodies, direct deposition of wastes to water bodies and contamination through seepages from landfill or dump sites. For more detailed account follow the link to the left on Water Pollution

Land pollution: - Lands used for industrial activities (gas stations, manufacturing factories, etc) are left contaminated after use. Several releases of chemicals, oil and other substances to the land. Contaminated sites abound everywhere in major locations of the world. Besides the chemicals released on the contaminated lands, several debris and wastes that constitute dangers are left on the sites. For more detailed account follow the link to the left on Land Pollution

What is a contaminant or contamination or pollution?

As contained above "Environment consists of Air, Water and Land/soil". A contaminant is any substance that impacts the environment negatively, thereby causing negative changes (or pollutiion) to the atmosphere".

The United States Environmental Protection Authority (USEPA) describes a contaminant as "any physical, chemical, biological, or radiological substance or matter that has an adverse effect on air, water, or soil"

Why do we care about pollution or contamination of our environment?

Contamination is dangerous to the safety and health of humans, wildlife and the environment. Some substances released to our environment constitute immediate danger humans and wildlife by causing diseases or even death. Some cause distressed growth of vegetation. Moreover, some substances are persistent in nature and can make it to our food chain.

Pollution

"Pollution is the introduction of substances (or energy) that cause adverse changes in the environment and living entities ."

Pollution need not always be caused by chemical substances such as particulates (like smoke and dust). Forms of energy such as sound, heat or light can also cause pollution. These substances that cause pollution are called pollutants.

Pollution, even in minuscule amounts, impacts the ecological balance. Pollutants can make its way up the food chain and eventually find its way inside the human body. Read on to explore the types of pollution and their implications.

Types of Pollution

As stated before, there are different types of pollution, which are either caused by natural events (like forest fires) or by man-made activities (like cars, factories, nuclear wastes, etc.) These are further classified into the following types of pollution:

- Air Pollution
- Water Pollution
- Soil Pollution
- Noise Pollution

Besides these 4 types of pollution, other types exist such as light pollution, thermal pollution and radioactive pollution. The latter is much rarer than other types, but it is the deadliest.

Air Pollution Air pollution occurs through enrichment (contamination) of the atmosphere or air with noxious gases and other undesirable substances; caused largely as a result of burning fuels and through release of gases by various industries and automobiles.

Sources of air pollutants Air pollutants come from many sources and contain diverse chemicals. All air contains natural contaminants such as pollen, fungi spores, and smoke and dust particles from forest fires and volcanic eruptions. It contains also naturally occurring carbon monoxide (CO) from the breakdown of methane (CH4); hydrocarbons; and hydrogen sulphide (H2S) and methane (CH4) from the anaerobic decomposition of organic matter. In contrast to the natural sources of air pollution, there are contaminants of anthropogenic origin. Coal-burning power plants, factories, metal smelters, vehicles are among the main anthropogenic sources of air pollutants.

Major Air Pollutants and Their Effects The most common and well-identified air pollutants are: -

a. Suspended Particulate This includes all particulate matters such as soot pollen, dust, ash, smoke etc. Such pollutants are easily seen and the common man could very easily be made to be aware of them. Major and visible damages of suspended particulates are:

1. Damage to buildings paints
2. Dirt into clothing
3. Obscure visibility
4. Corrode metals
5. When inhaled, suspended particulate irritates the respiratory tract.

b. Sulfur dioxide (SO_2) Sulfur dioxide is a colorless pollutant mostly released from industries and power-generating plants. Once in the atmosphere, SO_2 can be further oxidized to sulfur trioxide (SO_3), which reacts with water vapor or dissolves in water droplets to form sulfuric acid (H_2SO_4) which is the cause of acid rain. Sulfur dioxide:
1. Irritates respiratory system
2. Corrodes metals and statues
3. Impairs visibility
4. Kills or stunt growth of plants
5. Is a precursor of acid precipitation

c. Carbon monoxide (CO)

Carbon monoxide, odorless, colorless, non-irritant but highly toxic gas is found at high concentrations in urban areas. It is mostly released from motor vehicles, fuel wood combustion and industry. CO is a product of incomplete combustion. Its effect is that it: - Binds to hemoglobin in the blood, displacing oxygen and thereby reducing the amount of oxygen carried in the blood stream. - Slow down mental processes and reaction time

d. Nitrogen Dioxide (NO_2)

This is a colored gas than any other gas. It is formed when combustion occurs at high temperatures. The sources of NO_2 are power plants and automobile emission.

Nitrogen dioxide:

- Stunt plant growth
- Reduce visibility by its yellow brown smog it forms
- Contribute to the formation of acid rain.

e. Ozone (O3)

This is one of the constituents of photochemical oxidant. Photochemical oxidants are formed from a complex series of chemical reaction when NO2 and hydrocarbons react with O2 and sunlight to produce photochemical smog. Ozone formed on the upper part of the atmosphere (stratosphere) provides a valuable shield for the biosphere by absorbing incoming ultraviolet radiation. In ambient air (troposphere), however, ozone is a strong oxidizing agent and damages vegetation, building materials (such as paints, rubber, and plastics), and sensitive tissues (such as eyes, and lungs).

f. Hydrocarbons

Those compounds containing hydrogen and carbon atoms in various combinations are the hydrocarbon groups. Examples are benzene, and benzo(a)pyrene, which is potent carcinogen. Apart from their long time effect, they being catalysts for photochemical smog is the most felt problem.

g. Lead

Lead is a toxic metal, which is traced to automobile emissions from leaded gasoline. Lead is a metabolic poison and a neurotoxin that binds to essential enzymes and cellular components and inactivates them.

WATER

Water is one of the most important and most precious of natural resources, and a regular and plentiful supply of clean water is essential for the survival and health of most living organisms. As a consequence of rapidly expanding industrialization and excessive population growths, and most of our rivers, lakes, stream and other water bodies are being increasingly polluted. Water is regarded as " polluted " when it is changed in its quality or composition, directly or indirectly as a result of human's activities so that it becomes less suitable for drinking, domestic, agricultural, and recreational, fisheries or other purposes.

Sources of Water pollution Pollutants can enter waterways by a number of different routs. Sources of pollution can be categorized into two: point source pollution and non-point source pollution. Factories, power plants, sewage treatment plants, latrines that are directly connected to water bodies are classified as point sources, because they discharge pollution from specific locations. In contrast, non-point sources of water pollution are scattered or diffuse, having no specific location where they discharge into a particular body of water. Non-point sources include runoff from farm fields and feedlots, construction sites, roads, streets and parking lots.

Types and Effects of Water pollution

Although the types, sources and effects of water pollutants are often interrelated, it is convenient to divide them into major categories for discussion (Table. The followings are some of the important sources and effects of each type of pollutant.

Pollutant	Main source	Effects	Possible control
Organic oxygen demanding waste	Human sewage, animal wastes, decaying plant life, industrial waste	Overload depletes dissolved oxygen in water: animal life destroyed or migrates away: plant life destroyed	Provide secondary and tertiary wastewater treatment; minimize agricultural runoff
Plant nutrients	Agricultural runoff, detergents industrial wastes inadequate waste water treatment	Algal blooms and excessive aquatic plant growth upset ecological balances: eutrophication	Agricultural runoff too widespread, diffuse for adequate control
Pathogenic bacteria & virus	presence of sewage and animal wastes	Outbreaks of such diseases as typhoid	Provide secondary and tertiary wastewater

	in water	infectious hepatitis	treatment; minimize agricultural runoff
Inorganic chemicals	Mining manufacturing irrigation, oil fields	Alter acidity, basicity, or salinity: also render water toxic	Disinfect during waste-water treatment; stop pollutants at source
Synthetic organic chemicals (plastics, pesticides)	Agricultural manufacturing, and consumer uses	Many are not biodegradable; chemical interactions in environment are poorly understood many poisonous	Use of biodegradable materials; prevent entry into water supply at source
Fossil fuels (oils particularly)	Machinery, automobile wastes; pipeline breaks, offshore blowout and seepage, supertanker accidents, spills, and wrecks; heating transportation, industry; agriculture	Vary with location, duration, and type of fossil fuel; potential disruption of ecosystems; economic, recreational, and aesthetic damage to coasts	Strictly regulate oil drilling, transportation, storage; collect and reprocess engine oil and grease; develop means to contain spills
Sediments	Natural erosion, poor soil	Fill in waterways, reduce fish	Put soil conservation practices to use

	conservation practices in agriculture, mining construction	populations	

i. Infectious Agents The most serious water pollutants in terms of human health are pathogenic organisms. Among the most important waterborne diseases are typhoid fever, cholera, bacterial and amoebic dysentery, polio, hepatitis and schistosomiasis. The main source of these pathogens is from untreated or improperly treated human wastes. Animal feedlots or fields near waterways and food processing plants with inadequate waste treatment facilities also are sources of disease causing organisms.

ii. Oxygen Demanding Wastes The amount of dissolved oxygen (DO) in water is a good indicator of water quality and the kinds of life it will support. Oxygen is added to water by diffusion from the air, especially when turbulence and mixing rates are high, and by photosynthesis of green plants and algae. Oxygen is removed from water by respiration and chemical processes that consume oxygen. The addition of certain organic materials, such as sewage, paper pulp, or food processing wastes, to water stimulates oxygen consumption by decomposers. The impact of these materials on water quality can be expressed in terms of biological oxygen demand (BOD)- a standard test of the amount of dissolved oxygen utilized by aquatic microorganisms over a five-day period.

iii. Plant Nutrients and Eutrophication Aquatic plants require certain nutrients for health growth and metabolism. An excess of these essential elements (from such sources as sewage treatment plants, runoff from animal feedlots or fertilized agricultural lands), however, can result in a plant population explosion which leads to serious degradation of water quality and radical changes in the species composition of the over-fed lake, pond or stream. The process by which a body of water becomes overenriched with nutrients and as a result produces an over-abundance of plant life is known as eutrophication. Boye Pond, can be a classic example of eutrophication, which has been receiving a sustained solid and liquid waste discharge from inhabitants of Jimma Town, Southwestern Ethiopia, and now on the process being converted to a marshy area.

Although eutrophication can occur in sluggish streams, bays, and estuaries, it is most common in lakes and ponds. This is because lakes, unlike flowing bodies of water, flush very slowly; thus nutrientladen wastewaters or runoffs introduced into a lake tend to remain there for many years.

iv. Toxic Inorganic Chemicals Toxic, inorganic chemicals introduced into water as a result of human activities have become the most serious forms of water pollution. Among the chemicals of greatest concern are heavy metals, such as mercury, lead, tin, and cadmium. Other inorganic materials, such as acids, salts, nitrates and chlorine that normally are not toxic in low concentrations may become concentrated enough to lower water quality or adversely affect biological communities.

V. Organic Chemicals Thousands of different natural synthetic organic chemicals are used in the chemical industry to make pesticides, plastics, pigments and other products. Many of these chemicals are highly toxic. Exposure to very low concentrations can cause birth defects, genetic disorder, and cancer. They also can persist in the environment because they are resistant to degradation and toxic to the organisms that ingests them. Contamination of surface waters and groundwater by these chemicals is a serious threat to human health.

Important sources of toxic organic chemicals in water are improper disposal of industrial and household wastes and runoff of pesticide from farm fields, forests, roadside and other places where they are used in large quantities.

VI. Thermal Pollution Many industrial processes create problem of thermal pollution by discharging heat (in the form of hot water, air or effluent) into the environment. Such industries use a lot of water for cooling purposes and return this water to a stream at a higher temperature. The adverse effects of thermal pollution include:

• Change in species composition;

• Fish may migrate or be killed by suffocation (because warm water holds less oxygen than cold water);

• The BOD of the water rises;
• Increase the susceptibility of aquatic organisms to disease;
• Reproductive cycles of fish and other aquatic organisms may be disrupted.

Land/Soil Pollution

Humans and animals used resources that earth could supply for existence for millions of years. Earth (Land) being natural resources is also used for disposal of the wastes we generate. Even in the primitive society the hunters and gathers dispose their waste near and by their caves. Solid wastes are the wastes arising from human and animal activities that are normally solid and that are discarded as useless or unwanted.

It encompass the heterogeneous mass of throw away from mostly urban communities as well as the more homogenous accumulation of agricultural, industrial and mineral wastes. The problem of solid waste was not as bad as it is now. In the past, the number of population in urban and rural communities was not so populated.

But, the problem of solid waste began when first humans congregate in tribes, villages and communities. The practice of throwing waste into the streets, galleries, any where in the yard, and vacant areas led to the breeding of rats and flies. For example, in Europe because of waste accumulation at the time of formation of large communities resulted in increment of the rat population.

It was during that time that the great plague pandemic killed hundreds of thousands of people in the world. Present public health science proved that those rats, flies and other diseases vector breed in open dumps, in food storage facilities, and in other areas and houses. One study in USA revealed that there is 32 human diseases which have relationship to improper solid waste management.

Ecological impacts of solid waste include:-

a. Water and air pollution.

b. Liquid that seeps from open dumps or poorly engineered landfills will contaminate surface water and ground water found in the vicinity.

c. In mining areas, the liquid leached from waste dump may contain toxic elements such as copper, arsenic or may contaminate water supplies from unwanted salts of calcium and magnesium.

Some substances such as DDT, and mercury are relatively stable; they are non-degradable and insoluble in water. They are neither used nor eliminated, but are stored in the body, where they may exert a cumulative damaging effect on a variety of physiological processes .

Minamata Disease In the early 1950s, people in the small coastal village of Minamata, Japan, noticed strange behavior that they called dancing cats. inexplicably, cats would begin twitching, stumbling, and jerking about, as they were drunk. Many became "suicidal" and staggered off docks in to the ocean. The residents didn't realize at the time, but they were witnessing an ominous warning of an environmental health crisis that would make the name of their village synonymous with a deadly disease. Their cats were suffering from brain damage that we now know was caused by methyl mercury poisoning. In 1956, the first human case of neurological damage was reported.
A five-year old girl who had suddenly lapsed in to a convulsive delirium was brought into the local clinic. Within a few weeks there seemed to be an epidemic of nervous problems including numbness, tingling sensations, headaches, blurred vision, slurred speech, and loss of muscle control. For an unlucky few, these milder symptoms were followed by violent trembling paralysis and even death.
An abnormally high rate of birth defects also occurred. Children were born with tragic deformities; paralysis and permanent mental retardation. Lengthy investigations showed that these symptoms were caused by mercury from fish and seafood that formed a major part of the diet of both humans and their cats.
For years, the Chisso chemical plant (Plastic Manufacturer) had been releasing residues containing mercury into Minamata Bay. Since elemental mercury is not water soluble, it was assumed that it would sink into the bottom sediments and remain inert. Scientists discovered, however, that bacteria living in the sediments were able

to convert metallic mercury into soluble methyl mercury, which was absorbed from the water and concentrated in the tissues of aquatic organisms. People who ate fish and shellfish from the Bay were exposed to dangerously high levels of this toxic chemical. Altogether, more than 3,500 people were affected and about fifty died of what became known as Minamata disease.

For example, DDT is soluble in fat. It tends to accumulate in the fatty tissues of organisms. For this reason, like mercury, DDT is a prime candidate for biological concentration. The DDT that becomes concentrated in tissues of herbivores (such as insects) becomes even more concentrated in tissues of carnivores that eat quantities of the DDT-harboring herbivores. The concentration proceeds at each trophic level.

Pesticides Pesticides are substances, which kill pests and disease vectors of agriculture and public health importance. Pesticides are subdivided into groups according to target organisms:

- Insecticides; kill insects
- Rodenticides; kill rats and mice
- Herbicides; kill weeds
- Nematicides; kill nematodes Insecticides: the largest numbers of pesticides are employed against a wide variety of insects, and include: stomach poison (taken into the body through the mouth); contact poisons (penetrate through the body wall); and fumigants (enter insects through its breathing pores).

Inorganic insecticides These insecticides act as stomach poison. Lead arsenate, Paris Green, and a number of other products containing copper, zinc, mercury, or sulfur are examples of inorganic insecticides. Many of these products are quite toxic to man as well as to insects.

Botanical

Certain plant extracts are very effective contact poisons, providing quick knockdown of insects. Most botanical preparations are nontoxic to humans, and can be safely used.

Chlorinated hydrocarbons These are contact poisons. DDT, chlordane, lindane, endrine, alderin are some of the chlorinated hydrocarbons. These insecticides are broad-spectrum, and act primarily on the central nervous system, causing the insect to go through a series of convulsions prior to death. They are also persistent in the environment, breaking down very slowly, and therefore, retaining their effectiveness for a relatively long period after application.

Organophosphates Organophosphate are broad-spectrum contact poisons. Unlike chlorinated hydrocarbons, organophosphates are not persistent, usually breaking down two weeks or less after application. They are nerve poisons, which act to inhibit the enzyme cholinesterase, causing the insect to lose coordination and go into convulsion. Methyl parathion, phosdrin and malathion are examples of this group.

Carbamates These are contact poisons, which act in a manner similar to the organophosphates. Carbamates are widely used in public health work and agriculture because of their rapid knockdown of insects and low toxicity to mammals.

Pesticide Benefits

Disease control

Insects, rodents and ticks serve as vectors in the transmission of a number of disease-causing pathogens and parasites. Malaria, yellow fever, trypanosomiasis, onchocerciasis and plague (Black Death) are some of human diseases that are transmitted by disease vectors (insects and rodents). All of these diseases can be reduced by careful use of insecticides.

Crop protection

Plant diseases, insects, bird predation, and competition by weeds reduce crop yield worldwide by at least one-third. Post-harvest losses to rodents, insects, and fungi may as much as another 20 to 30 percent. Without the use of pesticides, these losses might be much higher.

Pesticide Problems While synthetic chemical pesticides have brought us great economic and social benefits, they are also causing a number of serious problems. Some of the problems are:

- Killing of beneficial species;
- Development of resistance;
- Environmental contamination
- Hazards to human health especially workers who do not use personal protection equipment during application

Radioactive Materials There are various kinds of atoms of each elemental substance, each with a slightly different make-up, some radioactive, some not radioactive. When radioactive materials are released into the environment, they become dispersed and diluted, but they may also become concentrated in living organisms and during food chain transfers by a variety of means. Radioactive substances may also simply accumulate in water, soils sediments, or air if the input exceeds the rate of natural radioactive decay.

Radioactive materials have the same chemical properties as the nonradioactive forms. Thus, radioactive iodine (I131), for example, can be incorporated into thyroxin, the thyroid hormone, as easily as nonradioactive iodine (I127). Strontium 90 is a radioactive substance. It is chemically very similar to calcium, and thus tends to be accumulated in the bones and other tissues rich in calcium. It can also damage the blood-forming center in the bone marrow.

Prevention and Control of Pollution As in disease, pollution prevention is far better and more desirable than its cure. There are various measures that can be taken for preventing pollution. The followings are some of the measures:

a. Recycling and reuse of waste materials;
b. Waste reduction;
c. Control the use of chemicals;
d. Proper disposal of wastes;
e. Treatment of wastes before discharge;
f. Use of "cleaner" energy sources, such as sun energy, wind, etc.;
g. Reduce emission of air pollutants using different techniques; h. Formulation of rules and regulations.

Noise Pollution

Noise pollution refers to the excessive amount of noise in the surrounding that disrupts the natural balance. Usually, it is man-made, though certain natural calamities like volcanoes can contribute to noise pollution.

In general, any sound which is over 85 decibels is considered to be detrimental. Also, the duration an individual is exposed plays an impact on their health. For perspective, a normal conversation is around 60 decibels, and a jet taking off is around 15o decibels. Consequently, noise pollution is more obvious than the other types of pollution.

Noise pollution has several contributors, which include:

- Industry-oriented noises such as heavy machines, mills, factories, etc.
- Transportation noises from vehicles, aeroplanes, etc.
- Construction noises
- Noise from social events (loudspeakers, firecrackers, etc.)
- Household noises (such as mixers, TV, washing machines, etc.)

EFFECTS OF NOISE POLLUTION

As well as damaging our hearing by causing — tinnitus or deafness —, constant loud noise can damage human health in many ways, particularly in the very young and the very old. Here are some of the main ones:

Physical

Respiratory agitation, racing pulse, high blood pressure, headaches and, in case of extremely loud, constant noise, gastritis, colitis and even heart attacks.

Psychological

Noise can cause attacks of stress, fatigue, depression, anxiety and hysteria in both humans and animals.

Sleep and behavioural disorders

Noise above 45 dB stops you from falling asleep or sleeping properly. Remember that according to the World Health Organization it should be no more than 30 dB. Loud noise can have latent effects on our behaviour, causing aggressive behaviour and irritability.

Memory and concentration

Noise may affect people's ability to focus, which can lead to low performance over time. It is also bad for the memory, making it hard to study.

Interestingly, our ears need more than 16 hours' rest to make up for two hours of exposure to 100 dB.

SOLUTIONS TO REDUCE NOISE POLLUTION

International bodies like the WHO agree that **awareness of noise pollution is essential to beat this invisible enemy.** For example: avoid very noisy leisure activities, opt for alternatives means of transport such as bicycles or electric vehicles over taking the car, do your housework at recommended times, insulate homes with noise-absorbing materials, etc. Educating the younger generation is also an essential aspect of environmental education.

Governments can also take measures to ensure correct noise management and reduce noise pollution. For example: protecting certain areas — parts of the countryside, areas of natural interest, city parks, etc. — from noise, establishing regulations that include preventive and corrective measures — mandatory separation between residential zones and sources of noise like airports, fines for exceeding noise limits, etc. —, installing noise insulation in new buildings, creating pedestrian areas where traffic is only allowed to enter to offload goods at certain times, replacing traditional asphalt with more efficient options that can reduce traffic noise by up to 3 dB, among others.

Bio-geo chemical cycles in nature:

In ecology, a **biogeochemical cycle** is a circuit or pathway by which a chemical element or molecule moves through both biotic ("bio-") and abiotic ("geo-") compartments of an ecosystem. In effect, the element is recycled, although in some such cycles there may be places (called "sinks") where the element is accumulates for a long period of time.

All chemical elements occurring in organisms are part of biogeochemical cycles.

In addition to being a part of living organisms, these chemical elements also cycle through abiotic factors of ecosystems, such as water (hydrosphere), land (lithosphere), and air (atmosphere); the living factors of the planet can be referred to collectively as the biosphere. The biogeochemical cycles provide a clear demonstration of one of the fundamental principles of biological systems: The harmonious interactions between organisms and their environment, both biotically and abiotically.

All the chemicals, nutrients, or elements used in ecosystems by living organisms—such as carbon, nitrogen, oxygen, and phosphorus—operate on a closed system, which means that these chemicals are recycled, instead of lost, as they would be in an open system. The energy of an ecosystem occurs in an **open system;** the sun constantly gives the planet energy in the form of light, which is eventually used and lost in the form of heat, throughout the trophic levels of a food web.

Although components of the biogeochemical cycle are not completely lost, they can be held for long periods of time in one place. This place is called a **reservoir,** which, for example, includes such things as coal deposits that are storing carbon for a long period of time. When chemicals are held for only short periods of time, they are being held in **exchange pools.** Generally, reservoirs are abiotic factors while exchange pools are biotic factors. Examples of exchange pools include plants and animals, which temporarily use carbon in their systems and release it back into a particular reservoir. Carbon is held for a relatively short time in plants and animals when compared to coal deposits. The amount of time that a chemical is held in one place is called its **residence time.**

The most well-known and important biogeochemical cycles include the carbon cycle, the nitrogen cycle, the oxygen cycle, and the water cycle.

Biogeochemical cycles always involve equilibrium states: A balance in the cycling of the element between compartments. However, overall balance may involve compartments distributed on a global scale.

Biogeochemical cycles of particular interest in ecology are:

- Nitrogen cycle
- Oxygen cycle
- Carbon cycle
- Water cycle

Nitrogen cycle

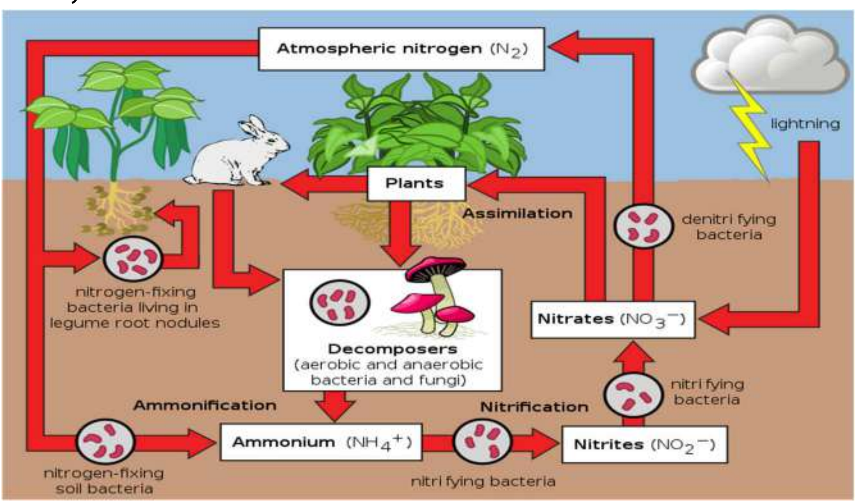
The **nitrogen cycle** is the biogeochemical cycle by which nitrogen is converted into multiple chemical forms as it circulates among atmosphere, terrestrial, and marine ecosystems. The conversion of nitrogen can be carried out through both biological and physical processes. Important processes in the nitrogen cycle include fixation, ammonification, nitrification, and denitrification. The majority of Earth's atmosphere (78%) is atmosphere nitrogen, making it the largest source of nitrogen. However, atmospheric nitrogen has limited availability for biological use, leading to a scarcity of usable nitrogen in many types of ecosystems.

The nitrogen cycle is of particular interest to ecologists because nitrogen availability can affect the rate of key ecosystem processes, including primary production and decomposition. Human activities such as fossil fuel combustion, use of artificial nitrogen fertilizers, and release of nitrogen in wastewater have dramatically altered the global nitrogen cycle. Human modification of the global nitrogen cycle can negatively affect the natural environment system and also human health

In plants, much of the nitrogen is used in chlorophyll molecules, which are essential for photosynthesis and further growth.

The nitrogen cycle reveals the harmonious coordination between different biotic and abiotic elements. Processing, or fixation, is necessary to convert gaseous nitrogen into forms usable by living organisms. Some fixation occurs in lightning strikes, but most fixations are done by free-living or symbiotic bacteria.

These bacteria have the nitrogenase enzyme that combines gaseous nitrogen with hydrogen to produce ammonia, which is then further converted by the bacteria to make its own organic compounds. Some nitrogen-fixing bacteria, such as *Rhizobium*, live in the root nodules of legumes (such as peas or beans). Here they form a mutualistic relationship with the plant, producing ammonia in exchange for carbohydrates. Nutrient-poor soils can be planted with legumes to enrich them with nitrogen. A few other plants can form such symbioses.

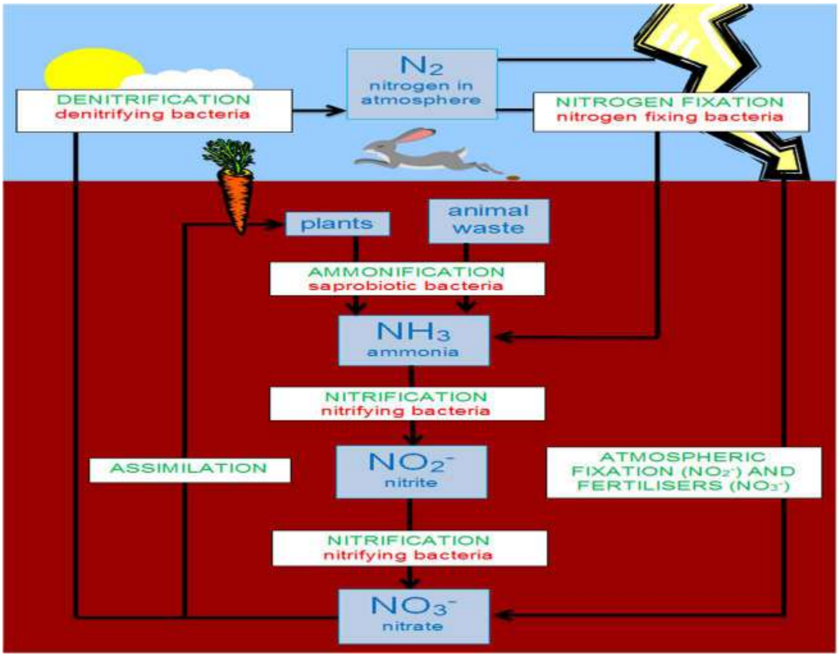


Other plants get nitrogen from the soil by absorption at their roots in the form of either nitrate ions or ammonium ions. All nitrogen obtained by animals can be traced to the eating of plants at some stage of the food chain.

Processes

Nitrogen is present in the environment in a wide variety of chemical forms including organic nitrogen, ammonium (NH^+_4), nitrite (NO^-_2), nitrate (NO^-_3), nitrous oxide (N_2O), nitric oxide (NO) or inorganic nitrogen gas (N_2). Organic nitrogen may be in the form of a living organism, humus or in the intermediate products of organic matter decomposition.

The processes in the nitrogen cycle is to transform nitrogen from one form to another. Many of those processes are carried out by microbes, either in their effort to harvest energy or to accumulate nitrogen in a form needed for their growth. For example, the nitrogenous wastes in animal urine are broken down by nitrifying bacteria in the soil to be used by plants. The diagram alongside shows how these processes fit together to form the nitrogen cycle



Nitrogen fixation

The conversion of nitrogen gas (N_2) into nitrates and nitrites through atmospheric, industrial and biological processes is called nitrogen fixation. Atmospheric nitrogen must be processed, or "fixed", into a usable form to be taken up by plants. Between 5 and 10 billion kg per year are fixed by lightning strikes, but most fixation is done by free-living or symbiotic bacteria known as diazotrophs. These bacteria have the nitrogenase enzyme that combines gaseous nitrogen with hydrogen to produce ammonia, which is converted by the bacteria into other organic compounds. Most biological nitrogen fixation occurs by the activity of Mo-nitrogenase, found in a wide variety of bacteria and some Archaea. Mo-nitrogenase is a complex two-component enzyme that has multiple metal-containing prosthetic groups.

An example of free-living bacteria is *Azotobacter*. Symbiotic nitrogen-fixing bacteria such as *Rhizobium* usually live in the root nodules of legumes (such as peas, alfalfa, and locust trees). Here they form a mutualistic relationship with the plant, producing ammonia in exchange for carbohydrates. Because of this relationship, legumes will often increase the nitrogen content of nitrogen-poor soils. A few non-legumes can also form such symbioses. Today, about 30% of the total fixed nitrogen is produced industrially using the Haber-Bosch process, which uses high temperatures and pressures to convert nitrogen gas and a hydrogen source (natural gas or petroleum) into ammonia

Assimilation

Plants can absorb nitrate or ammonium from the soil by their root hairs. If nitrate is absorbed, it is first reduced to nitrite ions and then ammonium ions for incorporation into amino acids, nucleic acids, and chlorophyll. In plants that have a symbiotic relationship with rhizobia, some nitrogen is assimilated in the form of ammonium ions directly from the nodules. It is now known that there is a more complex cycling of amino acids between *Rhizobia* bacteroids and plants.

The plant provides amino acids to the bacteroids so ammonia assimilation is not required and the bacteroids pass amino acids (with the newly fixed nitrogen) back to the plant, thus forming an interdependent relationship. While many animals, fungi, and other heterotrophic organisms obtain nitrogen by ingestion of amino acids, nucleotides, and other small organic molecules, other heterotrophs (including many bacteria) are able to utilize inorganic compounds, such as ammonium as sole N sources. Utilization of various N sources is carefully regulated in all organisms.

Ammonification

When a plant or animal dies or an animal expels waste, the initial form of nitrogen is organic. Bacteria or fungi convert the organic nitrogen within the remains back into ammonium (NH^{+}_{4}), a process called ammonification or mineralization. Enzymes involved are:

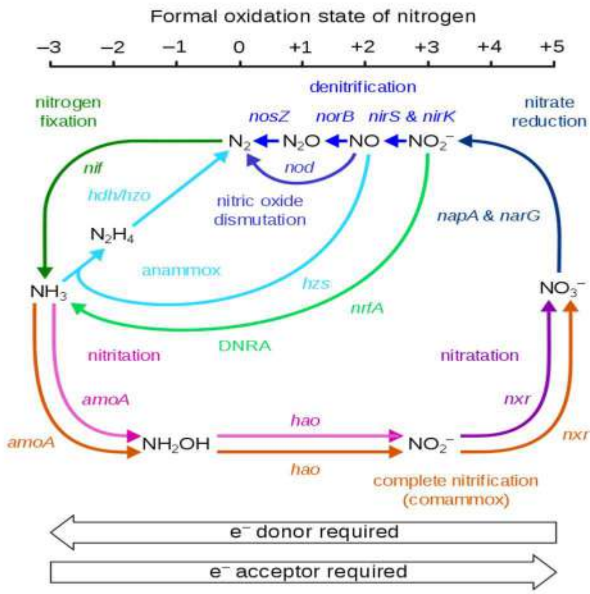
- GS: Gln Synthetase (Cytosolic & Plastic)
- GOGAT: Glu 2-oxoglutarate aminotransferase (Ferredoxin & NADH-dependent)
- GDH: Glu Dehydrogenase:
    - Minor Role in ammonium assimilation.
    - Important in amino acid catabolism.

Nitrification

The conversion of ammonium to nitrate is performed primarily by soil-living bacteria and other nitrifying bacteria. In the primary stage of nitrification, the oxidation of ammonium (NH^{+}_{4}) is performed by bacteria such as the *Nitrosomonas* species, which converts ammonia to nitrites (NO^{-}_{2}). Other bacterial species such as *Nitrobacter*, are responsible for the oxidation of the nitrites (NO^{-}_{2}) into nitrates (NO^{-}_{3}). It is important for the ammonia (NH3) to be converted to nitrates or nitrites because ammonia gas is toxic to plants.

Due to their very high solubility and because soils are highly unable to retain anions, nitrates can enter groundwater. Elevated nitrate in groundwater is a concern for drinking water use because nitrate can interfere with blood-oxygen levels in infants and cause methemoglobinemia or blue-baby syndrome.

Where groundwater recharges stream flow, nitrate-enriched groundwater can contribute to eutrophication, a process that leads to high algal population and growth, especially blue-green algal populations. While not directly toxic to fish life, like ammonia, nitrate can have indirect effects on fish if it contributes to this eutrophication. Nitrogen has contributed to severe eutrophication problems in some water bodies. Since 2006, the application of nitrogen fertilizer has been increasingly controlled in Britain and the United States. This is occurring along the same lines as control of phosphorus fertilizer, restriction of which is normally considered essential to the recovery of eutrophied waterbodies.



Denitrification

Denitrification is the reduction of nitrates back into nitrogen gas (N_2), completing the nitrogen cycle. This process is performed by bacterial species such as *Pseudomonas* and *Paracoccus*, under anaerobic conditions. T hey use the nitrate as an electron acceptor in the place of oxygen during respiration. These facultatively (meaning optionally) anaerobic bacteria can also live in aerobic conditions.

Denitrification happens in anaerobic conditions e.g. waterlogged soils. The denitrifying bacteria use nitrates in the soil to carry out respiration and consequently produce nitrogen gas, which is inert and unavailable to plants.

Dissimilatory nitrate reduction to ammonium

Dissimilatory nitrate reduction to ammonium (DNRA), or nitrate/nitrite ammonification, is an anaerobic respiration process. Microbes which undertake DNRA oxidise organic matter and use nitrate as an electron acceptor, reducing it to nitrite, then ammonium ($NO_3^- \rightarrow NO_2^- \rightarrow NH_4^+$). Both denitrifying and nitrate ammonification bacteria will be competing for nitrate in the environment, although DNRA acts to conserve bioavailable nitrogen as soluble ammonium rather than producing dinitrogen gas.

Anaerobic ammonia oxidation

In this biological process, nitrite and ammonia are converted directly into molecular nitrogen (N_2) gas. This process makes up a major proportion of nitrogen conversion in the oceans. The balanced formula for this "anammox" chemical reaction is: $NH^+_4 + NO^-_2 \rightarrow N_2 + 2H_2O$ ($\Delta G° = -357\ kJ{\cdot}mol^{-1}$).

Consequence of human modification of the nitrogen cycle

Impacts on natural systems

Increasing levels of nitrogen deposition are shown to have a number of negative effects on both terrestrial and aquatic ecosystems.[48][49] Nitrogen gases and aerosols can be directly toxic to certain plant species, affecting the aboveground physiology and growth of plants near large point sources of nitrogen pollution.

Changes to plant species may also occur, as accumulation of nitrogen compounds increase its availability in a given ecosystem, eventually changing the species composition, plant diversity, and nitrogen cycling. Ammonia and ammonium - two reduced forms of nitrogen - can be detrimental over time due to an increased toxicity toward sensitive species of plants, particularly those that are accustomed to using nitrate as their source of nitrogen, causing poor development of their roots and shoots. Increased nitrogen deposition also leads to soil acidification, which increases base cation leaching in the soil and amounts of aluminum and other potentially toxic metals, along with decreasing the amount of nitrification occurring and increasing plant-derived litter.

Due to the ongoing changes caused by high nitrogen deposition, an environment's susceptibility to ecological stress and disturbance - such as pests and pathogens - may increase, thus making it less resilient to situations that otherwise would have little impact to its long-term vitality.

Additional risks posed by increased availability of inorganic nitrogen in aquatic ecosystems include water acidification; eutrophication of fresh and saltwater systems; and toxicity issues for animals, including humans.

Eutrophication often leads to lower dissolved oxygen levels in the water column, including hypoxic and anoxic conditions, which can cause death of aquatic fauna. Relatively sessile benthos, or bottom-dwelling creatures, are particularly vulnerable because of their lack of mobility, though large fish kills are not uncommon. Oceanic dead zones near the mouth of the Mississippi in the Gulf of Mexico are a well-known example of algal bloom-induced hypoxia.

The New York Adirondack Lakes, Catskills, Hudson Highlands, Rensselaer Plateau and parts of Long Island display the impact of nitric acid rain deposition, resulting in the killing of fish and many other aquatic species.[54]

Ammonia (NH_3) is highly toxic to fish and the level of ammonia discharged from wastewater treatment facilities must be closely monitored. To prevent fish deaths, nitrification via aeration prior to discharge is often desirable. Land application can be an attractive alternative to the aeration.

Impacts on human health: nitrate accumulation in drinking water

Leakage of Nr (reactive nitrogen) from human activities can cause nitrate accumulation in the natural water environment, which can create harmful impacts on human health. Excessive use of N-fertilizer in agriculture has been one of the major sources of nitrate pollution in groundwater and surface water.

Due to its high solubility and low retention by soil, nitrate can easily escape from the subsoil layer to the groundwater, causing nitrate pollution. Some other non-point sources for nitrate pollution in groundwater are originated from livestock feeding, animal and human contamination and municipal and industrial waste. Since groundwater often serves as the primary domestic water supply, nitrate pollution can be extended from groundwater to surface and drinking water in the process of potable water production, especially for small community water supplies, where poorly regulated and unsanitary waters are used.

The WHO standard for drinking water is 50 mg NO_3^- L^{-1} for short-term exposure, and for 3 mg NO_3^- L^{-1}chronic effects. Once it enters human body, nitrate can react with organic compounds through nitrosation reactions in the stomach to form nitrosamines and nitrosamides, which are involved in some types of cancers (e.g., oral cancer and gastric cancer).

Impacts on human health: air quality

Human activities have also dramatically altered the global nitrogen cycle via production of nitrogenous gases, associated with the global atmospheric nitrogen pollution. There are multiple sources of atmospheric reactive nitrogen (Nr) fluxes. Agricultural sources of reactive nitrogen can produce atmospheric emission of ammonia (NH_3), nitrogen oxides (NO_x) and nitrous oxide (N_2O).

Combustion processes in energy production, transportation and industry can also result in the formation of new reactive nitrogen via the emission of NO_x, an unintentional waste product. When those reactive nitrogens are released to the lower atmosphere, they can induce the formation of smog, particulate matter and aerosols, all of which are major contributors to adverse health effects on human health from air pollution.

In the atmosphere, NO_2 can be oxidized to nitric acid (HNO_3), and it can further react with NH_3 to form ammonium nitrate, which facilitates the formation of particular nitrate. Moreover, NH_3 can react with other acid gases (sulfuric and hydrochloric acids) to form ammonium-containing particles, which are the precursors for the secondary organic aerosol particles in photochemical smog.

Oxygen cycle

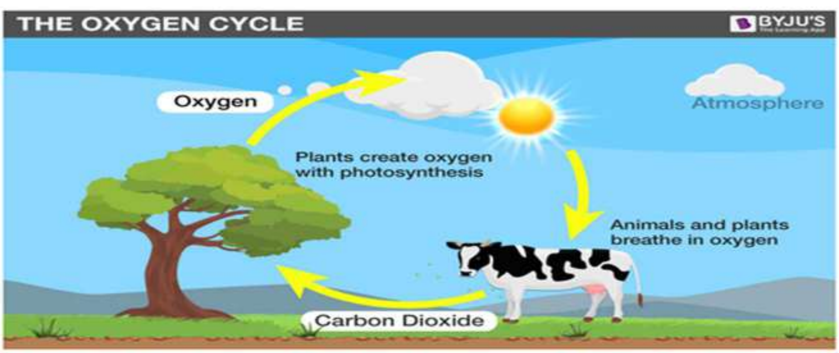
As we all know, air is a mixture of gases. The air in the atmosphere is composed of different gases, namely nitrogen (78%), oxygen (21%), argon and other trace gases ((1%).

According to Earth's history, oxygen gas was first introduced by cyanobacteria through the process of photosynthesis. Earlier, around 4.6 billion years ago, there was no life on planet earth because the atmosphere was devoid of oxygen. Later, there was a gradual increase in the oxygen levels and by the Carboniferous Period- 299 million years ago, oxygen reached the levels that were similar to today's estimates.

Today, oxygen is freely available in the air, and also dissolved in water. It is the second most abundant gas present in the atmosphere and also the most common element of the human body. It plays an essential role in most life forms on Earth and also serves as an essential element in biomolecules like proteins, and nucleic acids.

Read on to explore more about oxygen, its uses, production, and how it is recycled in a cyclic pattern.

What is Oxygen Cycle?



Oxygen cycle, along with the carbon cycle and nitrogen cycle plays an essential role in the existence of life on the earth. The oxygen cycle is a biological process which helps in maintaining the oxygen level by moving through three main spheres of the earth which are:

- Atmosphere
- Lithosphere
- Biosphere.

This biogeochemical cycle explains the movement of oxygen gas within the atmosphere, the ecosystem, biosphere and the lithosphere. The oxygen cycle is interconnected with the carbon cycle.

The atmosphere is the layer of gases presents above the earth's surface. The sum of all Earth's ecosystem makes a biosphere. Lithosphere, which is the solid outer section along with the Earth's crust and it is the largest reservoir of oxygen.

Stages of the Oxygen Cycle

The steps involved in the oxygen cycle are:

Stage-1: All green plants during the process of photosynthesis, release oxygen back into the atmosphere as a by-product.

Stage-2: All aerobic organisms use free oxygen for respiration.

Stage-3: Animals exhale Carbon dioxide back into the atmosphere which is again used by the plants during photosynthesis. Now oxygen is balanced within the atmosphere.

Uses of Oxygen

The four main processes that use Atmospheric oxygen are:

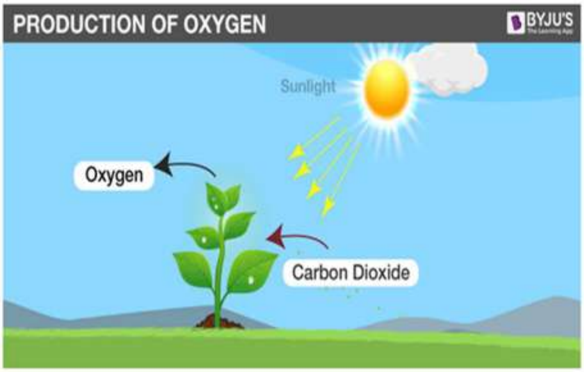
Breathing – It is the physical process, through which all living organisms including plants, animals, and humans inhale oxygen from the outside environment into the cells of an organism and exhale carbon dioxide back into the atmosphere.

Decomposition: It is one of the natural and most important processes in the oxygen cycle and occurs when an organism dies. The dead animal or plants decay into the ground, and the organic matter along with the carbon, oxygen, water and other components are returned back into the soil and air. This process is carried out by the invertebrates including fungi, bacteria and some insects which are collectively called as the decomposers. The entire process requires oxygen and releases carbon dioxide.

Combustion: It is also one of the most important processes which occur when any of the organic materials including fossil fuels, plastics and wood, are burned in the presence of oxygen and releases carbon dioxide into the atmosphere.

Rusting: This process also requires oxygen. It is the formation of oxides which is also called oxidation. In this process, metals like iron or alloy rust when they are exposed to moisture and oxygen for an extended period of time and new compounds of oxides are formed by the combination of oxygen with the metal.

Production of Oxygen



Plants: The leading creators of oxygen are plants by the process of photosynthesis. Photosynthesis is a biological process by which all green plants synthesize their food in the presence of sunlight. During photosynthesis, plants use sunlight, water, carbon dioxide to create energy and oxygen gas is liberated as a by-product of this process.

Sunlight: Sunlight also produces oxygen. Some oxygen gas is produced when the sunlight reacts with water vapour in the atmosphere.

Some Interesting Facts about Oxygen

- Phytoplankton is one of the most significant producers of oxygen, followed by terrestrial plants and trees.
- Oxygen is also produced when the sunlight reacts with water vapour present in the atmosphere.
- A large amount of oxygen is stored in the earth's crust in the form of oxides, which cannot be used for respiration process as it is available in the combined state.

Importance of Oxygen Cycle

As we all know, Oxygen is one of the most essential components of the Earth's atmosphere. It is mainly required for:

- Breathing
- Combustion
- Supports aquatic life
- Decomposition of organic waste.

Oxygen is an important element required for life, however, it can be toxic to some anaerobic bacteria (especially obligate anaerobes).

The oxygen cycle is mainly involved in maintaining the level of oxygen in the atmosphere. The entire cycle can be summarized as, the oxygen cycle begins with the process of photosynthesis in the presence of sunlight, releases oxygen back into the atmosphere, which humans and animals breathe in oxygen and breathe out carbon dioxide, and again linking back to the plants. This also proves that both the oxygen and carbon cycle occur independently and are interconnected to each other.

Carbon Cycle Definition

Carbon cycle is the process where carbon compounds are interchanged among the biosphere, geosphere, pedosphere, hydrosphere, and atmosphere of the earth.

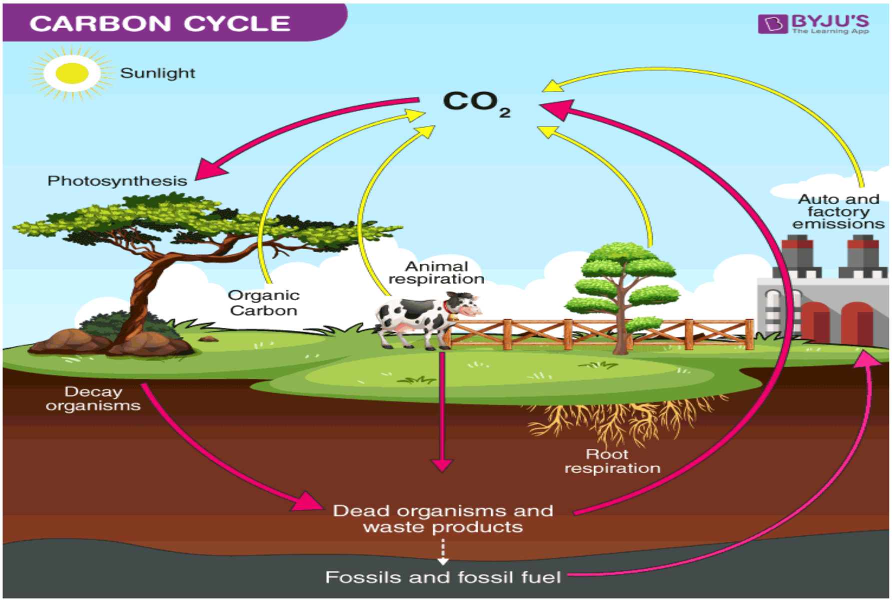
Carbon Cycle Steps

Following are the major steps involved in the process of the carbon cycle:

1. Carbon present in the atmosphere is absorbed by plants for photosynthesis.
2. These plants are then consumed by animals, and carbon gets bioaccumulated into their bodies.
3. These animals and plants eventually die, and upon decomposing, carbon is released back into the atmosphere.
4. Some of the carbon that is not released back into the atmosphere eventually become fossil fuels.
5. These fossil fuels are then used for man-made activities, which pumps more carbon back into the atmosphere.

Carbon Cycle Diagram

The carbon cycle diagram below elaborates the flow of carbon along different paths.



Carbon Cycle on Land

Carbon in the atmosphere is present in the form of carbon dioxide. Carbon enters the atmosphere through natural processes such as respiration and industrial applications such as burning fossil fuels. The process of photosynthesis involves the absorption of CO_2 by plants to produce carbohydrates. The equation is as follows:

$CO_2 + H_2O + \text{energy} \rightarrow CH_2O + O_2$

Carbon compounds are passed along the food chain from the producers to consumers. The majority of the carbon exists in the body in the form of carbon dioxide through respiration. The role of decomposers is to eat the dead organism and return the carbon from their body back into the atmosphere. The equation for this process is:

$CH_2O + O_2 \rightarrow CO_2 + H_2O$

Oceanic Carbon Cycle

This is essentially a carbon cycle but in the sea. Ecologically, oceans take in more carbon than it gives out. Hence, it is called a "carbon sink." Marine animals convert carbon to calcium carbonate and this forms the raw building materials require to create hard shells, similar to the ones found in clams and oysters.

When organisms with calcium carbonate shells die, their body decomposes, leaving behind their hard shells. These accumulate on the seafloor and are eventually broken down by the waves and compacted under enormous pressure, forming limestone.

When these limestone rocks are exposed to air, they get weathered and the carbon is released back into the atmosphere as carbon dioxide.

Importance of Carbon Cycle

Even though carbon dioxide is found in small traces in the atmosphere, it plays a vital role in balancing the energy and traps the long-wave radiations from the sun. Therefore, it acts like a blanket over the planet. If the carbon cycle is disturbed it will result in serious consequences such as climatic changes and global warming.

Carbon is an integral component of every life form on earth. From proteins and lipids to even our DNA. Furthermore, all known life on earth is based on carbon. Hence, the carbon cycle, along with the nitrogen cycle and oxygen cycle, plays a vital role in the existence of life on earth.

Water cycle

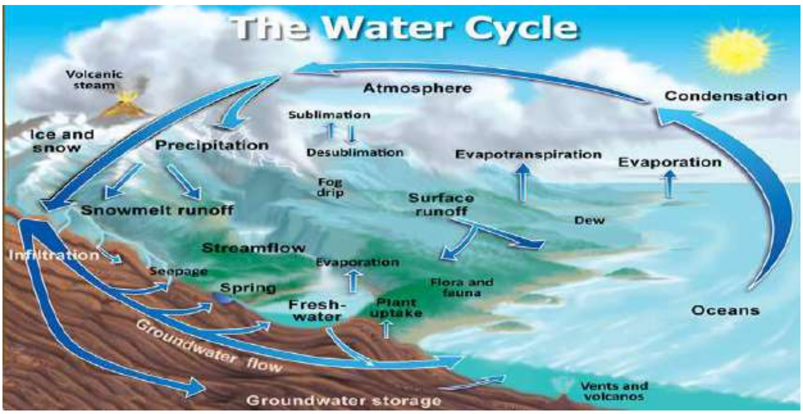
The **water cycle**, also known as the **hydrologic cycle** or the **hydrological cycle**, describes the continuous movement of water on, above and below the surface of the Earth. The mass of water on Earth remains fairly constant over time but the partitioning of the water into the major reservoirs of ice, fresh water, saline water and atmospheric water is variable depending on a wide range of climatic variables.

The water moves from one reservoir to another, such as from river to ocean, or from the ocean to the atmosphere, by the physical processes

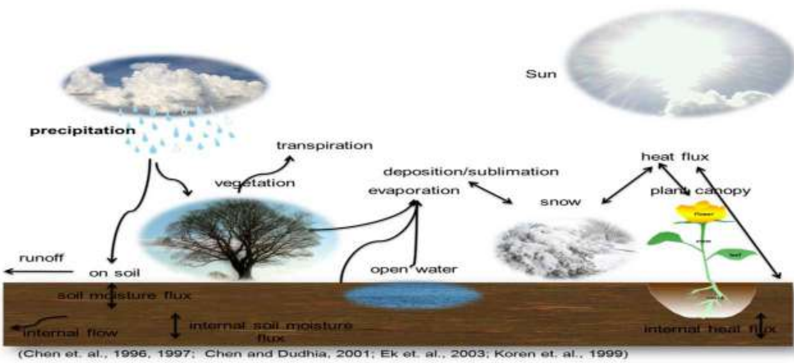
of evaporation, condensation, precipitation, infiltration, surface runoff, and subsurface flow. In doing so, the water goes through different forms: liquid, solid (ice) and vapor.

The water cycle involves the exchange of energy, which leads to temperature changes. When water evaporates, it takes up energy from its surroundings and cools the environment. When it condenses, it releases energy and warms the environment. These heat exchanges influence climate.

The evaporative phase of the cycle purifies water which then replenishes the land with freshwater. The flow of liquid water and ice transports minerals across the globe. It is also involved in reshaping the geological features of the Earth, through processes including erosion and sedimentation. The water cycle is also essential for the maintenance of most life and ecosystems on the planet.



Processes



Precipitation: Condensed water vapor that falls to the Earth's surface. Most precipitation occurs as rain, but also includes snow, hail, fog drip, graupel, and sleet. Approximately 505,000 km^3 (121,000 cu mi) of water falls as precipitation each year, 398,000 km^3 (95,000 cu mi) of it over the oceans.The rain on land contains 107,000 km^3 (26,000 cu mi) of water per year and a snowing only 1,000 km^3 (240 cu mi). 78% of global precipitation occurs over the ocean.

Canopy interception: The precipitation that is intercepted by plant foliage eventually evaporates back to the atmosphere rather than falling to the ground.

Snowmelt: The runoff produced by melting snow.

Runoff: The variety of ways by which water moves across the land. This includes both surface runoff and channel runoff. As it flows, the water may seep into the ground, evaporate into the air, become stored in lakes or reservoirs, or be extracted for agricultural or other human uses.

Infiltration

The flow of water from the ground surface into the ground. Once infiltrated, the water becomes soil moisture or groundwater. A recent global study using water stable isotopes, however, shows that not all soil moisture is equally available for groundwater recharge or for plant transpiration.

Subsurface flow

The flow of water underground, in the vadose zone and aquifers. Subsurface water may return to the surface (e.g. as a spring or by being pumped) or eventually seep into the oceans. Water returns to the land surface at lower elevation than where it infiltrated, under the force of gravity or gravity induced pressures. Groundwater tends to move slowly and is replenished slowly, so it can remain in aquifers for thousands of years.

Evaporation

The transformation of water from liquid to gas phases as it moves from the ground or bodies of water into the overlying atmosphere.

The source of energy for evaporation is primarily solar radiation. Evaporation often implicitly includes transpiration from plants, though together they are specifically referred to as evapotranspiration.

Total annual evapotranspiration amounts to approximately 505,000 km^3 (121,000 cu mi) of water, 434,000 km^3 (104,000 cu mi) of which evaporates from the oceans.[2] 86% of global evaporation occurs over the ocean.

Sublimation

The state change directly from solid water (snow or ice) to water vapor by passing the liquid state.

Deposition

This refers to changing of water vapor directly to ice.

Advection

The movement of water through the atmosphere. Without advection, water that evaporated over the oceans could not precipitate over land.

Condensation

The transformation of water vapor to liquid water droplets in the air, creating clouds and fog.

Transpiration

The release of water vapor from plants and soil into the air.

Percolation

Water flows vertically through the soil and rocks under the influence of gravity.

Plate tectonics

Water enters the mantle via subduction of oceanic crust. Water returns to the surface via volcanism.

The water cycle involves many of these processes.

Climate regulation

The water cycle is powered by solar energy. About 86 percent of global evaporation occurs from the oceans, reducing their temperature through the process of evaporation. Without the cooling effect of evaporation, the greenhouse effect would lead to a much higher surface temperature—an estimated 67° C—and a hotter planet.

Most of the solar energy warms tropical seas. After evaporating, water vapor rises into the atmosphere and is carried away by winds. Most of the water vapor condenses as rain in what is called the *inter-tropical convergence zone* (ITCZ), a low-pressure belt around the equator. This condensation releases latent heat that warms the air. This process, in turn, drives atmospheric circulation.

Changes in the water cycle

Over the past century, the water cycle has become more intense, as the rates of evaporation and precipitation have increased. It is thought that this is an outcome global warming, as higher temperatures increase the rate of evaporation.

Glacial retreat is also an example of a changing water cycle, where the supply of water to glaciers from precipitation cannot keep up with the loss of water from melting and sublimation. Glacial retreat since 1850 has been extensive.

Human activities that alter the water cycle include:

- Agriculture
- Alteration of the chemical composition of the atmosphere
- Construction of dams
- Deforestation and afforestation
- Removal of groundwater from wells
- Water abstraction from rivers
- Urbanization

CHAPTER III

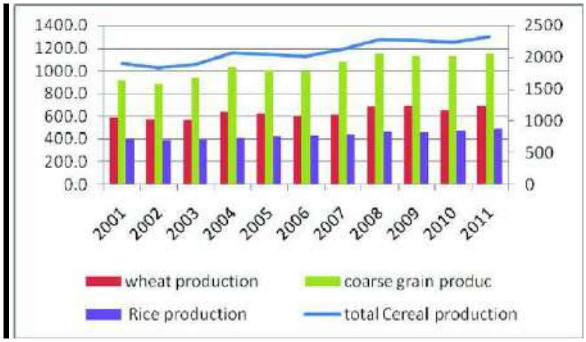
FARMING AND ANIMAL HUSBANDARY

Agriculture is the human enterprise by which natural ecosystems are transformed into ones devoted to the production of food, fiber, and, increasingly, fuel. Given the current size of the human population, agriculture is essential. Without the enhanced production of edible biomass that characterizes agricultural systems, there would simply not be enough to eat. The land, water, and energy resources required to support this level of food production, however, are vast. Thus agriculture represents a major way in which humans impact terrestrial ecosystems.

For centuries scholars have wrestled with the question of how many people Earth can feed. In 1798 English political economist Thomas Robert Malthus published what would become one of the most famous pamphlets in social science, *An Essay on the Principle of Population*. Malthus proposed that because population tended to increase at a geometric (exponential) rate, while food supplies could only grow at an arithmetic rate, all living creatures tended to increase beyond their available resources.

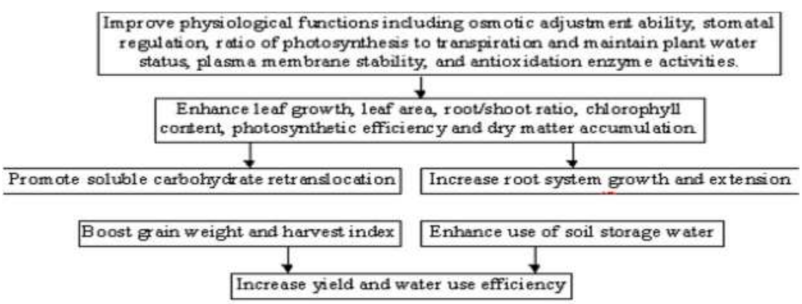
In terms of global food production a vast study on the ways in which agricultural productivity of cultivated lands is done and is measured in terms of harvested (typically edible) biomass. Agriculture involves the genetic modification of plant and animal species, as well as the manipulation of resource availability and species interactions.

Scientific and technological advances have made agriculture increasingly productive by augmenting the resources needed to support photosynthesis and by developing plants and animals with enhanced capacity to convert such resources into a harvestable form. The outcome is that world food production has in fact kept up with rapid population growth. Gains have been especially dramatic in the past 50 years.



But these gains carry with them serious environmental costs. Large-scale agriculture has reduced biodiversity, fragmented natural ecosystems, diverted or polluted fresh water resources, and altered the nutrient balance of adjacent and downstream ecosystems. Agriculture also consumes major amounts of energy and generates greenhouse gas emissions that contribute to global climate change. However, these negative impacts must be weighed against human demand for food, as well as the fact that agriculture is the primary livelihood for 40 percent of the human population. In some countries, more than 80 percent of the population makes a livelihood from farming, so increasing agricultural productivity not only makes more food available but also increases incomes and living standards.

Improvement in crop production



The future impacts of agriculture will depend on many factors, including world demand for food, the availability and cost of resources needed to support high levels of productivity, and technological advances to make agriculture more efficient. Global climate change is expected to alter temperature, precipitation, and weather patterns worldwide, thus changing many fundamental conditions that guide current agricultural practice.

How much of Earth's surface can be used for agriculture? The basic limits are temperature, topography, climate, soil quality, and available technologies, including scientific understanding of issues like plant and animal genetics. As technology improves over time, the zone where agriculture can be practiced successfully expands. Many social, political, and economic factors also shape agricultural land use, including land tenure patterns, population density, and environmental regulations.

As of the year 2000, about 37 percent of Earth's land area was agricultural land. About one-third of this area, or 11 percent of Earth's total land, is used for crops. The balance, roughly one-fourth of Earth's land area, is pastureland, which includes cultivated or wild forage crops for animals and open land used for grazing.

The physical constraints mean that not all farmland is equally productive, even with modern techniques and inputs. In areas where land is less productive, agriculture requires more techniques and inputs to address limitations such as poor soil quality. Less productive agricultural land generally has low market value, so in many countries farming must compete with other uses such as residential or commercial development or recreation. However, in areas that have received few modern inputs, such as many parts of Africa, fertilizer and other technologies can greatly increase productivity and raise the value of agricultural land.

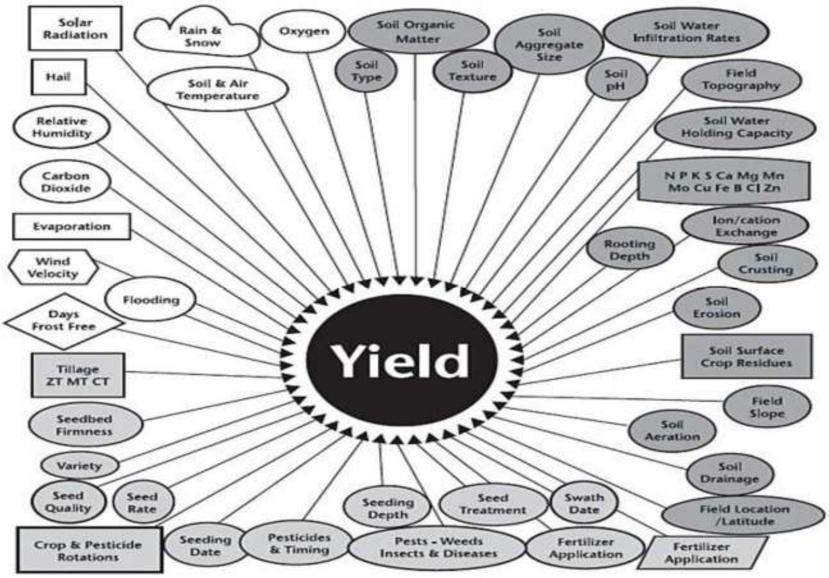
Agriculture is fundamentally different from undisturbed ecosystems because harvesting crops removes material from the system. The product that can be harvested from an agricultural system, which is called its yield, represents a loss of materials such as water and nutrients from the system. Farmers can increase yields by adding energy and materials, by increasing the efficiency of energy conversion and allocation to the harvested product, or by reducing losses that occur during the growing process.

Agricultural yields have risen steadily throughout the history of human cultivation, with particularly steep increases throughout the 20th century. From 1961 through 1999, the FAO's aggregate crop production index increased at an average rate of 2.3 percent per year and world crop production per capita rose at an average annual rate of 0.6 percent. Global production of major cereal crops more than doubled during this period.

Radical changes in agricultural inputs over the past century made this increase possible. Land and labor inputs have fallen drastically in industrialized countries, but technological advances such as large-scale irrigation, synthetic fertilizers, pesticides and herbicides, and capital investment (in the form of mechanization) have increased sharply. Scientific advances such as development of higher-yielding crop varieties have also contributed to increased productivity.

The new approach that played a major role in agriculture is "Green Revolution"—a 30-year transformation of agriculture in developing regions that started in the 1940s, when private foundations and national governments joined forces to distribute high-yielding crop varieties, synthetic fertilizer, irrigation, and pesticides to subsistence farmers

The Green Revolution helped world food production to increase at a rate faster than population growth from 1950 onward. However, these increases relied on synthetic fertilizer and irrigation because green revolution plant varieties were designed to produce high yields when supplied with high inputs of nitrogen and water. In other words, they were not inherently high-yielding plants (i.e., they were not able to use resources more efficiently than traditional varieties) and likely would have done worse under "natural" conditions. Many varieties were highly susceptible to pests and diseases, so they also required heavy use of pesticides to thrive. Because the new plants were short, they were more susceptible to competition from weeds, so farmers also had to use herbicides to raise them.



As agriculture became increasingly dependent on technological inputs throughout the 20th century, it also underwent a structural shift, particularly in developed countries. Instead of raising a diverse mix of crops, farmers increasingly planted large holdings of one or a few crop varieties that had been developed for high yields.

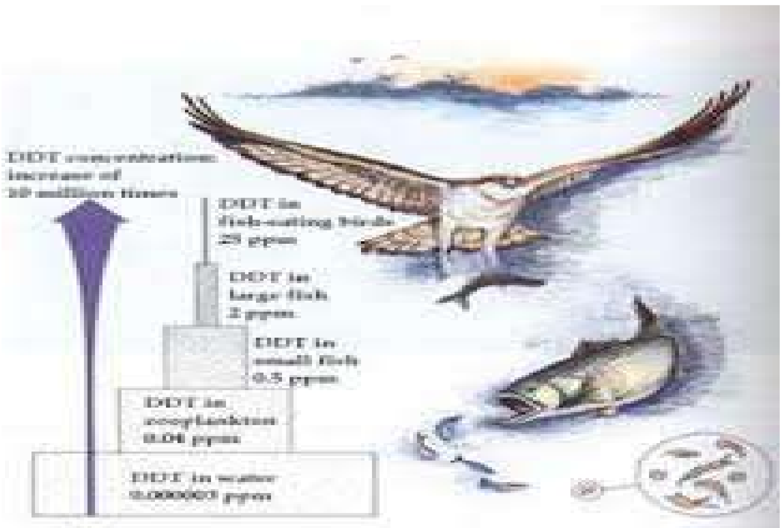
Monoculture makes it easier to cultivate large acreages more efficiently, especially using mechanized equipment and chemical inputs. However, these artificial ecosystems are vulnerable to outbreaks of pests and pathogens because they do not have natural protection from genetic diversity and they are typically nutrient-rich, thanks to abundant fertilizer use.

Moreover, many pest species have adapted to spread rapidly in ecosystems where recent disturbances, such as plowing, have eliminated natural predators

Agricultural pests include insects, mammals such as mice and rats, unwanted plants (weeds), fungi, and microorganisms such as bacteria and viruses. Humans have controlled pests with naturally-occurring substances such as salt, sulfur, and arsenic for centuries, but synthetic pesticides, first developed during World War II, are generally more effective.

Many of the first pesticides that were widely used for agriculture were organochlorines such as DDT (dichloro diphenyl trichloroethane), aldrin, dieldrin, and heptachlor. These substances are effective against a range of insects and household pests, but in the 1950s and 1960s they were shown to cause human health effects including dizziness, seizures, respiratory illness, and immune system dysfunction. Most organochlorines have been banned in the United States and other developed countries but remain in use in developing countries.

Bioaccumulation of DDT and other organochlorines drastically reduced populations of bald eagles and other large predatory birds that fed at the top of the food chain. The pesticides disrupted birds' reproductive systems and caused them to lay eggs with very thin shells that broke before young birds hatched.



Organochlorines were replaced in the 1970s with other pesticides that were less toxic and more narrowly targeted to specific pests. However, many of these newer options still killed off pests' natural enemies, and when the insecticides were used repeatedly over time, pests became resistant to them through natural selection (many types of insects can develop through entire generations in days or weeks). Today hundreds of species of insects and weeds are resistant to major pesticides and herbicides The magnitude of future agricultural effects on the environment will be influenced by many factors, including:

- **Actual demand for food.** Food demand will increase with population growth and rising income, which increases consumers' preference for animal protein.
- **Expansion of agricultural lands.** Agriculture will move into increasingly marginal areas because Earth's most fertile zones are already under cultivation, and will compete with other land uses such as urbanization.
- **Opportunities for increased yields.** Likely technological innovations include systems that increase availability of water and fertilizer; improved pesticides and biocontrols such as IPM; better soil conservation and management of microbial communities; and new crops that deliver increased yields under wider ranges of conditions and need fewer inputs than current strains.
- **Availability of water and chemical fertilizers.** The prices of these inputs are strongly affected by energy costs and competition for fresh water with other human activities.
- **Global climate change.** Variable weather is a major challenge for farmers because optimizing for high yields becomes more difficult as the range of potential weather conditions that might occur in any season increases. In the coming decades, global climate change is predicted to alter temperature and precipitation patterns in ways that could modify major elements of Earth's climate system

The introduction of new cultivated species and improved varieties of crop is a technology aimed at enhancing plant productivity, quality, health and nutritional value and/or building crop resilience to diseases, pest organisms and environmental stresses. Crop diversification refers to the addition of new crops or cropping systems to agricultural production on a particular farm taking into account the different returns from value-added crops with complementary marketing opportunities. Major driving forces for crop diversification include:

- Increasing income on small farm holdings
- Withstanding price fluctuation
- Mitigating effects of increasing climate variability
- Balancing food demand
- Improving fodder for livestock animals
- Conservation of natural resources
- Minimising environmental pollution
- Reducing dependence on off-farm inputs
- Depending on crop rotation, decreasing insect pests, diseases and weed problems
- Increasing community food security

Description:

New and improved crop species can be introduced though two different processes:

1. Farmer experimentation with new varieties. Farmers have introduced new and improved species over centuries, mainly in regions that constitute world centres of cultivated crop diversification, such as Meso-America, the Andes, Africa and parts of Asia, in response to environmental stress conditions. There are many thousands of existing varieties of all of the important crops, with wide variation in their abilities to adapt to climatic conditions. Agricultural researchers and extension agents can help farmers identify new varieties that may be better adapted to changing climatic conditions, and facilitate farmers to compare these new varieties with those they already produce. In some cases farmers may participate in crossing select seeds from plant varieties that demonstrate the qualities they seek to propagate to develop new varieties with the characteristics they desire.

2. The introduction of new crop species to diversify the crop production systems needs to take into account the following inter-related categories:

    - Availability and quality of resources including irrigation, rainfall and soil fertility.
    - Access to technologies such as seed, fertiliser, water, marketing, storage and processing.

- Household related factors covering food and fodder self-sufficiency requirement as well as investment capacity.
- Price and market related factors including output and input prices as well as trade policies and other economic policies that affect these prices either directly or indirectly.
- Institutional and infrastructure related factors covering farm size and tenancy arrangements, research, extension and marketing systems and government regulatory policies.

Breeding new and improved crop varieties enhances the resistance of plants to a variety of stresses that could result from climate change. These potential stresses include water and heat stress, water salinity, water stress and the emergence of new pests. Varieties that are developed to resist these conditions will help to ensure that agricultural production can continue and even improve despite uncertainties about future impacts of climate change. Varieties with improved nutritional content can provide benefits for animals and humans alike, reducing vulnerability to illness and improving overall health.

Crop Diversification - A strategy to Improve Agricultural Production

Introduction:

Farming continues to be the major source of food, nutrition, income and employment for the most of the rural population in India. The country's farming is characterized by presence of a large number of small and marginal scale farmers with small farm holdings. However the country is blessed with diverse agro-climatic conditions which enable the farmers to produce a large number of agricultural commodities.

The challenge of producing enough food for the growing population with the reducing holdings is a herculean task. With the development of commercial agriculture techniques during the post independent period the agriculture sector has been able to cater to the domestic and international markets. In the light of the focus on commercial farming the rich tradition of crop diversity of Indian farming lasts its glory.

Few crops are occupying major production area and are grown repeatedly year after year. This has resulted in emergence of several field levels biotic and abiotic constraints and overall reduction in the benefits realized from farming.

Crop diversification provides the farmers with a wider choice in the production of a variety of crops in a given area so as to expand production related activities on various crops and also to bring down the possible risk. Crop diversification in India is generally viewed as a shift from traditionally grown less remunerative crops to more remunerative crops.

The crop diversification is also taking place due to governmental policies, thrust on some crops, market reforms, infrastructure development, government subsidies, certain other price related support mechanisms, higher profitability and stability in production also induces crop diversification. Crop diversification and growing of large number of crops are practiced in dry-land areas to reduce the risk factor of crop failures due to recurring droughts. Crop substitution and crop shift are also taking place in the areas suffering with some specific soil related problems.

The country has made considerable progress in the farm sector during the last 50 years. From 'hand to mouth' conditions in the early sixties, the country has not only become self reliant in food grains but have acquired sufficient resilience to tide over the adverse conditions. The achievements in food production is the outcome of a policy framework of improving rural infrastructure including irrigation, research, extension, provision of agricultural inputs at reasonable prices, mechanization in farming, marketing support through minimum price mechanism, promotion of FPOs etc. Though an impressive achievement has been made in Indian agricultural sector farming continues to face poor infrastructure conditions and vagaries of climate change.

Only around 40 percent of the cultivated land is under irrigation system and farmers on the on the remaining 60 per cent of the land are completely dependent on rainfall, which is also greatly characterized by large variations in terms of precipitation both spatially and temporally. This has been further complicated by the vagaries of climate change.

For a large majority of farmers in different parts of the country gains from application of science tools and technologies in agriculture have yet to be realized. As a result, the productivity levels of many major crops in India do not compare very favourably with the yields obtained in agriculturally advanced countries. Due to limited capacities of the farmers to take advantage of the opportunities presented by liberalization is further limited. Efficient and effective management of agriculture is a crucial aspect in the years to come for acquiring enduring self-reliance and ensuring sustainable growth.

Factors responsible for crop diversification:

With the introduction of scientific and modern agricultural technologies there is a continuous surge for diversified agriculture. The changes in crop pattern, however, are the outcome of the interactive effect of many factors such as (a) Resource related factors mainly irrigation, rainfall and soil health (b) Technology related factors mainly seed, fertilizer, water use, marketing, storage and post harvest processing (c)Household related factors mainly food and fodder self-sufficiency requirement as well as investment capacity of the farmers (d) Price related factors covering output and input prices, trade and other economic policies that affect these prices (e) Institutional and infrastructure related factors covering farm size and tenancy issues, research, extension and regulatory policies of the government. These factors are highly inter-related.

The economic liberalization policies as well as the globalization process are also exerting strong pressures on the area allocation decision of farmers, essentially through their impact on the relative prices of inputs and outputs. While factors such as food and fodder self-sufficiency, farm size, and investment constraints are important in influencing the area allocation pattern among smaller farms, larger farmers with an ability to circumvent resources constraints usually go more by economic considerations based on relative crop prices than by other non-economic considerations.

Similarly, economic factors play a relatively stronger role in influencing the crop pattern in areas with a better irrigation and infrastructure potential. In such areas, commercialization and market networks co-evolve to make the farmers more dynamic and highly responsive to economic impulses.

What is most notable is the change in the relative importance of these factors over time. From a much generalized perspective, Indian agriculture is influenced more by economic factors. This need not be surprising because irrigation expansion, infrastructure development, penetration of rural markets, development and spread of short duration and drought resistant crop technologies have all contributed to minimizing the role of non-economic factors in crop choice of even small farmers.

What is more, the reform initiatives undertaken in the context of the ongoing agricultural liberalization and globalization policies are also going to further strengthen the role of price related economic incentives in determining crop composition both at the micro and macro levels. Obviously, such a changing economic environment will also ensure that government price and trade policies will become still more powerful instruments for directing area allocation decisions of farmers, aligning thereby the crop pattern changes in line with the changing demand-supply conditions.

Emergence of Farm Producers Organizations in some of the states has resulted in the coverage of vast area of cultivated land under one crop to ensure desired volume of the produce has brought significant changes to cropping pattern and has added a different dimension to farming by small farmers.

Consequences of changes in cropping pattern:

Various initiatives that have led to the changes in cropping pattern as discussed above have also brought in several socio-economic and environmental consequences. Introduction of high yielding verities, hybrids and intensive crop production technologies have fomented, among other things, an increasing tendency towards crop specialization and commercialization of agriculture.

While these developments have positive effects on land/labour productivity and net farm income, they have also endangered a number of undesirable side effects like reduced farm employment and crop imbalances and loss of crop diversity at the farm level.

Although the expansion of commercialized agriculture has fomented new sets of rural non-farm activities and strengthened the rural-urban growth linkages, it has also weakened the traditional inter-sectoral linkages between the crop and livestock sectors. Besides, crop pattern changes also lead to serious environmental consequences that take such forms as groundwater depletion, soil fertility loss and water logging and salinity - all of which can reduce the productive capacity and growth potential of agriculture over the long-term.

Crop diversification as a strategy for food and nutritional security and poverty alleviation

Crop diversification can be used as a strategy for addressing food and nutritional security. The diversification of horticultural crops especially fruits and vegetables have been very important in ensuring nutrition security. This also has played a pivotal role in poverty reduction. It is not only in the increase of food grain production but also the production of commercial crops like cotton, oilseeds, sugar cane, fruits and vegetables as well as livestock production including fisheries have contributed significantly to poverty reduction.

Crop diversification can help the farmers in addressing the important determinants of poverty such as (i) lack of income and purchasing power (ii) lack of productive employment (iii) the continuous increase in price of food (VI) inadequacy of social infrastructure, affecting the quality of life of the people and their employability. The governments at the centre and the state are focussing on doubling food production with a focus on food grains such as rice, wheat, coarse cereals, pulses; oilseeds; sugar cane; fruits and vegetables; meat; milk and fish. The Action Plan envisages a detailed strategy and specific problems of productivity to substantially increase the supply of various food items in such a way that the demand for such items for the entire population is comfortably met and some exportable surplus also becomes available.

Crop diversification as strategy for issues of natural resource management:

Subdivision and fragmentation o land holdings in the country apart from diversion of cultivable land for various other purposes provides very little scope for further expansion of the net sown area (142 m/ha) and that land scarcity will become an acute feature of the rural economy. Water is another important natural resource which is facing several challenges and there are several concerns regarding water resources in the country and the states. Therefore, a judicious use of land and water resources will have to be the central theme for sustainability of agricultural growth. There has been a growing concern in recent years about the deteriorating conditions of soil health and water resources due to unscientific management. The deterioration in land and water resources has been in the form of land degradation, water logging and decline in water table. There is a greater need to have an integrated approach in the management of plant nutrients, chemicals and taking effective measures to deal with the overall pollution problems.

There are several possible technologies and alternatives to reduce the use of chemicals in agriculture. These alternatives are not perfect substitutes to chemicals but adoption of these can substantially reduce the adverse impact on environment. Proper land and water management policies would reduce environmental degradation. Community and village level farmers institutions have to be encouraged to participate in protecting natural resources from degradation. Programmes for regeneration of land and water resources need to be strengthened. Scientific crop diversification options are to be planned suiting the land capabilities.

Constraints in crop diversification:

The concept of crop diversification in the country is taking the form of increased areas under commercial crops including vegetables and fruits since independence. However, this has gained momentum in the last decade favouring increased area under vegetables and fruits and also to some extent on commercial crops like sugar cane, cotton and oilseeds crops specially soybean.

The major problems and constraints in crop diversification are primarily due to the following reasons with varied degrees of influence:

(a) More than 60 per cent of the cropped area in the country is rain fed and is dependent on rainfall

(b)Sub-optimal and over-use of resources like land and water resources, causing a negative impact on the environment and sustainability of agriculture

(c)Inadequate supply of improved and quality seeds and planting material of improved cultivars

(d)Fragmentation of land holdings and lack of mechanization of agriculture due investment constraints and land holding sizes

(e)Poor basic infrastructure like rural roads, power, transport, communications etc

(f)Inadequate post-harvest technologies and inadequate infrastructure for post-harvest handling of perishable horticultural produce

(g)Very weak agro-based industry

(h)Inadequate research - extension - farmer linkages

(i)Inadequately trained human resources and large scale illiteracy amongst farmers

(j)Emerging species of diseases and pests affecting most crop plants

(k)Poor database for horticultural crops and insufficient investments in the agricultural sector.

Opportunities in crop diversification due to globalization:

With the advent of WTO and India being a member and signatory to GATT, the scenario of the agricultural sector cannot be the same as that of past. With the liberalization of trade and providing the market access of agricultural produce between the different countries, the country will be required to promote much more diversified agriculture. For crops on which we have substantial area and production, especially foodgrains, the import market has to be insulated through increased productivity which gives us a kind of comparative advantage and also a level playing field so that large scale importation is contained and farmers' interests are protected.

The crops which are traditionally exported like basmati rice and spices and condiments also need to be supported in terms of area expansion and quality improvement to look towards much more opportunity for export. Crop diversification in the areas of certain tropical fruits and also a few vegetables also need support for both production and post-harvest handling in terms of their export opportunity.

Accelerated growth in fruits and vegetables production is also required for improved nutrition of the country's population. In future, with improved living standards along with increased purchasing power, more and more people will look for nutritional and quality foods which will also call for greater crop diversification.

There are some production areas such as food crops, plantation crops, poultry, dairy, sugar, cotton and oilseeds in which India has made its mark. There are some in which its emerging strength is already evident - sericulture, marine and inland fisheries for example.

There are also others which now attract less attention, but in which the competitive advantages that India possesses can put it on the top of the world. No country grows such a wide range of fruits, vegetables, and flowers and in such abundance as India and yet it has no record worth mentioning in horticultural exports.

The rich variety when processed and marketed can help India take care of the health needs of its population besides being major export commodities.

Opportunities due to emerging technologies:

It is being increasingly realized that agriculture is no longer a subsistence activity carried out by peasant cultivators, but rather an enterprise and manufacturer of biomass using land, water, genetic material and the latest in technology. The agriculture of the twenty first century will increasingly be farmers' entrepreneurship harnessing technologies to optimize returns from his land and investments he makes on it.

Biotechnology and genetic engineering in crops with focus on primary productivity and also on many quality traits will go a long way to improving the yield and quality of many important crop plants. With the advent of such emerging technologies and consequent scope for increased economic returns, the diversification in favour of such crops will be the future focus. Many other related technologies and their adoption will also inject an added dimension in crop diversification.

Decision support systems, governmental policies, geographic information system, application of information technology leading to market information etc., will also lead to crop diversification primarily on economic considerations.

Research and developmental support for crop diversification

In order to support the crop diversification sound research and development initiatives are essential. The future agriculture is much more science knowledge and skill based rather than the traditional subsistence agriculture. In the wake of globalization and opening up of several opportunities in the global market, there will be much more opportunity for entrepreneurship development in agriculture.

This also calls for paradigm shifts in research and technology development and also the transfer of technology for successful crop diversification. The research system not only needs to address the issues connected with continuance and indulgence and knowledge in the areas of emerging technologies but also create a cadre of scientists through the continuous upgrade of skills and human resource development.

The researchers also need to popularize the technologies, impart knowledge and skills to the extension functionaries for the transfer of technologies to the farmers.

This knowledge-based farming will call for much more interaction between the researchers, extension workers and farmers. The fruits of the innovative technologies should reach the farmers at the earliest and also spread in the quickest possible time. The use of ICT in agriculture can be one solution for transfer of technologies. The revolution brought about by the mobile telecommunication can be used to the advantage of transfer of technologies to the farmers.

Institutional and infrastructure developments in support of crop diversification

To sustain and operationalize crop diversification, institutional support is required. Crop diversification in terms of reducing the risk of rainfed farmers is vital for Africa.

However, crop diversification in well endowed area is more of an economic consideration. The National Agricultural Research System with its Crop and Commodity based Institutions, Natural Research Management Based Institutions and State Agricultural Universities are jointly addressing the issues connected with the crop diversification. The government of India has also developed a counter support mechanism through the establishments of Crop Directorates for each of the major crops and groups of crops for development and technology transfer focus on each of these crops and commodities. These Directorates act as coordinating agencies between the research and development activities on the one hand and between the central and state governments for technology transfer and other promotional activities.

Policies and strategies for crop diversification:

Realizing the importance of crop diversification, the central and state governments have taken several initiatives. Horticulture sector has been given highest importance considering its importance in nutrition security. Some of the important programs of the government include

(a)launching of National Horticulture Mission

(b)Launching of Technology Mission for the Integrated Development of Horticulture in the North-Eastern Region

(c)Implementing National Agriculture Insurance Scheme

(d) Operationalizing Technology Mission on Cotton

(e) Provision of Capital Subsidy for construction/modernization/expansion of cold storages and storages for horticultural produce

(f)Creation of Watershed Development Fund at the National level for the development of rain-fed areas (g)Infrastructure Support for Horticultural Development

(h)Strengthening Agricultural Marketing

(i)Seed Bank Scheme

(k) Cooperative Sector Reforms etc are some examples. Similarly state of Karnataka has also initiated several programs that directly and indirectly support crop diversification in the state. Some of them include: (i) Launching of a program for promoting Farm Producers Organizations in horticulture sector (ii) Weather-based crop insurance for horticulture crops (iii) Promotion of protected cultivation of high value vegetables (iv) Establishment of IFAB (International Flower Auction Bangalore) for promotion of production of flower crops (v) Promotion of green house cultivation of vegetables etc have lead to diversification of farming. More such programs are required to further diversify the farming in the state and the country for the benefit of farmers.

MAJOR PESTS AND DISEASES

Many insect and mites attack trees in World. Although some affect production in nearly all locations, many others are of only local significance. Relatively few species cause significant crop loss in their own right, and are only a problem when the population exceeds damaging thresholds. The less important species may at times require special attention, especially if their natural enemies have been disrupted by chemical sprays.

There are a few diseases affecting leaves, flowers and fruit, and some others causing tree deaths or decline. However, no major disease currently limits production in the Region. Brown blight (Peronophythora litchii) infects leaves, panicles and fruit in China and Thailand, but can be controlled with metalaxyl. Anthracnose (Colletotrichum gloeosporoides) and similar diseases also attack fruit in China, India and Australia. Parasitic algae and nematodes affect some orchards, but can be readily controlled with available chemicals. Various organisms have been associated with tree deaths or decline in Asia and Australia, although their pathogenicity is yet to be proven.

Major pests

Regardless of where lychee is grown, several insect groups attack the flowers, fruit, leaves and branches. Lepidopterous fruit borers are generally the most important pests affecting production. Other important species include various leaf- and flower-eating caterpillars and beetles, bark borers, scales, leaf mites, fruit-sucking bugs, fruit-piercing moths and fruit flies.

Fruit borers

Conopomorpha sinensis Bradley, known as the lychee stem-end borer in China and the lychee fruit borer in Thailand, is the major pest in most seasons. This pest was previously recorded as *Acrocercops cramerella* (now *Conopomorpha cramerella* Snellen). *C. sinensis* and the related *C. litchiella* Bradley both attack lychee, the latter preferring leaves and shoots, while *C. cramerella* is restricted to rambutan and cocoa (Bradley, 1986).

C. sinensis lays yellow, scale-like eggs 0.4 x 0.2 mm long on the fruit any time after flowering, as well as on new leaves and shoots. Both lychee and longan are affected. The eggs hatch in three to five days, with the larva immediately penetrating the fruit, leaf or shoot. They tunnel through the flesh of the fruit that often fall from the tree.

In Thailand, fruit are inspected weekly from fruit set to detect eggs of *C. sinensis*, which are very small and almost invisible to the naked eye. Infested fruit should be picked and destroyed, at infestation levels of 1 to 2 percent. When the pest becomes more active, permethrin is applied weekly, up to two weeks before harvest. In Taiwan Province of China, cypermethrin, deltamethrin, carbofuran or fenthion during early fruit set is recommended to prevent damage later in the season. Moths can be excluded by enclosing the fruit panicles in nylon mesh bags, but is uneconomic in areas with high labour costs. If the parasitoids *Phanerotoma* sp. and *Apanteles* sp. are not active, fallen fruit should be removed to reduce the build-up of moths.

All stages of the leaf-miner, *Conopomorpha litchiella* Bradley, are similar to those of the fruit borer. The female lays its eggs on new shoots and the small, light-yellow eggs hatch three to five days later. The newly hatched larva is creamy white, and bores into shoots and leaf blades, usually into the mid-rib and veins. The moths are attracted to leaf flushes that emerge during the rainy season from June to October in Thailand. Affected shoots often wilt.

Bearing trees should be inspected during early flush development and sprayed if necessary. The leaf flush before flower initiation is very important as it supplies the carbohydrates needed for fruit development. If 30 to 40 percent of the larvae are parasitised, spraying is not recommended. Young, non-bearing trees do not need to be sprayed either. This also allows the parasitoids to build up in the orchard.

The insect originally referred to as *Argyroploce illepida* Butler (= *Cryptophlebia carpophaga* Walsingham) in India (Butani, 1977), is actually *Cryptophlebia ombrodelta* Lower (Bradley, 1953). It also occurs in Thailand, China, Japan, Taiwan Province of China and Australia, but only in the latter area is it regarded as a significant pest. The creamy white eggs of these species are oval and flat with a reticulate surface, and are about 1.0 x 0.8 mm. They are laid singly or in groups of up to 15 on the fruit surface. The newly hatched larva feeds on the fruit skin and then tunnels towards the seed. In immature fruit, the young larva bores directly into the seed, which is completely eaten. A single larva may damage two or three fruit, if the fruit are small. However, they prefer mature colouring fruit with larger seeds.

In South Africa, the insect growth regulator, triflumuron as a single, full cover spray 40 days before harvest, or two sprays of teflubenzuron a fortnight apart commencing when the fruit are 10 mm in diameter, are recommended. Alternatively, the panicles can be covered with paper bags. The bags also improve fruit colour and overall quality. In Queensland, carbaryl and azinphos-methyl have been used with varying success. Several sprays commencing at fruit colouring are applied on a calendar basis, with monitoring for the presence of eggs less common. Newer insecticides including the insect growth regulator, tebufenozide, provide better control, with less disruption to natural enemies.

The various species of *Cryptophlebia* are attacked by their own complex of egg, larval and pupal parasitoids; however, these do not always keep borers below economic thresholds. Egg parasitoids such as *Trichogrammatoidea fulva* Nagaraja from India and *T. cryptophlebiae* from South Africa and Australia, offer the best prospects for biological control.

Fruit-piercing moths

Fruit-piercing moths such as *Eudocima (Othreis) fullonia* (Clerck), *Eudocima salaminia* (Cramer) and *Eudocima jordani* (Holland) are important throughout Asia, Australia and the South Pacific. The larvae of these moths develop on a variety of host plants such as the coral tree, *Erythrina*, and vines of the Menispermaceae (*Legnephora*, *Stephania*, *Fawcettia*, *Tinospora*, *Carronia*, *Sarcopetalum*, *Pleogyne* and *Hypserpa*).

The moths have a proboscis that drills a neat hole in the skin of the fruit allowing them to suck the juice from the flesh. Contamination of the wound with yeasts and bacteria carried on the proboscis destroys the fruit. *Drosophila* spp. attracted to the fermenting juice hastens deterioration. Within a few days, a frothy exudate seeps from the fruit and stains undamaged fruit close by. In Australia and Thailand, farmers go to their orchards at night with spotlights and attempt to catch the moths. However, this is futile.

Australian farmers also make traps by draping shade cloth loosely over a frame of wire and baiting it with fermenting citrus and bananas. The moths feed on the fruit and become entangled in the folds of the shade cloth when they attempt to fly off. Several traps are required to protect an orchard and even then, substantial damage is sustained. In Thailand, ripe bananas and pineapples are dipped in insecticide and hung in the trees to poison the feeding moths. In some countries, panicles are covered with paper bags. In recent times, parrots and fruit bats have become a severe problem for growers in Australia. Fine nets erected over the orchard control fruit-piercing moths as well as the vertebrate pests.

Leaf-feeding caterpillars

Oxyodes scrobiculata F. and *Oxyodes tricolor* Guen. occupy similar niches in Thailand and Australia. In Australia, *O. tricolor* attacks trees in southern Queensland, but is not a pest in the north. The castor oil looper, *Achaea janata* (L.), is a voracious feeder in Australia and often infests trees in large numbers at the same time as *O. tricolor*. The caterpillars can cause severe defoliation.

In Thailand it is recommended that carbaryl be applied when there are two to three young larvae per leaflet. Shaking the tree to dislodge larvae onto the ground improves the effectiveness of the sprays. If 40 percent or more of larvae are parasitised, sprays should not be necessary. In Australia, *Bacillus thuringiensis* Berliner (Bt), endosulfan or methomyl may be used when damaging populations of *O. tricolor* appear.

Leafrollers

Olethreutes perdulata Meyr. is an occasional pest in Queensland. *Platypeplus aprobola* (Meyrick) has also been recorded in Australia, China and India. *Adoxophyes cyrtosema* Meyr. and *Homona coffearia* Nietner attack trees in Guangzhou and Fujian. The latter species along with *Homona difficilis* is recorded in lychee, longan and rambutan in Thailand. The orange fruit borer, *Isotenes miserana* (Walker), is another leafroller that also attacks flowers and fruit in Queensland.

P. aprobola is a minor pest in China and India where it attacks leaves and flowers. However in Australia, it is part of a complex of species contributing to a significant loss of flowers. In China, *A. cyrtosema* and *H. coffearia* also feed on leaves, flowers and fruit.

In Australia, the damage caused by leafrollers is tolerated so long as it is restricted to the foliage and unlikely to affect flower initiation. If necessary, methomyl or carbaryl can be applied when 20 percent of leaf flushes are infested, to minimize damage to young trees or at critical periods of leaf growth in older trees. In India, rolled leaves that contain larvae are removed manually during light infestations, but phosphamidon, fenitrothion or endosulfan are applied for heavy infestations.

Beetle borers

The longicorn beetle, *Aristobia testudo* (Voet), is a serious pest of lychee and longan in Guangdong. The beetle has one generation per year, with adults emerging from June to August. The females girdle branches by chewing off 10 mm strips of bark, with the eggs laid on the wound and covered with exudate. The larvae hatch from late August and live under the bark until January when they bore into the xylem and create tunnels up 60 cm long. In Taiwan Province of China, the white-spotted longicorn beetle, *Anoplophora maculata* (Thomson), has a one-year life cycle. Adults emerge in spring and females insert about twenty eggs individually into T-shaped incisions in the bark, 0.5 m above the soil surface. The larval period lasts about ten months. In Australia, the longicorn beetle, *Uracanthus cryptophagus*, causes similar damage (Plate 7).

Tunnelling by the larvae may kill branches, but rarely whole trees. Ring-barking of twigs by ovipositing adults causes the shoot tips to die and snap off. In China, regular inspections of trees during adult activity enable orchard workers to remove the beetles. Eggs and young larvae can also be removed at the same time. Established larvae can be located from the appearance of their frass, which is packed into the ends of tunnels. They can then be 'fished out' with wire hooks and knives. Alternatively, dichlorvos is injected and the tunnels sealed with clay.

Scarab beetles

The elephant beetle, *Xylotrupes gideon* (Linnaeus), is important in all areas of Australia. The larvae develop in the soil or mulch where they feed on plant roots and humus. The large, heavily-sclerotised and sexually-dimorphic adults emerge in spring. Later, they are attracted to the fruit as they ripen, especially those that have split or been damaged by parrots and fruit bats. They then start attacking sound fruit and can cause significant economic losses in the week or so leading up to harvest. Chemical control is unsatisfactory. Manual removal is effective in small trees, but difficult in large trees. Labour is relatively expensive in Australia, so this operation adds significantly to growing costs.

Soft scales

Pulvinaria (*Chlorpulvinaria*) *psidii* (Maskell), the green shield scale, infests trees in China, Taiwan Province of China, Australia and India. In Queensland, crawlers are produced in spring by adult scales that infest the leaves and twigs. Some of these crawlers move onto the flowers and young fruit. The female scales are sometimes mistaken for mealybugs because the egg masses that are covered in waxy filaments cover the ends of the scale.

Soft brown scale, *Coccus hesperidum* Linnaeus, is an occasional pest in Queensland, where chemicals have disrupted its parasitoids or it is protected by ants. *Parasaissetia nigra* (Nietner) and *Saissetia coffeae* (Walker) infest trees in India along with *C. psidii*, but they are not important.

These scales cause no damage as they feed, but the fruit become unmarketable when significant populations develop on the surface, as they often do in China, Taiwan Province of China and Australia. The scales also produce honeydew, which supports the growth of sooty mould on infested fruit and panicles, and those below. These discoloured fruit are downgraded or rejected in the market-place.

Severe infestations may be controlled with methidathion, although applications of mineral oil are preferred so that effective predators, the mealybug ladybird, *Cryptolaemus montrouzieri* Mulsant, and the green lacewing, *Mallada signata* (Shneider) are not affected.

Bugs

Several bugs belonging to Tessaritomidae attack lychee and longan throughout Asia and Australia. *Tessaritoma papillosa* Drury occurs in southern China, Vietnam, Thailand, Myanmar, the Philippines and India, although Butani (1977) notes that *Tessaritoma javanica* Thunberg and *Tessaritoma quadrata* Distant, are the main species in India. In Australia, *Lyramorpha rosea* Westw. is known as the lychee stink bug, but rarely causes damage.

In China, *T. papillosa* has one generation per year. Adults tend to aggregate and over-winter mostly on lychee and longan, but may also be found on other hosts in warm protected areas. In spring, the females are attracted to trees with new flowers and shoots. They mate and lay up to 14 egg masses, each containing about 14 eggs, on the back of leaves. Peak egg-laying occurs in March in Guangdong, but continues through to September. The first nymphs mature in June, while there are still old adults in the trees. These old adults may have lived for up to a year, and generally die by August. The new adults do not mate immediately, but mature over winter and mate and lay eggs the following spring.

Adults and nymphs feed on terminals, which may be killed, and also on flowers and fruit, causing these to fall. Liu and Lai (1998) claimed that up to 30 percent of fruit in commercial orchards are damaged despite chemical applications.

In Guangdong, the main natural enemies are the egg parasitoids, *Encyrtus* (*Ooencyrtus*) sp., *Anastatus* sp. and *Blastophaga* sp. which parasitise 70 to 90 percent of eggs laid late in the season. Similar results were recorded by Liu and Lai (1998) when parasitised egg cards were hung in trees during March. In orchards under integrated pest management, combined parasitism rates by *Anastatus* sp. and *Ooencytus* sp. may reach 50 percent in June, but may be less than 3 percent in orchards that rely on chemicals. During the 1970s, biological control in Guangdong was initiated using the egg parasitoid *Anastatus japonicus* Ashmead, the flat venter wasp, after field trials had demonstrated its value. Since only 10 percent of eggs are parasitised by April when most of the eggs are laid, natural control is ineffective. In contrast, very good control with up to 90 percent parasitism is achieved after mass release of wasps.

In Thailand, the egg parasitoids *Anastatus* sp. nr. *japonicus* and *Ooencrytus phongi*, operate in a similar manner to their counterparts in China. Low levels of control are achieved during the critical early fruit production period, building up to good levels later. Mass rearing of the parasitoids in the wild silk worm, *Philosamia ricini* Hutt., and releasing them early, produced results similar to those in China. *Anastatus* sp. and *O. phongi* parasitised 79 percent and 21 percent of eggs, respectively .

If chemicals are used, the timing of sprays is critical because the bugs vary in their susceptibility to trichlorfon at different times of the year, depending on body fat content and its nature.

Amblypelta nitida Stål, the fruitspotting bug, and *Amblypelta lutescens lutescens* (Distant), the banana spotting bug, are major pests of tropical fruit in Queensland (Waite, 1990). The adults over-winter on citrus or non-crop native or exotic ornamentals, and start to move into lychee and longan orchards in spring when the trees flower. They prefer to feed on green fruit, and so are very common just after fruit set. Orchards near rainforests where the bugs breed are particularly susceptible .

The bugs feed on the developing seed and this causes the fruit to fall a couple of days later. The puncture mark is invisible on the fruit surface and the only way to distinguish damage from natural drop is to dissect the fruit. Fruit that has been attacked typically have a tan lesion on the seed testa. Endosulfan should be applied if more than 10 percent of fallen fruit have been stung. Usually, a maximum of two sprays applied two weeks apart, during the first six weeks after fruit set is sufficient.

Mites

Erinose mite, *Aceria litchii* (Keiffer), also known as hairy mite, hairy spider, or dog ear mite, occurs throughout China, Taiwan Province of China, India, Pakistan and Australia. Females lay eggs singly on the leaf surface amongst the erineum induced by their feeding. The eggs are only 0.032 mm in diameter, spherical and translucent white. The mites are also small, only 0.13mm long and pinkish-white. All stages have only four legs, but are quite mobile and move easily from old leaves to infest new flushes. Their feeding stimulates the production of the erineum where they shelter and feed. Numbers vary with the cycle of shoot growth, and are highest in summer and lowest in winter. Planting material obtained as marcots may be infested if they have been taken from trees with the mites. Later infestations occur when the mites are moved around the orchard by direct contact between trees, or carried around by orchard workers, wind and bees.

The mites attack new leaves causing a felt-like erineum to be produced on the under-surface. This forms as small blisters but may eventually covers the entire leaf, causing it to curl. In severe cases, whole terminals may be deformed. The young erineum is silver-white, changing to light brown and dark reddish-brown, and eventually black. The greatest numbers of mites are found in the intermediate stages.

Many leaves are ruined if infestations are severe (Plate 8). This generally causes no problems in established trees, but can debilitate young orchards. There can also be a problem if the mite moves from leaves onto the developing flowers and fruit. Fruit set can be disrupted or the fruit deformed. Such fruit are unmarketable.

Numerous species of predatory mites, particularly those from the Phytoseidae, have been recorded with *A. litchii*. *Agistemus exsertus* Gonzalez (Stigmaeidae), has been used for control in Guangdong, Guangxi and Fujian.

Branches infested with the mite should be cut off and burnt. The mites can be controlled by applying insecticides when they move from the older leaves to a new flush. The leaves should be checked regularly for symptoms over summer and autumn. Not all trees in an orchard will be flushing or infested at the same time. In Australia, three sprays of dimethoate or wettable sulphur every two to three week during leaf emergence and expansion generally provide adequate control. Chemicals recommended in China include dichlorvos, dimethoate, dicofol, chlorpyrifos, omethoate and isocarbophos.

Gall flies

The leaf midge, *Dasyneura* sp., is a major pest in China. *Litchiomyia chinensis* Yang and Luo was described from specimens reared from galls on lychee leaves collected in Guangdong. The larvae over-winter in the galls produced as a result of their feeding. They pupate in the soil, with the adult flies initiating the first of eight overlapping generations from March. The midges prefer damp, closed canopies and dry out in exposed areas. The adults lay eggs in lines on young leaves. The larvae then mine the leaf, causing 'watery dots' that later become the “galls”. These turn brown and eventually drop out, giving the leaf a “shot-hole” appearance.

In susceptible orchards, monitoring is not effective and preventive procedures are required. As with erinose mite, infested leaves can be removed after harvest and burnt. Later in the spring, methyl parathion (2.5 percent) at 75 kg per ha can be distributed under the trees, or isofenphos (0.001 percent) can be sprayed on the ground just prior to emergence of the adults. In autumn, isocarbophos (0.001 percent) should be sprayed twice over two weeks during early leaf development.

Fruit flies

In Queensland, *Bactrocera tryoni* (Froggatt) occasionally attacks lychee, but is not considered economically significant. Females lay their eggs through the skin of the fruit, often utilizing cracks and wounds made by other pests. Although the eggs can hatch, the larvae rarely survive, probably because of the juice in mature fruit drowns them. The flies in Queensland, and related species in Africa and Hawaii, are capable of ovipositing through the skin of lychee, although some cultivars may be too thick. The only real fly problem appears to be in South Africa, with *Ceratatis rosa*. However, the level of damage is still quite low. In South Africa, pheromone-baited traps can be used for monitoring populations. Control is achieved with bait sprays of protein hydrolysate mixed with trichlorfon or mercaptothion. Alternatively, the panicles can be covered with paper bags after the November fruit drop.

Major diseases

No major disease currently limits commercial production in Asia. Diseases are more important after harvest, although undoubtedly many of the fruit are infected before picking. There are a few organisms that infect the leaves, flowers and fruit, and a few others associated with tree decline and tree deaths. Chemicals are generally available for controlling diseases on the flowers and fruit. In contrast, more efforts need to be made to control the loss of trees.

Brown blight

Brown blight, *Peronophythora litchii*, is a major disease in both lychee and longan in China and Thailand, although more important in the former. It is also reported to affect lychee in India. It is well described in Guangdong, and attacks leaves and panicles, as well as fruit that can be infected right up to harvest. These infections all reduce production and shelf life. Flower panicles are particularly susceptible. Immature fruit turn brown, while those infected before harvest have a white mildew growing on the skin.

The fungus over-winters in the soil or on old infected fruit, with the spores spread by wind, rain and insects. Continuous wet weather and temperatures of 22° to 25°C favour infection. It is suggested that growers clean up their orchard by removing shaded, infected and dead branches after harvest. Copper oxychloride during winter and copper sulphate in spring also help to reduce inoculum levels. These chemicals are replaced by fosetyl-Al or metalaxyl during flowering and fruit development.

Anthracnose

Anthracnose, *Colletotrichum gloeosporoides*, is a major disease in Guangdong, and also occurs in India. Although it attacks leaves and branches, along with flowers and flower stalks, infected fruit are unmarketable. Lesions on the leaves may appear as small round light grey areas, or irregular brown marks at the tips. In contrast, infections are much more obvious on the flowers and fruit. Outbreaks are common after warm wet weather. The fungus may not always cause immediate disease, which sometimes only becomes apparent after harvest. Fungicides are used during an initial outbreak, but are not always effective.

A form of anthracnose caused by *Colletotrichum gloeosporioides* (*Glomerella cingulata* in the sexual state) also affects trees in Australia. Pepper spot causes superficial skin blemishes to the fruit, but does not effect production, fruit quality or shelf life. More than half of the crop may be unmarketable in some orchards. The disease has been recorded on all cultivars, but is most severe on the popular "Kwai May Pink".

The disease first appears as brown pinhead freckles, usually on the top of semi-mature fruit, in areas with overhanging branches. The spots do not increase in size, but rapidly turn black. More spots appear on the top and sides of the fruit and may, by harvest, cover up to half of the fruit surface. Infections over-winter on the leaves, with the fungus potentially spread from nurseries to new orchards.

Until the appearance of pepper spot, lychee was generally free of diseases affecting fruit or foliage in Australia. However, the occurrence of the disease has resulted in attempts to control it using copper oxychloride and copper hydroxide. Calendar sprays of copper are costly and could lead to unacceptable residues if used close to harvest. Other chemicals such as mancozeb are being evaluated.

Tree decline

A slow decline and a sudden death have been recorded in China, Viet Nam and Australia, especially in poorly drained soils. It can affect the whole tree or just one or two branches. The symptoms include a sudden branch wilt that is followed by the decline of new growth on the affected branch over a period. In other situations, the tips die without wilting. The tree or branch may recover temporarily, but subsequently dies. Parts of the tree flush and grow, while other sections die.

A number of organisms including *Phytophthora*, *Pythium* and *Fusarium* have been isolated from the roots of trees, but it is not known where they cause the disease. A root rot caused by *Clitocybe* is reported to kill trees in the Philippines. Growers are advised not to plant on waterlogged soils.

Armillaria occasionally attacks roots and the base of trees of any age causing death or slow decline. The fungus may survive in the soil, or on stumps and roots of various trees for many years. The planting sites need to be fumigated before establishing new trees in the orchard.

Parasitic algae and nematodes

A parasitic algae, *Cephaleuros virescens*, occasionally attacks trees in Australia causing loss of vigour. Cultivars such as “Souey Tung” and “Haak Yip” are very susceptible. It can be controlled with two sprays of copper, before and after the wet season.

Nematodes such as *Xiphinema*, *Paratrichodorus* and *Helicotylenchus* are a problem in South Africa, but whether they are significant in Australia and Asia is not yet clear. Post-plant nematicides are used in South Africa, but have not been evaluated elsewhere.

What is natural pest and disease control?

Pests and diseases are part of the natural environmental system. In this system there is a balance between predators and pests. This is nature's way of controlling populations. The creatures that we call pests and the organisms that cause disease only become 'pest and diseases' when their activities start to damage crops and affect yields. If the natural environmental system is imbalanced then one population can become dominant because it is not being preyed upon.

The aim of natural control is to restore a balance between pest and predator and to keep pests and diseases down to an acceptable level. The aim is not to eradicate them altogether, as they also have a role to play in the natural system. Once a pest or disease has started to attack a crop, the damage cannot be repaired and control becomes increasingly difficult. Where possible, use techniques to avoid or prevent pest and disease attack in the first place. These are the methods of pest and disease control described in this booklet:

- A healthy soil
- A healthy crop
- Resistant varieties
- Rotation
- Good hygiene
- Soil tillage
- Soil pH
- Timely sowing
- Companion planting
- Plants to attract predators and parasites
- Barriers
- Traps
- Light traps
- Fly traps
- Hand picking
- Biological control
- Natural pesticides
- Social prevention

Why is natural control preferable to chemical control?

Pesticides do not solve the pest problem. In the past 50 years, insecticide use has increased tenfold, while crop losses from pest damage have doubled. Here are three important reasons why natural control is preferable to pesticide use.

Cost Using natural pest and disease control is often cheaper than applying chemical pesticides because natural methods do not require buying expensive materials from the outside. Products and materials which are already in the home and around the farm are most often used. Safety for people There is much concern over the dangers of chemical products. They may be misused because the instructions are not written in the language spoken by the person using the product.

There have been many reports of people suffering from severe skin rashes and headaches as a result of using chemical pesticides. There are an estimated one million cases of poisoning by pesticides each year around the world. Up to 20,000 of these result in death.

Most of the deaths occur in developing countries where chemical pesticides, which are banned in Europe or the USA, are still available.

Safety for the environment Pests are often controlled with man made chemicals which have many harmful effects, for example:

- Artificial chemicals kill useful insects which eat pests.
- Artificial chemicals can stay in the environment and in the bodies of animals causing problems for many years.
- Artificial products are very simple chemicals and insect pests can very quickly, over a few breeding cycles, become resistant to them and can no longer be controlled.

Knowing the problem

Before taking action to control pests and diseases it is very important to make sure that the problem is correctly identified. Only then can you hope to succeed. Knowledge of pests and diseases will help you to decide whether the problem is caused by a pest, a disease, a mineral deficiency in the soil or an environmental factor.

A good identification book may help with this. Proper identification should be the first step in controlling the problem and, more importantly, in preventing it from happening again. The following pages describe a general approach to natural pest and disease control and give some specific examples.

A healthy soil A soil managed using organic methods will give plants a balanced food supply. Plants which are fed well, like people, will be much more resistant to pest and disease. So caring for the soil is important. It should be managed in ways that develop and protect its structure, its fertility and also the millions of creatures for which it is a home. Caring for the soil involves providing a regular input of organic residues in the form of animal manures and plant remains.

The aim is to:

- Maintain levels of humus (organic material) that give structure to the soil
- Feed organisms which live in the soil
- Provide nutrients for crops

Whilst chemical fertilisers appear to improve plant growth, their use can also have negative effects. A plant may look healthy but, because of the high content of nitrogen given by the chemical fertiliser, causing fast sappy growth, it is very attractive to pests. It has been observed that aphids lay double the number of eggs on a plant grown with chemical fertilisers compared to organically grown plants.

A healthy crop

By giving plants the right growing conditions they will be more able to resist pests and diseases. Also, the right choice of crop will help to deter pests and disease. A crop growing in an area where it is not suited is more likely to be attacked. You should take account of the soil type, the climate, the altitude, the available nutrients and the amount of water needed when selecting your crops. Plants will only yield well and resist pests and diseases if they are grown under the most suitable conditions for that particular plant. To help ensure a healthy crop, weeding should be done early and regularly to stop weeds from taking nutrients which should be going to the crop.

Resistant varieties and genetic diversity

Within a single crop there can be many differences between plants. Some may be tall, some may be able to resist particular diseases. There is most variety in the traditional crops grown by farmers. These have been grown and selected over many centuries to meet the requirements of the farmer. Although many of these are being replaced by modern varieties, seeds are often still saved locally.

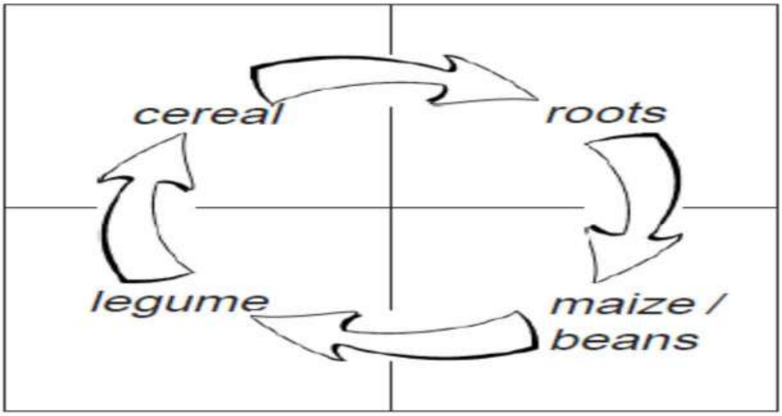
Crops which have been bred by modern breeding methods tend to be very similar and if one plant is susceptible to a disease, all the other plants are as well. Although some new modern varieties may be very resistant to specific pests and diseases they are often less suited to the local climate and soil conditions than traditional varieties. It can therefore be dangerous to rely too much on any one of them.

A wide variety or “genetic diversity” between the plants within a single crop is important. This helps the crop to resist pests and diseases and acts as an insurance against crop failure in unusual weather such as drought or flood. It is important to remember this when choosing which crops to grow.

Crop rotation

Growing the same crops in the same site year after year can encourage a build up of pests and diseases in the soil. These will transfer from one crop to the next. Crops should be moved to a different area of land each year, and not returned to the original site for several years.

For vegetables a 3 to 4 year rotation is usually recommended as a minimum. Crop rotation also helps a variety of natural predators to survive on the farm. A typical 4 year rotation would include a cycle with maize and beans, a cereal and a root crop with either of the following; 1. Grass or bush fallow (a fallow period where no crops are grown). 2. A legume crop where a green manure, which is a plant grown mainly for the benefit of the soil, is grown.



With crops such as brassicas and onions which are usually grown in a vegetable garden the whole year round, the populations of certain pests and diseases can keep increasing because there is always a suitable host plant for them. Breaking the cycle can help to solve the problem. This can be done through rotation within the vegetable garden

Good hygiene

If infected plant material, live or dead, is left lying around, pests and diseases can be passed on to future crops. Debris should be cleared up and disposed of. This can be done by composting the debris. The composting process will kill some pests and diseases and produce compost which is a good soil improver and fertiliser. Some diseases may survive being composted. If in doubt, the infected material should be burnt.

Soil tillage

Many pests spend part of their lives as larvae or pupae in the soil. Ploughing or digging when the soil is dry can reveal the pest and they will dry out and die in the sun, or they can be picked off the ground by hand or birds or other predators. Ploughing can also push the pest deep down into the ground where they will not be able to survive. Ploughing and disturbing the soil should be carefully considered against the harmful effects it may have such as destroying the structure of the soil and causing soil erosion.

Soil pH

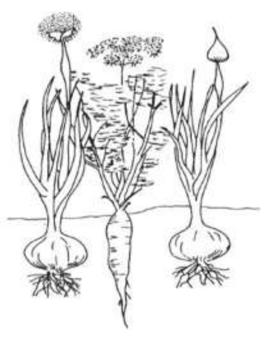
The pH (acidity or alkalinity) of a soil can affect some diseases. Changing the pH can reduce the problem. For example, potato scab is less severe in more acid (pH below 7) soils. A layer of grass mowings added to the bottom of the potato trenches at planting time will make the soil more acid and reduce the disease. Clubroot is less severe in alkaline conditions (pH above 7) therefore liming the soil to make it more alkaline can reduce the problem.

Timely sowing

It is often the young of many pests (larvae, caterpillar), rather than the adults, that cause damage to crops. Problems can be avoided by delaying sowing until the egg laying period of a pest is over, or by protecting the plants during this period. It is therefore important to know the life cycle of pests, so that timely sowing can be carried out. In Ghana, for example, farmers in the forest zone only plant maize in the main rainy season. In the lesser rainy season, the maize is attacked by stem borers.

Companion planting

Companion planting means growing certain plants to protect other plants from pests or diseases. This may be because the pest is deterred by the companion plant, or because it is attracted to the companion plant rather than the crop. For example onions planted either side of a row of carrots help to deter carrot flies. You need to sow 4 rows of onions for 1 row of carrots. This effect will only last as long as the onions are growing leaves. Many pests avoid garlic, so this can be used very effectively



Growing onions with carrots to help deter carrotfly for companion planting with most crops. In a similar way farmers in Zimbabwe have found that placing mint leaves near spinach plants will deter insect pests. By planting milkweed among vegetables, some African farmers have effectively reduced the number of aphids on their crops. This is because aphids are more attracted to the milkweed than to the vegetables. Companion planting can also mean that one plant acts as a barrier for another. In Columbia, jassid infestation in beans is reduced when beans are sown 20 to 30 days after maize. The maize acts as a shelter for the beans.

Plants to attract predators and parasites

Similarly to companion planting, which seeks to deter pests from the main crop, attractant plants can be grown to attract predatory insects

Areas of natural habitat

Bushes and trees are a home for many useful insects and birds. They provide resting areas, shelter and food. Areas of natural habitat can be left around the edges of fields where crops are grown. If these areas are destroyed then there is likely to be an imbalance between the populations of predator and pest.

Specific plants to attract beneficial insects

There are many plants that can be grown to attract natural predators and parasites which will help to keep down pests and diseases. Flowers such as marigolds (Tagetes), mint (Mentha), sunflower (Helianthus annus), sunhemp (Crotalaria juncea) as well as local legumes are useful attractant plants. Hoverflies, whose larvae feed on greenfly are attracted to the flowers of herbs and vegetables such as fennel, celery, dill, carrots and parsnips (Umbelliferae family). The nectar and pollen that these flowers provide will help to increase the number of eggs that these insects lay. Umbellifers will also provide food to various parasitic wasps whose young live on aphids and some caterpillars. Red hot pokers (Kniphofia uvaria) are used in parts of Africa to attract birds that eat aphids.

Barriers

Barriers are physical structures put in place to prevent a pest from reaching a plant. They keep pests away from a plant but do not kill them. Here are some examples that you can adapt, depending on the resources available to you:

Crawling insects

Cut the top off a transparent plastic bottle and place it firmly into the ground, over a young plant. This stops pests such as slugs from reaching the plant.

Using an old plastic bottle to protect a young plant

Climbing insects

To help protect trees from attack by insects, grease bands can be used. Wrap a piece of plastic or a long leaf around the trunk of the tree. Spread any kind of thick grease on top of this. Fold over the top of the foil or plastic to form an overhang to protect the grease from being washed away by rain. Check the grease every week to ensure that the grease is intact. This prevents crawling insects such as ants, fruit fly larvae, slugs, snails, beetles or caterpillars from damaging trees, especially fruit trees, or grain stores.

Termites

Digging a 70-100cm trench around buildings and nurseries can prevent attack from subterranean species of termites. This is a good method of control however it is hard work. Alternatively, barriers can be built. These should be partially above and below ground and should be made from material that is impenetrable to termites such as basalt, sand or crushed volcanic cinders. Particle size of the material is critical, they should not be too large for the termites to carry away, and not so small that termites can pack the particles to create a continuous passage through which they can move.

Bait traps

The use of baits and traps are traditional methods which have become neglected because of the increasing use of chemical pesticides. Here are some examples:

Cutworms

Method one

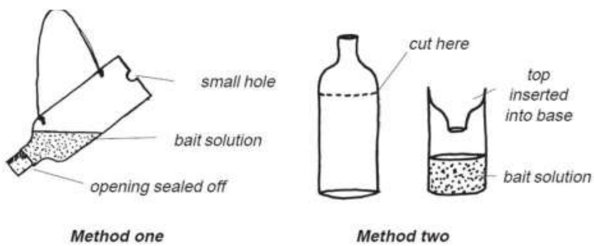
Mix equal quantities of hardwood sawdust, bran, molasses and enough water to make the solution sticky. Spread around the base of the plants in the evenings. The molasses attract the cutworms and as they try to pass through it they get stuck. The substance dries out in the sun and the pest dies.

Method two

Mix 100 grams (g) of bran, 10g of sugar, 200g of water, 5g of pyrethrum powder. Spread around the base of the plants. The cutworms eat the substance and die.

Fruit fly

Traps need to be put in place before an attack is likely to start. For fruit fly, the traps should be baited 6 to 8 weeks before the fruit ripen. Here are two examples of trap constructions which could be adapted:



Examples of fruit fly traps filled with bait

Method one

Make a small hole in the bottom of a plastic bottle or container. Seal the top of the bottle with a lid or stopper. Fill one quarter of the bottle with the bait. Hang the bottle upside down from trees around fields or gardens. The flies are attracted to the bait through the small hole. They are then trapped and drown in the bait

Method two

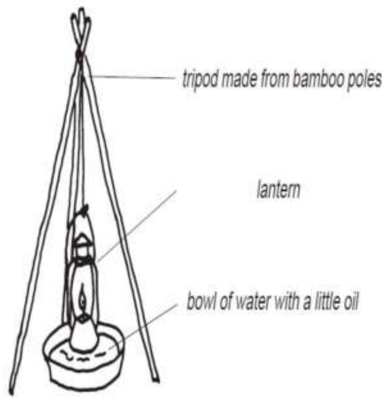
Cut the top of a plastic bottle off. Pour some bait in the bottom half of the bottle. Turn the top half of the bottle upside down and place in the bottom half. Again the flies are attracted into the bottle and drown in the bait. Here are two different baits for fruit fly that can be poured into the traps:

• Mix 1 litre of water, 250 millilitres (ml) of urine, a few drops of vanilla essence, 100g of sugar and 10g of pyrethrum powder.

• Mix 1 teaspoon of pyrethrum powder, 250g of honey, a few drops of vanilla essence, 250g of orange or cucumber peel or pulp and 10 litres of water.

Light traps

Light traps are set up at night and attract a variety of flying insects including moths, mosquitoes, chafer beetles, american bollworms, army worms, cutworms, brown rice plant hopper, green rice leaf hopper, rice black bugs, rice gall midges, rice stem borers and tomato hornworms. Make a tripod construction from wooden poles or bamboo. Press the poles down firmly into the ground to secure it so that it cannot be blown over or knocked down by animals. Suspend a lantern from the top of the construction over a bowl of water with a little oil in it.



Fire risks must be kept in mind and the lamps must be hung so that the wood does not catch fire. The best timing for placing light traps around a garden or field, depends on the life cycle of the insect and the development stage of the crop. The best time is just after the moths emerge but before they lay eggs, so it is important to know the life cycle of the pests.

Fly trap Fly

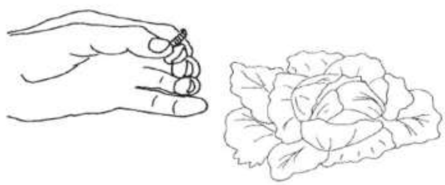
traps are large boards measuring about 30cm by 30cm which are painted bright yellow/orange and covered with an adhesive such as oil or glue. Different pests are attracted to different colours so you need to experiment. The flies are attracted to the bright colour of the board and fly onto it. They get stuck in the oil or glue and die. For example, leaf minors are attracted to yellow, so place several yellow boards 60cm off the ground (on a table or hung from a tree). The board will attract a huge number of insects, which means a considerable reduction of pests.

Pheromone traps

Pheromone is the sexual attractant produced by some female insects. If a trap is baited with this it will attract the male insects into the trap from which they cannot escape. Pheromone traps alone can reduce pest damage. Alternatively they give an indication of pest populations and therefore the best time to apply control methods. Pheromones traps are usually prepared by commercial companies and may be costly to the farmer. However, if you have a particularly severe pest problem it may be worth investing in one rather than using chemical pesticides.

Hand picking and squashing

In some cases it may be possible to pick pests directly off the crops. This can be done especially with caterpillars and other large insects



Handpicking caterpillars from a cabbage plant

in small plots of land. Smaller pests such as aphids can be squashed on the plant. Parts of plants that are diseased can be cut or broken off the plants to prevent the spread of the disease.

Biological control

Biological control means using one creature or organism to control a pest. This often involves introducing a creature or organism, which is known to be predatory, to an area with the aim that it will control the population of the pest. Some widespread pest and disease problems have been dealt with in this way by government projects. For example, a variety of creatures have been introduced to control the cassava mealy bug in Kenya. Here are other examples of creatures or organisms which are known to control certain pests: • Control of

Cabbage caterpillars: Bacillus thuringiensis is a bacteria which kills many types of caterpillar, but only when they eat it. This bacteria (which can be bought as a commercial product called "Bactospeine") is applied to brassicas (cauliflowers, cabbages) as a spray.

• Control of Vine weevils: Nemasys H is a preparation containing parasitic nematodes which seek out and destroy vine weevil larvae. It is watered onto the soil

Biological control does not have to involve buying commercial products.

\It can be achieved on a small-scale by encouraging natural predators to live and breed in the area where pests are a problem. This can be achieved by having trees and hedges around the farm to provide a home for them. There are many insects and animals which should be encouraged because they feed on pests. Here are some examples: Frogs, toads, hedgehogs, mice, moles, bats, birds, chamelions, lizards, spiders, ants, assasin bugs, black-kneed capsids, bees, branchid wasps, parasitic wasps, dung beetles, ground beetles, earthworms, hawk moths, dragon flies, hoverflies, lacewings and stick insects.

Natural pesticides

If pests and diseases cannot be prevented or controlled by cultural and physical means, it may be necessary to use natural pesticides. Many growers have developed ways of making their own sprays from plants such as garlic, chillies, marigolds and many others.

These are inexpensive and have proved to be very effective. Here are some examples: A solution can be made from marigold using water and soap. The liquid acts as a crop strengthener to help potatoes, beans, tomatoes and peas resist blight, mildew and other fungal diseases.

It also repels aphids, caterpillars and flies. Garlic spray is particularly good against army worms, Colorado Beetle, False codling moth, Khapra beetle, Mexican bean beetle and Imported cabbage worm. Garlic can also kill nematodes if soil or batches of soil are drenched with garlic liquid.

Social prevention

It may be necessary to work with surrounding farmers to destroy a pest. For example the variegated grasshopper (Zonocerus variegatus), usually has 1 or 2 nests per hectare. These can be destroyed by raking out the eggs from the nest and leaving them in the sun to dry out and die. The nest could be on another farmer's farm but it could affect your crops. Joint action and cooperation between all farmers could considerably reduce infestation.

Basic precautions in pesticide usage

A. Purchase:

o Purchase only just required quantity e.g. 100,250,500 or 1000 ml for single application in specified area.

o Do not purchase leaking containers, loose, unsealed or torn bags.

o Do not purchase pesticides without proper/ approved LABELS.

B. Storage:

- Avoid storage of pesticides in the house premises.
- Keep only in original container with intact seal.
- Do not transfer pesticides to other container.
- Never keep them together with food or feed/ fodder.
- Keep away from the reach of children and livestock.
- Do not expose to sun-light or rain water.
- Do not store weedicides along with other pesticides.

C. Handling

Never carry/ transport pesticides along with food materials.

Avoid carrying bulk - pesticides (dusts / granules) on head,shoulders or on the back.

D. **Precautions for Preparing Spray Solution:**

- Use clean water.
- Always protect your NOSE, EYES, MOUTH, EARS and HANDS.
- Use hand gloves, face mask and cover your head with cap.
- Use polyethelene bags as hand gloves, handkerchiefs or piece of clean cloth as mask and a cap or towel to cover the head (Do not use polyethelene bag contaminated with pesticides)

- Read the label on the container before preparing spray solution.
- Prepare spray solution as per requirement.
- Do not mix granules with water.
- Concentrated pesticides must not fall on hands etc. while opening sealed containers.
- Do not smell the sprayer tank.
- Avoid spilling of pesticide solution while filling the sprayer tank.
- Do not eat, drink, smoke or chew while preparing solution.
- The operator should protect his bare feet and hands with polyethelene bags.

E. Equipment:

- Select right kind of equipment.
- Do not use leaky, defective equipment.
- Select right kind of nozzle.
- Don't blow/clean clogged- nozzle with mouth.
- Use old tooth-brush tied with the sprayer and clean with water.
- Do not use same sprayer for weedicide and insecticide.
- Never re-use empty pesticide container for any purpose

F. Precautions for applying pesticides:

- Apply only at recommended dose and dilution.
- Do not apply on hot sunny day or strong windy condition.
- Do not apply just before the rains and also after the rains.
- Do not apply against the wind direction.
- Emulsifiable concentrate formulations should not be used for spraying with battery operated ULV sprayer.
- Containers, buckets etc. used for mixing pesticides should not be used for domestic purposes.
- Avoid entry of animals and workers in the fields immediately after the spraying.

G. Disposal:

- Left over spray solution should not be drained in ponds or water lines etc. 'throw it in barren isolated area, if possible.
- The used/ empty containers should be crushed with a stone / stick and hurried deep into soil away from water source.
- Wash the sprayer and bucket etc with soap water after spraying.

Hybridization in plants and animals

Hybridization is the process of interbreeding between individuals of different species (interspecific hybridization) or genetically divergent individuals from the same species (intraspecific hybridization). Offspring produced by hybridization may be fertile, partially fertile, or sterile.

Plants hybridize much more frequently and successfully than animals do. Pollen from flowering plants disperses widely and may land on flowers of other species. Chromosomal doubling (polyploidy) occurs more frequently in plants and facilitates the fertility of the hybrid offspring. Finally, plant forms are less stringently controlled than animal forms, and so the intermediate form of a plant hybrid is more likely to be physiologically successful.

One of the first persons to study plant hybridization was Josef Kölrueter, who published the results of his experiments on tobacco in 1760. Kölrueter concluded that **interspecific** hybridization in nature is rare unless humans disturb the habitat. Since that time, many instances of hybridization among various plant species have been documented.

Definition in short: The mating or crossing of two plants or lines of dissimilar genotype are known as hybridization.

The chief objective of hybridization is to create genetic variation, when two genotypically different plants are brought together in F1. Segregation and recombination produce many new gene combinations in F2 and the later generations, i.e., the segregating generations. The degree of variation produced in the segregating generations would, therefore, depend on the number of heterozygous genes in the F1 which in turn depend upon the number of genes for which the two parents differ.

The aim of hybridization may be the transfer of one or few qualitative characters, the improvement in one or more quantitative characters, or use the F1 as a hybrid variety.

Types of Hybridization:

Based on the taxonomic relationships of the two parents, hybridization may be classified into two broad groups.

1. Inter-varietal Hybridization:

The parents involved in hybridization belong to the same species; they may be two strains, varieties or races of the same species. It is also known as intra-specific hybridization. In crop improvement programmes, inter-varietal hybridization is the most commonly used. An example would be crossing of two varieties of wheat (T. aestivum), rice (O. Sativa) or some other crop.

The inter-varietal crosses may be simple or complex depending upon the number of parents involved.

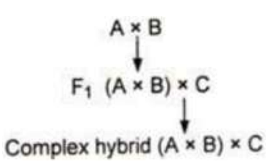
Simple Cross:

In a simple cross, two parents are crossed to produce the F1. The F1 is selfed to produce F2 or is used in a backcross programme, e.g., A x B → F1 (A x B).

Complex Cross:

More than two parents are crossed to produce the hybrid, which is then used to produce F2 or is used in a backcross. Such a cross is also known as convergent cross because this crossing programme aims at converging genes from several parents into a single hybrid.

Three Parents (A, B, C)



2. Distant Hybridization:

This includes crosses between different species of the same genus or of different genera. When two species of the same genus are crossed, it is known as inter-specific hybridization; but when they belong to two different genera it is termed as intergeneric hybridization. Generally, the objective of such crosses is to transfer one or few simply inherited characters like disease resistance to a crop species.

Sometimes, inter-specific hybridization may be used for developing a new variety, e.g., Clinton oat variety was developed from a cross between Avena sativa x A. byzantina (both haploid oat species), and CO 31 rice variety was developed from the cross Oryza sativa var. indica x O. perennis.

Procedure of Hybridization:

The breeder should have clear cut objectives in making a cross, and the parents should be selected to fulfil these objectives. The parents are evaluated for various characteristics before being crossed. Flowers of the parent to be used as female are emasculated by hand; suction, hot, cold or alcohol treatment to check for male sterility or self-incompatibility.

The emasculated flowers are immediately bagged and tagged. Emasculation is done one day before the stigma becomes receptive, usually in the evening between 4-6 P.M. The emasculated flowers are pollinated by hand the next morning. It is desirable to use as large an F1 population as the resources permit to provide the maximum chance for recombination.

Consequences of Hybridization:

Segregation and recombination produce a large number of genotypes in Fr The number of different genotypes possible in F2 increases geometrically with an increase in the number of segregating genes. Homozygosity increases rapidly with continued selfing. The frequency of completely homozygous plants also increases rapidly. By F7, about 73 percent of the plants become completely homozygous even when 20 genes are segregating. Transgressive segregation (**transgressive segregation** is the formation of extreme phenotypes) may occur, but usually the recovery of such recombinants will be very difficult.

In Situ Hybridization: A Practical Approach: Flowers bearing only pistils or stamens are said to be imperfect flowers. Plants that have separate pistillate and staminate flowers on the same plant (such as maize) are called monoecious. Plants that have male and female flowers on separate plants (such as asparagus) are called dioecious. Through artificial means (controlled pollination), hybridization of both cross-pollinated and self-pollinated plants can be accomplished.

Artificial hybridization is an important aspect of improving both cross-pollinated and self-pollinated plants. The breeder must know the time of development of reproductive structures of the species, treatments to promote and synchronize flowering, and pollinating techniques.

Objectives or Aims of Hybridization

Aims or objectives of hybridization can be enlisted as follows

- To create genetic variability
- To bring together desired qualitative characters found in different plants or plant lines into one plant or plant line i.e. to transfer desired character/s from other varieties to the considered one.
- To make F1 useful as hybrid variety
- Improvement of one or more quantitative characters

Applications to Agriculture: The concept of hybrid vigor, or heterosis, resulted from hybridization. Heterosis (or heterozygosis) occurs when the hybrid outperforms its parents for a certain trait.

The phenomenon of heterosis has been exploited in crop plants, such as maize, sorghum, sunflower, onion, and tomato.

Maize (corn) was the first crop in the United States in which hybrids were produced from inbred lines. It was George Shull who, following the rediscovery of Mendel's laws of inheritance in 1900, conducted the first experiments on inbreeding and crossing, or hybridizing, of inbred lines. Shull suggested that inbreeding within a maize variety resulted in pure (homozygous) lines and that hybrid vigor resulted from crossing of pure lines because heterozygosity was created at many allelic sites.

Hybrid maize was introduced in the United States in the late 1920's and early 1930's, after which U.S. maize production increased dramatically from the use of hybrids.

Heterosis now drives a multi-billion dollar business in agriculture. Yield improvement made in various crops in which heterosis were detected has been tremendous. In 1932 in the United States, 44.8 million hectares (111 million acres) were required to produce 51 million metric tons of maize grain, with a mean yield of 1.66 metric tons per hectare. In 1994 it took only 32 million hectares (79 million acres) to produce 280 million metric tons of grain, with a mean yield of 8.69 metric tons per hectare. In the United States in 1996, twenty-one vegetable crops occupied 1,576,494 hectares (3.9million acres), with a mean of 63 percent of the crop in hybrids.

Heterosis saved an estimated 220,337 hectares (544,459 acres) of agricultural land per year, feeding 18 percent more people without an increase in land use. From 1986 to 1995, the best rice hybrids showed a 17 percent yield advantage over the best inbred-rice varieties at the International Rice Research Institute. Despite the impact that heterosis has had on crop production, its molecular genetic basis is still not clear. It is hoped that with the progress being made in the genetic sequencing of various plant species, a better understanding of heterosis will emerge.

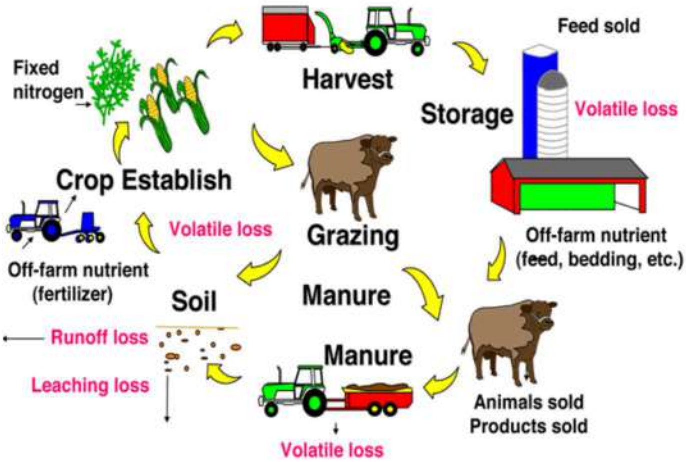
Exploitation of Heterosis

Plant breeding entails hybridization within a species as well as hybridization between species or even genera, called wide crosses. The latter are important for generating genetic variability or for incorporating a desirable gene not available within a species. There are barriers, however, for accomplishing interspecific and intergeneric crosses.

Plants of the same species cross easily and produce fertile progeny. Wide crosses are difficult to make and generally produce sterile progeny because of chromosome-pairing difficulties during meiosis. Triticale is the only human-made cereal crop, which is a cross between the genus Triticum (wheat) and the genus Secale (rye). The first fertile triticale was produced in 1891.

Some of the interspecific and intergeneric barriers should be overcome via the newer techniques of gene transfer. It is expected that genes from wild relatives of cultivated plants will continue to be sought to correct defects in other wise high-yielding varieties

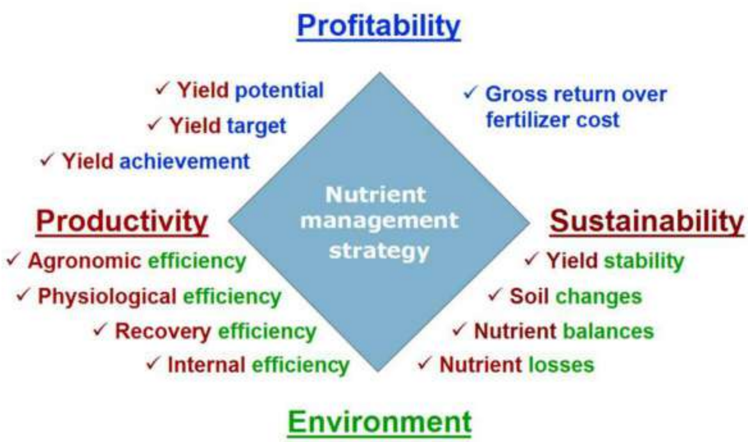
Nutrient management is using crop nutrients as efficiently as possible to improve productivity while protecting the environment. Nutrients that are not effectively utilized by crops have the potential to leach into groundwater or enter nearby surface waters via overland runoff or subsurface agricultural drainage systems. Too much nitrogen or phosphorus can impair water quality. Therefore, a major principle of crop nutrient management is to prevent the over-application of nutrients. This not only protects water quality but also benefits a farm's bottom line.



The keys to effective crop nutrient management are developing and following a yearly plan and conducting soil tests to determine the nutrient needs of crops. (Increasingly, soil nitrate testing before applying fertilizer and plant tissue testing are also used.) It is essential to keep good records on the rate, method and timing of all nutrient applications.

It is also important to note the source of the nutrients, be they purchased fertilizers, manure or other bio-solids, legumes or irrigation water. Residual nutrients in the soil must also be accounted for. Keeping good records help farmers compare expenses and returns from year to year. In short, good records provide solid information that helps farmers and crop consultants decide whether and how to adjust nutrient application rates, methods and timing.

For water quality purposes, nutrient management is especially important on slopes, on soils with high phosphorus levels and in environmentally sensitive areas. Sensitive areas include shoreland (land near rivers, stream, lakes and wetlands), areas around sinkholes, wells and surface drainage inlets, areas with sandy soil or shallow soil over bedrock (especially fractured bedrock) and wherever groundwater is close to the surface



There are many ways to fine-tune or modify nutrient application rates, methods and timing to ensure that nutrients are used as efficiently as possible. Below are some examples:

Banding, side-dressing and injection are examples of methods to place nutrients where they are most likely to be used by plants. Cover crops or green manures can be used to similar effect; they help nutrients stay in the soil where plants can use them.

- GPS grid sampling and flow meters are used to tailor nutrient application rates to the needs of each soil type rather than using the same rate across an entire field. This is called variable-rate application; it is an important technique because farm fields (especially larger fields) typically contain several soil types.
- Examples of strategies related to timing include (1) splitting the total amount of fertilizer into two or more applications during the growing season, rather than applying it all at once and (2) avoiding

fall application of nitrogen altogether (i.e., applying it in the spring, closer to when crops need it).

Why practice nutrient management on your farm?

 Enhances profitability by significantly reducing purchased fertilizer costs

 Protects surface water quality by minimizing nutrients, organic matter and pathogens in agricultural runoff

 Protects groundwater in wellhead protection areas from nitrate contamination

 Aids compliance with limit manure application rates

 Improves soil quality and productivity by increasing nutrient retention and water holding capacity and enhancing soil structure

 May improve air quality by reducing ammonia emissions

 Helps protect public health when nutrient application occurs near municipal or domestic wells, residences, businesses, schools and public lands

Animal Husbandry: Applied Biology

What is Animal Husbandry?

Animal husbandry refers to livestock raising and selective breeding. It is the management and care of animals in which the genetic qualities and behavior of animals are further developed for profit. A large number of farmers depend upon animal husbandry for their livelihood.

Animals provide us with a variety of food products which have high nutrient values. Therefore, they require a lot of care and attention.

Animals are bred commercially in order to meet the high demand for food. Dairy products from animals like cows, buffaloes, goats, are rich sources of protein. These animals are called milchy animals as they provide us with milk.

Another set of animals that provide nutrient-rich food are hen, ducks, goose, etc. They provide us with eggs which again are rich sources of protein.

Animals like chicken, duck, ox, goat, pigs, etc are bred for meat. Other than these domestic animals we have other sources of nutrients as well, they are marine animals. The seafood we eat has very high nutrient values. They are sources of a variety of nutrients like fat, proteins, **vitamins and minerals**.

Livestock and Management

The well being of human population is directly linked to the natural resources of a country. Natural resources are of various kinds. They are plants, animals, land, water and minerals. Animal husbandry and dairying have been mainly rural-based, generating employment and revenue among the rural people. Sustainable programmes are patterned by many governmental agencies to improve the livestock and its management. Intensive crossbreeding programme in cattle has led to the evolution of high-yielding milch animals.

Animal husbandry means domesticating and raising animals like cows, sheep, pigs, camels and many more for different purposes. Animal husbandry is carried out since the pre-historic times when early men realized the profits of animal husbandry. In countries like India, cow and buffalo are the prime domestic animals that are used for plowing and in food products like milk, cheese, butter and many others. Another popular aspect of the animal husbandry is the poultry where chickens are raised for food like meat and eggs.

One will be amazed to know that animal husbandry is carried out in the remotest areas in the world, domesticating of yak in hilly areas and camels in the deserts are the greatest examples of it. In the present world scenario, animal husbandry is one of the integral parts of the agriculture. The agro-sector has climbed sky heights with undue assistance of the animal husbandry. The big brands have entered the business and revolutionized the traditional husbandry practices. The new hybrids are able to serve more than earlier ones. The new hybrids animals including cows and chickens yield more meat and milk. These hybrids grow at faster pace and need lesser attentions.

Animal husbandry with new techniques has led to better awareness for raising animals. People are more aware and conscious about the hygiene and safeguard their animals from predators and diseases as well. People have shown great deal of interest in taking guidelines and assistance from the help centers and magazines serving knowledge about the technicalities of animal husbandry. The increasing demand of the food material like meat, eggs has made the animal husbandry a safe and sound occupation to invest. Even husbandries like fish farming have risen due to this fact. Several researches are carried out for the development of the animal husbandries. In addition, govt. fore sighting the profits is encouraging animal husbandry by setting several institutes and is flexing the policies that benefits to the husbandry sector people.

Advantages of animal husbandry

1. Animal husbandry helps us in providing proper feed, proper shelter and protection against diseases to the domestic animals. Thus, animal husbandry helps in proper management of the domestic animals.
2. Animal husbandry helps us in developing high yielding breeds of various domestic animals through cross breeding. Thus, animal husbandry increases the availability of various food products such as milk, eggs and meat, which are obtained from domestic animals.

3. Animal husbandry helps in raising the living standard of farmers. As a result of higher production of animal products, the income of farmers increases.
4. Animal husbandry helps in systematic disposal of animal wastes. Thus, it helps in maintaining healthy environment.

DISADVANTAGE

1. Animal husbandry can affect the environment because animals are vital part of ecosystems.
2.If they are any way dominated by humans, it may cause imbalance in ecosystems.

Dairy a part of animal husbandry

Dairy operation consists of proper maintenance of cattle, the collection of milk, processing the milk, and it's by products. Dairying is the production and marketing of milk and its products. Dairy technology made rapid growth in the latter half of the 19th century. New methods and equipments are available for machine-milking of cows. Artificial feeds and nutrient foods are manufactured to improve the milk yield of cows. Breeding techniques and applications of biotechnology in livestock improvement programme of cattle have tremendously increased the production of new breeds with high milking capacities. Since milk forms a staple food, majority of the population in this macrocosm rely on milk for their protein supplement.

Important cattle breeds and their characteristics

There are 25 different breeds of cattle in Namibia and, much like rugby teams and car preference; all of them have supporters and naysayers.
The reality is that no two farms are exactly alike, so cattle producers need to know their land to determine which breeds are best suited for their environment.
Indigenous breeds are mostly kept in communal areas, such as the Sanga (related to the South-African Nguni). These animals are well

adapted to the harsh local environment, which is characterised by high temperatures, prolonged dry periods, pests and diseases. Moreover, they require minimal management, but are still productive.

Commercial farmers tend to keep exotic breeds, which are "high output" animals. These animals require high management since they are not tolerant to the harsh Namibian environment. The major breeds are the Afrikaner, Bonsmara, Brahman and the Simmentaler.

When you produce oxen, it is advisable to use of crossbreeds. Crossbreeding is necessary to capture the best qualities of the breeds involved. For example, some breeds mature at an early age, but they do not have the necessary conformation and mass, while others may have both conformation and mass, but do not have the fat layer required. Mixing breeds and keeping an eye on genetics helps isolate the best qualities suited to one's needs.

Brahmans, for example, tend to have the right fat layer but not always the correct mass and conformation.

For example, if you crossbreed a Brahman with a Simmentaler, you tend to have the correct mass at an early age of about 24 months as well.

Crossbreeding may be used to develop animals with characteristics for optimum production in a particular region. This results in a change in the genetic makeup and improves productivity. Animals that are properly cross-bred make better use of extra feed and improved management. This is referred to as the efficiency of the animal.

Characteristics of a Brahman

Brahman cattle are known for their extreme tolerance to heat conditions. They are also more resistant to parasites and disease due to their oily skin, which may help repel insect pests. A Brahman cow is a good mother, offering protection and an abundance of milk for her calves. Brahman calves tend to have high weights at weaning because of the rich milk given by Brahman cows. The Brahman is one of the most popular breeds of cattle intended for meat processing. Brahman cattle live longer than many other breeds, often still producing calves at the age of 15 years and older.

Characteristics of a Bonsmara

The Bonsmara is functional, efficient and is well adapted to the extensive African climate. Bonsmaras are very fertile and breed small calves for easy calving. Bonsmaras are subject to minimum growth standards and produce high quality meat. Bonsmaras have a calm temperament and are handled with ease. Bonsmaras are equally suitable for cross-breeding as well as pure cattle farming.

Characteristics of an Afrikaner

Perhaps one of the most important characteristics of the Afrikaner is its suitability for cross-breeding with exotic beef breeds. Another outstanding characteristic is the Afrikaner's resistance to most of the country's endemic diseases, such as redwater, heartwater and gall sickness. The cattle are well adapted to veld conditions in the warm, arid and extensive grazing areas of the country, and react well to intensive feeding. The short, strong, shiny hair discourages tick attacks. Its meat is of high quality and tender, tasty and succulent.

Characteristics of a Simmentaler

The Simmentaler breed adapts easily to the most varied conditions. Simmentalers are bred all over the world for their high beef yields. The heavy muscling, length and overall size and weight of the animal are combined to produce a well fleshed carcass of solid red meat with a minimum of waste fat. In crossbreeding, the Simmentaler has proved very successful. It provides good growth, a large frame and thus a better beef yield to its crossbred progeny. It improves the quality of the meat with white fat and excellent marbling. It improves the milk yield, resulting in strong development of the calves in suckler herds.

Characteristics of Nguni cattle

Nguni cattle are known for their fertility and resistance to diseases. The cattle are heat tolerant. They have long productive lives and

cows will produce 10 or more calves, calving regularly. The cows show great efficiency and often wean calves that weigh 45-50% of their body mass. They develop excellent resistance to ticks and immunity to tickborne diseases. Disease incidence and mortality are low. Nguni fatten well on natural grazing as well as in the feedlot. The historical development of the Nguni has resulted in a breed with good temperament and mothering ability.

Cattle farming:

A cattle farming is the practice of rearing cattle by providing facilities for raising livestock.

Livestock includes domestication of cows, buffaloes, sheep, goats, pigs etc. A cattle farming is carried out to raise cows and buffaloes as important livestock. The two major species of Indian cattle are *Bosindicus,* or cows, and *Bosbubalis,* or buffaloes.

Milch animals and drought animals

Basing on their utility, cattle are classified into two types namely milch animals and drought animals.

• Milch animals or dairy animals produce milk. Males of this type are not useful for working on farm.

• Draught animals are used for carrying out agricultural work like tilling, irrigation and carting. Cows belonging to this category are poor milk-yielding varieties.

Management practices for cattle farming Management practices for cattle include cleaning, sheltering and feeding.

a) Cleaning involves periodic washing to get rid of dirt and loose hair.

b) Shelter facilities include well ventilated roof sheds which protect cattle from rain, cold and sun.

c) Feeding of cattle includes supply of uncontaminated and balanced diet.

Animal feed are of two types namely roughage feed and concentrate feed.

• Roughage feed contains high fibre content and provides energy. It comprises fodder grasses, silage and legumes rich in fibre.

• Concentrate feed is a mixture of cereals, seeds and oilseed cake rich in protein content. This type of feed is easily digestible and it helps the animal in increasing body weight.

d) Cattle should be protected from diseases. Diseases in cattle are caused by both external and internal parasites. External parasites live on the skin and cause skin diseases. Internal parasites affect the stomach and intestinal parts.

Certain preventive measures of diseases in animals are listed.

- Proper disposal of dead animals and animal wastes.
- Shelters should be clean, dry and well ventilated.
- Periodic visit of veterinary physician to check the animals.
- Hygienic management of animals and animal products.

e) Infectious diseases are caused by pathogens like bacteria, viruses and fungi. Sheds should be cleaned and disinfected regularly. Vaccination against various diseases should be provided to farm animals. Vaccination should be given against various diseases.

f) Milk production centres should be maintained for the animals which give birth to young ones. Milk production depends on duration of lactation period. Lactation period is the period following the birth of a calf during which milk is produced by the animal. Lactation period can be enhanced by administering certain hormonal injections.

g) Cross-breeding is done between foreign and local breeds of animals to facilitate the growth of animals with desired qualities. Example: Foreign breed like Jersey cow, with long lactation period, is crossed with local breed like Red Sindhi cow, with high resistance to disease, to obtain offspring of desired qualities like long lactation period and high resistance to diseases.

Disease Management

The third responsibility of cattle farming management is to maintain disease-free breeds. Animals are not an exception to disease. They also suffer from numerous diseases. This may affect the health as well as productivity of animals; even cause their death. Parasites, bacteria, and viruses are the major villains here. These microbes infect the cattle externally as well as internally. Vaccination is the one solution for the protection against bacterial and viral infections.

LIVESTOCK SECTOR IN ZAMBIA: OPPORTUNITIES AND LIMITATIONS

The Livestock Sector in Zambia is increasingly becoming an important component of Zambia's economy. For example, its contribution to the National Gross Product in 1996 and 1997 was estimated at 6.4 and 6.5% respectively. This accounts for about 35% of the total agricultural production. In 1997, the livestock sector accounted for 33% of agricultural exports.

In Zambia, about 23% of the per capita supply of protein comes from animal products. However, with regard to meat consumption, beef is the most preferred, followed by pork, chicken, rabbit, mutton/lamb and goat meat. Cattle contribute at least 61% of the meat and milk consumed in the country. In view of the above, the livestock sector has tremendous potential and capacity in contributing to poverty alleviation, increasing the socio-economic status of most people and, consequently, contributing significantly to the economic growth of the country.

However, the potential of the sector is under-estimated and hence minimal. This paper will attempt to discuss the production ratios and major limitations to increased productivity. For the purpose of this workshop the discussion will be confined to ruminants.

PRODUCTION RATIOS AND MAJOR CONSTRAINTS TO INCREASING PRODUCTIVITY OF RUMINANTS

Ruminant livestock numbers in the traditional sector comprise 2.7 million cattle, 700 000 goats and 70 000 sheep. These figures represent 82, 97 and 64% of the national cattle, goats and sheep respectively. Most of these animals are concentrated in Eastern, Western and Southern Provinces. Despite these large numbers, their productivity is very low and hence the livestock production sub-sector is not expanding at a sufficient rate to meet the needs of each household and increasing population.

The demand for animal products is constantly out stripping the production and supply. The increased output of animal products observed in the traditional sector, has largely been due to increased animal population rather than increased productivity. For example cattle numbers in the traditional sector are increasing by 3.5% per annum. Sheep and goats numbers have been estimated to increase at 5 to 7% respectively, per annum. The increase in cattle and goat numbers is justified by the increasing number of traditional farmers who are going into livestock farming.

In Zambia, constraints to increased ruminant production include inadequate marketing infrastructure such as low price incentives; disease (tick borne diseases, helminthiasis, trypanosomosis); inappropriate livestock research; inadequate extension services and poor animal husbandry practices. However, there is concrete evidence that nutritional stress, in terms of quantity and quality of available grazing, particularly during the dry season (April November), limits ruminant productivity. For instance, in cattle, low productivity is manifested by high calf and adult mortality rates (20 and 9% respectively) and overall low reproductive efficiency

[1]. The low reproductive efficiency is characterised by low conception and calving rates (45-50%) coupled with periods of anoestrous and long calving intervals (>450 days)

Nutritional stress, due to crude protein deficiency in mature natural veld grass, has also been responsible for slow growth rates (five-to-seven years to reach mature market weight, low birth and weaning weights;

[2]); low milk production and inefficient performance of draught animals, due to their poor physical condition resulting from underfeeding during the long dry season.Mature poor quality roughages are deficient in rumen degradable nitrogen, RDN

[3]. The consequences are reduced dry matter intake of such poor quality roughage, largely due to a limited supply of RDN for rumen microbial activity

[4]. Ruminants that depend entirely on poor quality roughage are, therefore, unable to meet their nutrient requirements (amino acids) for reproduction, growth rate and milk production during the long dry season. Most ruminants fed on poor quality roughage, especially during the long dry season, are always in negative nitrogen balance

[5], an indication that these roughages are unable to meet the nutrient demand for maintenance and production

[6]. The low feeding value of roughages may ultimately give rise to a poor response to veterinary treatments and inadequate exploitation of the genetic potential of both indigenous and, to a greater extent of exotic breeds. The net effect is low output of milk, meat, wool, hides and skins, with corresponding increased costs of production

[7]. Where nutrition is inadequate, as is the situation in most parts of Zambia, parasites have major effect on ruminant productivity, emphasising the greater necessity for the control of diseases and parasitism Other than a limited supply of RDN in poor quality roughage, poor performance of ruminants in the traditional sector is further complicated by a critical shortage of veld grass due to severe overgrazing, especially in most parts of the Eastern and Southern provinces of Zambia, where cattle and goat numbers have soared.

The scarcity of grazing is enhanced by uneven distribution of rainfall and persistent droughts, resulting in reduced biomass availability; the Southern, Eastern and Western Provinces being the most affected. The scarcity of grazeable veld grass is further complicated by the distribution of tsetse fly. Livestock numbers are negatively correlated to the severity of tsetse infestation. It is estimated that about one third (120 000 km2) of Zambia's natural grazing resource is infested and unusable , thus confining the livestock to the remaining two thirds. Consequently this causes a negative impact on the environment and productivity of both the uninfected areas and livestock.

The problem of shortage of grass in most parts of Zambia is exacerbated by the ever increasing importance of arable production of cash crops (maize, sorghum, millet, wheat, rice, groundnuts, soybeans, sunflower, cotton and sugarcane) at the expense of grazing land. However, the residues arising from these crops, particularly maize, sorghum, millet, wheat and sugar cane can be utilised by ruminants when veld grass is scarce. Unfortunately, as with mature veld grass, crop residues have a low feeding value due to their low protein content

[8]. In Zambia, approximately 2.06 million, 59 600, 95 777, 13 653 and 53 278 metric tons respectively of maize, sorghum, millet, rice and wheat straws are produced annually. Nakambala Sugar Estate grows

sugarcane and hence produces substantial quantities of cane tops, bagasse and molasses as sugarcane by-products. This suggests that crop residues and molasses are more important as a source of feed for ruminants in the dry season, particularly in the traditional sector. However, crop residues are grossly under utilised, much being burnt or destroyed by winter fires. Therefore, there is a need for specific research to develop appropriate technologies which will encourage the use of this local feed resource base, particularly sugarcane tops, bagasse, maize and sorghum stovers, agro-industrial by-products (oil cakes) and forage legumes. It is important to note that technologies that are aimed at improving the feeding value of roughages should be socially acceptable to the subsistence farmers, technically feasible, economically viable and environmentally friendly.

Advantages of cross-breeding

Cross-breeding helps in the development of certain desired characteristics in animals.

- To increase milk production
- To increase resistance against diseases.
- To enhance the varieties with longer lactation period.
- To rely on less amount of quality feed.

Farming methods

Poultry farming

Poultry farming has now become very popular. It is recognized as an organized and scientifically based industry with tremendous employment potential. It plays an important part in the rural economy of India. It provides a ready source of income to the cultivator. Besides meat and eggs, poultry supplies feathers and rich manure.

The following factors are being taken into consideration for the growth of poultry farming

1) Small initial investment
2) Availability of quality chicks
3) Short generation interval
4) Quick, assured and better returns compared to other livestock species
5) Availability of trained man power

6) Better understanding and knowledge of the improved and scientific methods of feeding

7) Management and health control.

Rearing involves the following stages:- Selection of eggs, incubation and hatching of eggs, brooding or care of new borns, housing of poultry, feeding of poultry are the important steps in rearing of chickens.

1. Selection of eggs: - Eggs meant for hatching and rearing must be selected very carefully.

The following points should be considered during selection of eggs.

(1)The egg should be fertile

(2) Over-sized and small sized eggs should not be selected instead medium sized should be preferred

(3) Dark-brown shelled eggs hatch earlier than light-brown shelled eggs

(4) Freshly laid eggs are preferred for rearing.

2. Incubation and hatching:

The fertilized hen's egg undergoes development during incubation and hatching processes. The fully formed bird emerges out of egg after a hatching period of 21-22 days. During this period the egg must obtain optimum temperature, humidity and ventilation etc. The maintenance of newly laid eggs in optimum condition till hatching is called **incubation**.

The incubation is of two types namely **natural incubation** and **artificial incubation**. In the natural incubation method, the eggs are subjected to the care of mother. Only a limited number of eggs can be incubated by a mother hen. In artificial incubation the eggs are maintained in a chamber (incubator) which stimulates the optimum environmental condition. In artificial incubation more number of eggs can be incubated than natural incubation.

***3.* Brooding: -** Brooding is the care and management of young chickens for four to six weeks immediately after hatching. Like incubation, brooding also has the natural and artificial methods. In the former, day-old chickens are left to the care of mother and in the latter temperature controlled artificial brooder is used.

Factors involved in brooding:

Temperature: - The hatched chicks are kept inside the incubator for about 36 hours and then transferred to artificial brooder. The optimum temperature is 330c during the first 3 days. During the subsequent weeks of brooding the temperature is reduced by 30c each week till it reaches 210c.

Ventilation: - Fresh air movement is important for good health and proper growth of the chicks. Poor ventilation results in the accumulation of carbon monoxide, ammonia and water vapour which may lead to microbial infection.

Floor space: - Adequate floor space is to be provided for the proper development of chicken. Minimum 500sq.cm of floor space per chickens is to be provided. Crowding of chickens leads to poor growth and induces cannibalistic tendencies amongst the birds.

Litter: - The floor of the brood house is layered by beds of hay, rice husk or saw dust and this is called **litter**. The litter bed should be 5 to 7.5cm thick and it must be kept dry.

Light: - To keep the brood house free from infectious germs, the brood house must be well ventilated. Evenly distributed sunlight promotes proper growth of the birds and formation of vitamin D.

***4.* Housing of poultry: -** Open sided poultry is popular in our country. The primary objective of providing housing to poultry is to protect them from sun, rain and predators and to provide comfort. Poultry house should be well ventilated. It should be kept cool in summer and warm in winter. The floor of the poultry house should be moisture-proof, rat proof, free from cracks, easily cleanable and durable.

5. Poultry feeding: - Feeding of poultry bird is an important part of rearing. The diet of chickens must contain adequate amount of water, carbohydrates, proteins, fats, vitamins and minerals. The food stuffs such as maize, barley, rye, wheat, oats, oil cake, rice etc are to be given in standard requirements.

Poultry byproducts

Poultry and poultry products are highly perishable. Hence, due attention has to be paid to the problems relating to processing, preservation and marketing of poultry and poultry products for the benefit of producers, processors and consumers. In a poultry processing unit, raw materials go as waste in the form of blood, feathers, heads and feet.

Hatchery waste includes infertile eggs, dead embryos, and hatchery unstable chicken. Large quantity of wet droppings is also available. Processing and using of these byproducts will not only reduce the cost of poultry production, but also solve the disposal problem and minimize pollution hazard. A great deal of work has been done for processing these by-products into feather-meal, poultry

By products meal, hatchery byproducts meal, egg shell meal, albumin flake, dried and poultry manure.

Poultry diseases: - There are four main **types of disease** affecting poultry: metabolic and nutritional diseases; infectious diseases; parasitic diseases; and behavioural diseases.

Metabolic and nutritional diseases

These are conditions caused by a disturbance of normal metabolic functions either through a genetic defect, inadequate or inappropriate nutrition or impaired nutrient utilisation. These include Fatty Liver Syndrome, Perosis (or slipped tendon), Rickets and Cage Layer Fatigue.

Infectious diseases

An infectious disease is any disease caused by invasion of a host by a pathogen which subsequently grows and multiplies in the body. Infectious diseases are often contagious, which means they can be spread directly or indirectly from one living thing to another. These include Avian Encephalomyelitis, Avian Influenza, Avian Tuberculosis, Chicken Anaemia Virus Infection (or CAV), Chlamydiosis, Egg Drop Syndrome (or EDS), Fowl Cholera (or Pasteurellosis), Fowl Pox, Infectious Bronchitis, Infectious Bursal Disease (or Gumboro), Infectious Coryza, Infectious Laryngotracheitis, Lymphoid Leukosis, Marek's Disease, Mycoplasmosis, Necrotic Enteritis, Newcastle Disease and Salmonellosis.

Parasitic diseases

Parasitic diseases are infections or infestations with parasitic organisms. They are often contracted through contact with an intermediate vector, but may occur as the result of direct exposure. A parasite is an organism that lives in or on, and takes its nourishment from, another organism. A parasite cannot live independently. These include Coccidiosis, Cryptosporidiosis, Histomoniasis, Lice and Mites, Parasitic Worms (or Helminths), Toxoplasmosis and Trichomoniasis.

Behavioural diseases

Abnormal behavioural patterns can lead to injury or ill health of the abnormally behaving bird and/or its companions. These include Cannibalism (or aggressive pecking).

Pisciculture

\Pisciculture or fish culture, included under the broad term‗aquaculture', can be defined as the ‗farming and husbandry of economically important fish, under controlled conditions'.

Fish farming is a productive venture. Fishes are highly nutritious sources of easily digestible proteins (rich in lysine and methionine. They are essential amino acids); minerals like calcium, phosphorous, iron, sodium, potassium, magnesium and sulphur; vitamins such as A, D and health promoting fats.

Fish are the source of polyunsaturated fatty acids which are helpful in cholesterol regulation and promoting cardiac health. Fish farming can help in integrated rural development by generating employment opportunities.

Definition

Fish farming is the raising of fish for personal income or profit. Based on the environment in which culture is done, fish farming may be categorized as freshwater fish farming, brackish water fish farming, saltwater or marine fish farming (mariculture).

Characters of cultivable fish

The following criteria should be considered before selecting a fish for farming purpose.

Rate of growth: Fish which grow to a larger size in shorter period are suitable for culture. Example: Carps.

Adaptation to climate: The cultured species of fish should be able to adapt to the local climatic conditions of the farm.

Tolerance: The fish should have the capacity to tolerate wide

Acceptance of artificial feed: When more number of fish is to be accommodated in a limited space, there is the need for supplementary feeding on compounded diets. The fish should show ready preference for these feeds.

Resistance: It is desirable that the cultured fish is strong enough to resist the common diseases and attack of parasites.

Amiability and compatibility: The fishes proposed to be cultured together (poly culture') should be able to live together without interfering or attacking the other.

Conversion efficiency: The species of fish which give more edible flesh per unit of food consumed is preferred.

Consumer's preference*:* Food preference of people varies with the geographic regions. Hence, the species cultured should be easily marketable locally or to the

Aquaculture is the rearing of fish either for home consumption or commercial purposes.

Advantages of keeping fish (fish farming)

i It is cheap and a good source of protein, vitamins and mineral salts. Here it is a good substitute for meat.

ii It is a source of income for farmers after harvesting and selling the fish.

iii Fish farming facilitates proper use of land which is not suitable for crop or livestock production.

iv It provides an easy and cheap source of fish whenever need arises. This is because fish is got from nearby ponds instead of going far away rivers and lakes.

v The dangers associated with fishing in rivers and lakes are reduced (ie drowning)

vi farmers can economically control the type and number of fish in a pond which is not possible where fish farming is not practiced.

Considerations in fish farming

When practicing aquaculture, the type of fish kept should be

i Suitable for that particular area (in terms of climate) and pond it lives

ii Popular amongst the community

iii Easy to market

iv Able to reed rapidly under good management.

Advantages of keeping Catfish

i It has the ability to breath for some time after a pond dries up.

ii It can withstand high water temperatures.

iii It feeds on a wide variety of foods e.g worms, small fish, snails etc. It can be kept with tilapia in the same pond. This provides them with food as it can eat the tilapia fry and fingerings.

FEEDING HABITS

The different fish types feed on different types of feed and have different feeding habits. This means that the farmer must have the right knowledge so as to give the right feeds in order to bet high pond harvests.

Nile Tilapia

This feeds on algae which can only be seen with the help of a microscope. Their presence in the water is indicated by the green colour of the water

- ➢ Algae grows very well in water fertilized with organic or artificial fertilizers.
- ➢ Nile tilapia finds it difficult to eat large plant parts because their mouth is not adapted for that. However the large plant parts eventually rot and become manure for algae growth.
- ➢ Nile tilapia kept in ponds has learnt to eat artificial feeds. It can be given cooked or left over foods.

Tilapia Zillii

This is different from Nile tilapia in their feeding habits. Trlapia zillii is adapted to eating on soft parts of large plants. Plants commonly used to feed tilapia zillii include young cabbage leaves, young yam leaves and other vegetables (weeds) Its mouth structure is adapted to feeding on large plant parts and not for the tiny plants (algae).

If the pond contains both tilapia zillii and Nile tilapia, it can be both fertilized and fed with soft plant materials. Fertilization benefits the Nile tilapia while tilapia zillii feeds on the large plant parts.

Luuka (Ngege) (Oreochromis Leucostictud)

- "Luuka" naturally fees on tiny green plants (algae) like Nile tilapia.
- It mainly feeds from mid water other than the pond bottom.

- Because of similar feeding habits Luuka competes with Nile tilapia for space and food.
- It does not freely feed on large plant leaves but can benefit from dead decaying leaves acting as manure.
- Luuka kept in ponds has learnt to eat a variety of food types including cooked food and dry formulated feeds.

African Catfish

- This lives and feeds predominantly at the bottom of t pond.
- It is an omnivore and a scavenger as feeds on a mixture of dead decomposing plant and animal materials (debris) at the bottom of ponds.
- It is a predator as it feeds on other animals like mollusks and fish.
- It is also a cannibal because it feeds on its own young ones.

- A mixture of catfish and tilapia produces better yields because of the differences in their feeding habits.

Mirror Carp

- Predominantly lives and feeds at pond bottoms.
- Is described as omnirous as it feeds on a mixture of dead decomposing plant and animal materials (detritus)

- It stays at the bottomof ponds stirring mud and sand looking for food and hence constanly making pond water silty.
- It does not feed on fresh plant materials or algae and does not live in mid water. This makes the carp suitable for its culture together with Nile tilapia in the same pond with minimum competition.

BREEDING HABITS

- Each of the fish type reared in aquaculture has a different style of breeding and bringing up of its young.
- Fish matures and starts reproducing while still at a small size but continues to grow. However, the rate of growth fails once reproduction starts.

Nile tilapia

- Matures from the age of 8 – 10 months from when it hatches depending on the warmth in the region.
- Fry is stocked at 2 months old and so Nile tilapia matures in ponds after 6-8 months at 100g or sometimes less.
- Lower temperatures slow the growth rate of Nile tilapia. For example it takes a shorter time to mature warm parts of Uganda like West Nile, Northern and Eastern Uganda

compared to the highland zones of Kabale, Kapchorwa where it takes over 10 months to mature.

Reproduction

- The mature male Nile tilapia builds nests at eh shallow regions of the pond bottom.
- The female lays eggs in the nests and the male fertilizes them.
- After fertilization, immediately the female takes them up in her mouth for incubation and nursing the fry.
- Incubation of the eggs and the fry takes over two weeks.
- During incubation, the female does not have time to feed and so grows thin.
- The female resumes proper feeding after one month.
- Because the male does not take part in incubation of the eggs and fry, it resumes feeding quickly and so does not lose weight during reproduction.

2. Tilapia Zillii

- Matures at about the same time as Nile tilapia (6 – 8 months) in ponds depending on the warmth of the region.
- It does not incubate eggs and nurse fry in her mouth. It simply guards and protects them from enemies. Hence it takes shorter time to resume reproduction then Nile tilapia. So it probably does not lose as much weight during reproduction as Nile tilapia does.

3. "Lukka" (Oreochromis leucostictus)

- Reproduces in exactly the same way as Nile tilapia. The only differences are that
- "Lukka" matures earlier from 5 – 7 months in ponds at a smaller size (50g)
- It produces more frequently every 1 – 2 months and hence tends to congest in

  ponds much more quickly than Nile tilapia.
- "Lukka" reproduces freely with Nile tilapia when stocked in the same pond. The offspring (hybrid)

produced is a little bigger than the pure "Lukka" but smaller than pure Nile tilapia parent.

4. The Catfish ("Mmale")

- Matures at 7 – 10 months in ponds at a weight of 500g and above.
- It does not freely reproduce in the ponds they have grown in. Once in a while they may reproduce especially during heavy rains when pond water levels change. But only a few fry survive..
- Mmale is normally induced to reproduce using a part of the brain (the pihiitary) of another individual.
- Incubation of the eggs and nursing of the young (fry) is done artificially.
- It does not reproduce with any tilapia or carp.

5. Mirror Carp (carp)

- Matures at 7 – 9 months at a weight of 500g and above. Males mature at least a month earlier.
- It does not freely reproduce in the ponds they live in.
- They are artificially induced to reproduce by the following process.
- Mature males and females are separated from each other and stocked in different ponds.
- They are fed on protein rich feed for at least a month
- They are checked for ripeness to reproduce.
- A pond for reproducing them is drained and dried for at least a week.
- The pond is then filled with fresh water and special plant materials planted for egg attatchment.
- Then the ready males and females are brought together into the reproduction pond keeping water streaming through it.
- The eggs are kept in the pond and fry is nursed and fed in this pond.

Performance of different types of fish in ponds

Growth and performance of a fish in ponds depends on a number of factors namely:-

i **Genetic makeup of that type**

some types of fish grow faster than other due to the good genes they naturally have for growth.

ii **Environmental conditions**

For grows faster in warmer regions than in cooler ones. Some have better tolerance for hard environmental conditions than others.

iii **Management**

Even if the fish has the best genes and the environment is very good e.g warmer regions, if management eg feeding is poor, the fish will not grow well.

Therefore in order to get good yields, all the above three factors must be availed to the fish.

FISH PONDS

Fish ponds are not just a water hole in the ground but are artificial water bodies which must be very well managed in order to get good fish harvests.

Fish ponds must provide a good environment for the fish to live a health life, grow and reproduce well. Pond water must be free from diseases, toxic chemicals and predators, fresh air and food.

Site selection for a good fish pond

i) The water source quality and quantity must be permanent. It should be near a permanent water body e.g river or spring with very reliable water throughout the year. This water must be free from pollution, clean and well aerated.

ii) The soil must be impervious to water so as not to drain water away. e.g clay soil, to hold water in the pond water should not seep into or out of the pond.

iii) The pond should be on a slightly slopy site where it fills by gravity because it is very expensive to pump water in and out of the pond.

iv) The pond shape should be rectangular for easy construction and fishing by seining.

v) A pond should be above the water table to make it easy to drain and avoid flooding.

vi) The pond should be near market centres to make it easy to transport and sell the fresh fish. This is because fresh fish is bulky and perishable especially where there are no deep freezers or drying facilities.

vii) For security reasons, a pond should be near home. It also saves time to move to the pond so as to control thieves and vermines.

viii) The size of the land must be large enough to accommodate a large pond and leave a dyke big enough for movement of people and equipment, water channels etc.

ix) It should not be a weland because water in such places has a lot of acid which makes it impossible to rear fish.

x) It should be free from stones (gravel) and sand to prevent draining of pond water.

Steps in pond construction

After satisfying the requirements for site selection, a fish pond can be constructed following the steps below:-

(i) Mark out the pond area and walls using pegs.

(ii) The area (site) should be cleared of the vegetation, tree stumps and stones.

(iii) Dig out the top soil and put it aside. Dig out the sub soil and use it to build the pond walls. When building the walls

- Do not use organic materials because they promote leakage after decomposition.
- Make them firm to avoid water leakages.
- Avoid using pure clay because it cracks when ponds dry.
- Mix clay with sand to prevent cracking of walls.
- Make the top of the walls at least 30 cm above the water level when the pond is filled to avoid over flooding.
- Cover the walls with top soil and plant grass to prevent wall erosion by rain water.

(iv) Put pipe (inlets and outlets) to ensure good drainage of the pond and filling of the pond. Inlet pipes are put above the normal water level while the outlet pipes are put at the bottom of the wall. Another outlet pipe should be put above the walls to drain out excess water especially during floods. The pipes can be metallic or large hollowed out bamboo.

(v) The base of the pond must be sloping gently and evenly towards the lower end (outlet) and free of stones or roots. This allows draining out water easily when need arises.

- Cover the floor with lime about 14 days before filling the pond with water. This maintains the PH of the soil and facilitates the work

(vi) of the fertilizer that may be put in the pond

Important pond structures

Inlet and outlet

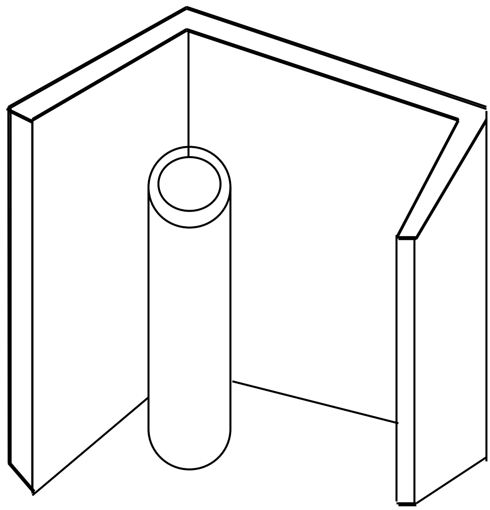
(i) The sluice

The sluice is a structure for the inlet or outlet made of two parallel concrete slabs with two parallel columns of groves. It is closed by slotting pieces of timber in the graves and packing clay in the space between the graves.

The outlet pipe is screened t prevent fish from escaping. Inlet pipe is also screened to prevent entry of will fish.

The monk

This is a three sided concrete structure with the drainage pipe in the centre. The structure is expensive and more difficult to operate.



The pipe system

More recently the plastic pipe system has been widely adapted for the inlet and outlet. The pipes have elbows at the bends to make them easy to operate. Plastic pipes are much easier to fix and operate in addition to being cheap. For larger ponds, pipes should be larger to ease water flows.

Pond Repair

This is by building back the collapsed pond banks and re-shaping the pond using firm soil from the pond bottom. Any leakages are also sealed off.

After repair, the pond is prepared for stocking as for new ponds ie liming, fertilization fixing inlets and outlets and filling the pond with water.

After filling the pond with water, it is left for atleast two weeks before stocking.

- During this period, sufficient quantities of natural food organisms develop
- Also the pond is becoming rich with small animals that are good food for the fry.

Just before stocking, the pond should be fished through with a net twice or three times to remove any wild fish frogs or any other animal that may have entered the pond.

MANAGEMENT OF FISH IN THE POND

Preparation and liming of a newly constructed pond for stocking

Applying lime

The new pond is drained completely if it had been filled with water. Lime is applied to cover the entire pond bottom. Lime is applied because of the following reasons:-

(i) To kill off germs and parasites that may be in t he water (those which survive in water).

ii) To reduce the acid level of the water because if this is high the fish may stop eating and die high acid levels prevent the growth of natural food for the fish.

While builders lime (calcium hydroxide) is commonly used in ponds. A 25 kg bag is adequate for a 400m^2 pond.

Lime can be applied in the following ways:-

i) As a powder spread very thinly over the surface of the pond bottom. When applying it as a powder protect the nose, mouth and hands because lime is corrosive.

ii) The lime can also be mixed in water and applied to the pond.

NOTE

Too much lime should not be applied fish prefers a PH range of 7.5 to 8.0. This PH can be determined using litmus paper dipped in a sample of H_2O collected from the pond in a glass for 2 -4 seconds.

Preparation of a pond from which fish has been harvested

A used pond will require repairs and treatment as a result of the following:-

- The pond banks may have been damaged by the collapsing of the soil.
- Banks may also be damaged by certain types of fish that dig into the bank e.g catfish (Mmale) and carp.
- Mud at the pond bottom may accumulate to levels that begin to affect the productivity of the pond.
- Ponds may develop leakages through the dyke due to the growth of tree roots or the digging by some fish.
- Some eggs or fry of previous harvest may remain in the pond and contaminate the new stock.
- In the pond mud, some diseases causing agents and parasites may accumulate. These may infect the new fish stock.

Because of the above reasons, the following treatments and repairs are required:-

i) The pond should be drained completely.

ii) The mud is removed from the pond bottom. The mud may be allowed to dry until it cracks because this makes it lighter and easier to remove. The lighter surfaces mud rich in manure can be used to fertilise gardens. The firm part of clay is used to repair the broken banks and dykes.

iii) Broken banks and dykes are repaired of any leakages.

Applying lime

Lime is applied to the pond bottom to kill off any remaining fish eggs, fry, parasites or any other disease agents.

Filling the pond with water

After liming, structures are fixed (inlet and outlet) and the pond is filled with water.

Emphasis is put on screening the mouths of the inlet pipe to prevent entry of un wanted fish, and outlet pipe to prevent loss of fish.

Water is filled into the pond from the supply channels until the correct level is achieved.

POND FERTILISATION

This is the application of organic or inorganic fertilizer at least once every two weeks in pond water. Fertilizers in the pond make it possible for natural foods of the fish to grow. Therefore fry should never be stocked before sufficient quantities of natural foods have developed in the pond

Natural foods of most fish include:-

(i) Tiny green plants which cannot be seen by naked eyes. Their presence is indicted by the green colour of the water (algae)

(ii) A wide variety of tiny animals which cannot be seen by naked eyes.

(iii) Large animals like worms, insects, snails etc that feed on algae also act as food for fish.

Types of fertilizers

These include

1. **Organic manures (fertilizers)**

These include

- Chicken droppings
- Pig dung and urine
- Goat/sheep dung
- Compost
- Sunflower cake
- Cow dung and urine
- Chopped vegetation and leaves

2. Inorganic fertilizers

These are the artificial fertilizers and are expensive. They include NPK, SSP, Urea, DAP (Diammonium Phosphate).

Application rates of fertilizers

A Organic manures

Application rate of organic manures can be summarized as below

Source of manure	Application rates for different ponds		
	200m^2 pond	500m^2 pond	1000m^2 pond
Chicken and	6 kg / week	15 kg / week	30 kg / week

duck manure (when dry)	($^1/_2$ jerry can per week)	1 jerry can per week	2 jerry cans per week
Pig manure wet	6 kg / week ($^1/_2$ jerry can per week)	15 kg / week 1 jerry can per week	30 kg / week 2 jerry cans per week
Cow dung 30	20 kg / week (1jerry can per week)	50 kg / week $2^1/_2$ jerry can per week	100 kg / week 5 jerry cans per week

NOTE

(i) Chicken and duck manure is the best and cow dung is he least effective.

(ii) Chicken and duck manure release more nutrients while cow dung releases less nutrients.

(iii) Chicken feeds are rich in nutrients and yet birds do not extract all the nutrients. Some of the nutrients are lost in the droppings which can be used directly as food.

(iv) The wet/moist manure is best

(v) During drying, some nutrients like nitrogen fume out reducing the effectiveness of the manure.

(vi) It is therefore recommended to apply the manure when wet or to cover it before use.

B Inorganic fertilizers

- for DAP (Diammonium phosphates, apply 300 g to a 400m^2 pond daily until the right level is attained.
- For SSP or TSP with 150g urea for a 400m^2 pond until the right level is attained.

Methods of application of fertilizers

(a) Organic manure

- The manure is collected fresh.
- It may be covered under shade and is kept moist by regular watering.
- It may also be directly paired into the pond.
- The manure can be placed in a crib constructed of sticks, at the corner of the pond where water enters from

In case of sunflower cake

- Weigh the dry cake (10 kg / 500m^2)
- Soak it in a little water over night. The quantity of water should be just enough to make a thick liquid.
- The following day, the soaked cake is sprinkled all over the pond surface.
- The process is followed and done every week.

(b) Inorganic manure application methods

The fertilizers (inorganic) are intended to supply two major nutrients N and P for growth of natural food for fish.

- Because DAP contains both nitrogen and phosphorus, it is usually added alone the pond.
- SSP and TSP are mainly sources of phosphorus and not nitrogen. Therefore the two fertilizers must be applied to the pond with urea which contains nitrogen.

FEEDING THE FISH

Fish in ponds can be fed in many ways as follows:-

1. **Feeding fish by fertilizing the pond**

This is the cheapest way of feeding fish. However production of natural food through fertilization is usually limited by the environment. Production of natural food through fertilization is usually limited by the environment. Production of fish using pond fertilization as the only sole method of feeding fives low results (maximum 0.3 kg/m^2/yr). This low production can only suffice for subsistence purposes an for household nutrition (NAADS 2005)

2. **Feeding fish on larger plant materials**
Among the reared fish only tilapia Zillii feeds effectively on larger plant materials. However the plant materials must be soft. The best way to get plant materials easily is to plant them in the dyke space around the pond. These plants are harvested and placed in the pond e.g Dodo.

3. **Feeding fish on other fish**
This occurs only where the African Catfish ("Mmale") which is a predator is reared. This can be done by stocking the "Mmale" (predator) together with a large quantity of the prey fish like Nile tilapia. The prey fish should be stocked when it has a larger size than the predator so that they are eaten. This makes them (pre) able to reproduce young ones for the African catfish (Mmale) to feed on.

4. **Feeding fish on artificial feed**
For commercial production of more than 0.5 kg/m^2 per year, the farmer must provide good quality feeds either to supplement the fertilization or as the only source of feed. Artificial feed is more expensive than fertilizing the fish pond. Therefore it must be used where the farmer is producing intensively for markets that offer good price for fish otherwise artificial feed should supplement the other methods

Nutritional requirements of fish

Nutritional requirements of fish varies according to the type and ages of each fish. For example

Nutrient	Fry	Juvenile	Grower	Brood stock
Protein	42 – 39%	37%	35%	37%
Fats	< 8	< 8	6	5
Starch	25	25	25	25
Minerals	1 – 3	1 – 3	1 – 3	1 – 3

Vitamins	< 1	< 1	< 1	< 1

Nutrient requirements % of different age group of fish

FISH HARVESTING

Fish must be harvested when it has attained the right size and when market is readily available.

The right size is determined through regular sampling, recording the average weight and increase in average weight each month. The right size (age) is attained where there is no difference in the average weight or increase in average weight each month.

Example

Growth of fish in Jacob's pond

Month when sampling is done	Average wt. of fish each month (g)	Increase in average wt. each month (g)
1	4.7	0
2	9.0	4.3
3	10.6	1.6
4	12.0	1.5
5	28.9	16.9
6	65.5	36.6
7	121.2	55.7
8	191.8	70.5
9	270.2	78.5
10	380.0	109.8
11	440.0	60.0
12	471.7	31.7
13	504.5	32.8
14	515.0	10.5
15	516.0	1.0
16	517.0	1.0
17	517.5	0.5
18	518.0	0.5

The data shows that the monthly increase in fish weight rises until month 10(ten). After this month the rate of growth keeps falling and yet the quantity of food the fish eats increases. It is advisable to harvest the fish at month 10 (ten).

Methods of tools for harvesting fish

The common methods and tools for harvesting fish from ponds include the following

1. **Harvesting by draining the pond**

This is the simplest and most effective method. Water is drained out of the pond by opening the outlet sluice gates or lowering the popes at the outlet. As the water level drops and moves towards the deeper end of the pond, the fish drift with it. Finally all the fish will collect at the outlet and is collected by hand or with a net.

Harvesting is made much easier if a depression is made at the point of outlet as a "harvesting bay". In this way fish is picked clean and does not burry in the mud.

This method is suitable for both small and large ponds but for large ponds, it is used in combination with fish collected from the mud tends to be dirty and dies quickly. Therefore during harvesting, there should be two buckets of clean water for cleaning and rinsing the fish. The water can be replaced when it gets dirty.

2. **Using basket traps**

Basket can only be used in harvesting small ponds. Where the farmer cannot afford the move expensive tools.

The basket is made from twigs and other climbing plants. The larger end is the mouth which has a value that does not allow the fish to escape once it enters. Some bait e.g food is put in the basket to attract the fish to come in. The trap is placed in the pond with the open and facing the main pond water. It is given enough time like 30 minutes to one (1) hour for the fish to enter.

Basket traps are simple to make and cheap to buy because they are locally made.

They are also easy to operate

However

- It is limited t only small ponds less than $200m^2$.
- It cannot harvest all the fish in the pond. Finally the pond has to be drained in order to harvest all the fish.

3. Using hooks

Hooks are sold in shops for fishing equipment. These vary in size from number 1 (the largest) to number 10 (the smallest).
A hook is fixed on to a rope tied to a handle. A bait e.g earth worm is fixed on to the hook. The hook and its rope (hook and line) are simple to make and use.

Disadvantages

- A hook and line cannot harvest all the fish from the pond because it catches only one fish at a time. Finally the pond has to be drained for complete harvesting.
- It depends on luck and the operator cannot choose the fish to catch.
- It injures and is not a good method for sampling fish to be returned into the pond.
- It is only suitable for small ponds up to 10 x 20 metres.
- It catches randomly and even smaller fish may be caught leaving larger ones.

4. Using cast nets

A cast net is like an umbrella and is tied on a rope. When cast over the pond, it opens out, and as it sinks deep into the pond the mouth is closed, trapping any fish that will be in the water space enclosed.

Attributes of cast nets

- Cast nets are cheap to buy
- Is simple to operate
- Does not require a large labour force but only one person is needed.
- It catches by chance and the operator does not have much choice of the fish to catch.

- It does not harm the fish and so the fish can be returned into the pond.

Disadvantages

- Its operation is limited to only small ponds (10x20m).
- It is time wasting for larger ponds
- It requires training in the skills of operation.

5. Using lift nets

Lift nets are nets made into a sack with one open end that is dipped into the pond to scoop up fish. The mouth of the lift net is made of a ring made from a cane or a metal rod. The length of the rod or cane is about 1 ½ - 2 metres long before bending into a ring. The wider ends are tied into the metal ring. The two open edges of the net are seemed together to make an inverted umbrella and the two pieces closed by tying.

The lift net can be braided by hand or are bought and trimmed into a cone with one wider end and one narrow end. The wider ends are measured to half the length of the ring for each net. Food is placed around the net and left for 30 minutes for fish together above it while feeding. Quickly the net is lifted with the fish that was in the water above it.

Advantages

i) A lift net can harvest a reasonable quantity of fish as much as 30 kg at a go and therefore can be used for commercial production.

ii) The method does not bruise or stress the fish and it can be delivered to market when still fresh.

Disadvantages

i) The lift net is not suitable for ponds larger than 2.000m^2 as it cannot harvest all the fish.

ii) The pond should be drained so as to complete the harvest.

6. The seine net

The seine net is the conventional pond net. It is like an open curtain made of a net with small meshes. The top side of the net is tied to a rope on which plastic round spheres (floats) are attatched at about one (1) metre interval to keep the net floating on water.

It has heavy cement balls on another side that keeps the net at the bottom of the pond. Therefore the net remains open during fishing. The bottom side is tied to another rope on which small stones are attatched at about 1 metre interval. The length of the net an extra 3 – 5 metres to make a curve when it is operated eg a pond with a width of 20 metres requires a seine net of 25m long.

Advantages

i) It makes bulk harvests

ii) It lasts long with minor repairs e.g up to 5 years.

iii) It is most appropriate for large size ponds

iv) If used carefully, it does not injure fish much and the fish can be returned in the pond.

Disadvantages

i) It is expensive to purchase.

ii) It requires more labour to operate

7. Using gill nets

Gill nets have varying mesh sizes. It is operated by setting it well spread in he pond and left there. It is checked after about an hour or longer. Fish is caught when it pushes its head through the meshes and gets trapped. The gill net is highly selective and the size of fish caught depends on the size of the net. The gill net cannot harvest all the fish in the pond.

Advantages

i) It may catch many fish

ii) Is easy to operate

iii) Only one person can set it

Disadvantages

i) It cannot be used to harvest all he fish

ii) One has to enter the pond in order to harvest

iii) It harms fish and hence cannot be used to harvest and return some fish in the pond

MARKETING OF FISH

Displaying Fish for marketing

Whenever possible fish should be presented for sale I its fresh form because live fish is the most fresh state. As soon as fish dies it gets bad and the longer it stays, the more smelly it becomes. When fish goes bad, the market price falls.

Different forms in which fish can be sold

The different forms in which fish can be presented to consumers (buyers) include the following:-

i) Dip fried in oil for immediate consumption.
ii) Sold live or freshly killed
iii) Preserved in ice
iv) Processed (eg sundried, salted or smoked)
v) At higher industrial levels, it may be filleted and chilled for supermarkets or export.

The form in which the fish is marketed depends on:-

i) How near the market is
ii) What the market prefers
iii) The amount of fish to be sold
iv) The need to add value and improve profit.

Apiculture: Apiculture is the art of beekeeping, but more than just keeping hives and harvesting honey, it includes setting up properly located and constructed hives, making sure bees have access to plentiful sources of nectar, and preparing the harvested liquid honey after it has been taken from the hive. It also includes being aware of local laws governing the keeping of bees and processing of their products and even marketing the final products.

Beehives are enclosed structures in which honey bees live and raise their young.

- The practice of maintaining honey bee colonies in beehives is called bee-keeping or apiculture.

- Apiaries or bee farms are established for commercial production of honey.
- Bee-keeping is a cheap and popular agricultural
- enterprise.
- Honey produced in bee-hives is the source of honey used in food and medicines.
- Taste and the quality of the honey depend upon the flowers the bees visit for nectar collection.
- Wax obtained from these hives is used in ointments, polishes.

Types of bees

Apis Cerana indica is the local variety of bees available for honey production.

Apis dorsata and Apis Florae are other common varieties used for honey production. An Italian bee variety, *Apismellifera*, is commonly used for commercial honey production. Bees of this species are known for high amount of honey collection.

Nurturing Bees for an economic value:

Colonies of bees are highly socialized groups of insects that create their own ecosystems in and around their hives. A detailed understanding of how this society functions is necessary to get the most out of raising them. Before even beginning to set up a beekeeping hobby or business, gaining a thorough knowledge of bee anatomy, behavior, and ecology can build an invaluable basis for the business. An individual who undertakes the responsibility of keeping a hive is taking on an entire civilization of creatures.

Apiculture does not have to be a large-scale project. Keeping a few hives can give families access to endless honey as well as related products like beeswax candles and fresh honeycombs. It can also go hand-in-hand with other activities, such as gardening, as a few properly managed hives can provide invaluable pollination services to flowers, fruit trees, and vegetables.

Some of the hands-on processes of apiculture include constructing the hives and upkeep on these outdoor structures that can become weathered by the elements. Handling the bees can be one of the most difficult tasks. A smoker and proper clothing can help the beekeeper keep from getting stung while removing honeycombs or carrying out the delicate procedures of replacing the hive's queen bee.

While it may seem strange to relate management techniques to bees, it is a vital skill. Beekeepers must know what the bees require before they can build a successful hive, including providing consistent sources of fresh water, nectar, and pollen. An individual who is both aware and respectful of the natural cycle of bees will find handling them much easier, and he or she will also be alert to pests and threats to the hive before they become a real problem. Keeping an eye on rainfall charts, temperatures, climate changes, and information on area vegetation can help the alert beekeeper avoid or prepare for potential problems.

BEE PRODUCTS AND THEIR USES

Bee products include the following:

i) Honey

This is the sweet viscous juice collected from beehives. It is found in the cells of the honeybee comb. Ripe honey is usually found in sealed combs and can be kept indefinitely.

Unsealed honey is not mature (ripe) and therefore ferments shortly after it is harvested.

ii) Beeswax

This is produced from the bee's own body during the warm period of the day. The bee uses wax to build the comb cells in which their broods are reared. Honey and pollen are also stored in the cells. A bee consumes 8 to 15 kilograms of honey in order to produce one kilogram of bee wax. In most countries beeswax collection is not known because people do not know that local bee wax is useful

iii) Propolis

This is a resinous material collected by bees from leaves and buds of certain trees. It is greenish black in colour and gummy in consistence. Bees use propolis in the following ways:

- To fill cracks in their hives.
- To make the hive waterproof.
- To glue the top bars to the hive body.
- To strengthen the thin borders of their comb.
- Propilis is an embalming material used to cover any dead hive intruder that bees cannot remove from the hive.
- Propolis has several pharmacological properties, for example it is used in preparations to treat some skin diseases.
- Propolis is also marketable abroad.

iv) Pollen

This is collected by bees and sorted in comb cells. It is fed to the brood in the larval stage. Pollen can be collected from beehives by the use of pollen traps that remove the pollen pellets from the pollen baskets (Corbucular) on the hind legs of the foraging bees. Pollen can be collected from beehives by beekeepers and saved for feeding to the bees when there are no plants in flower to produce pollen for the bees.

In developed countries, pollen is used in some expensive dietary supplements because of its medicinal properties

v) Royal Jelly (Bee milk)

This is used by bees to feed the queen bee and the young larvae less than three days old. It is secreted from the glands of the 5 – 1 day old worker bees. Studies show that royal jelly is a good source of vitamin B. It is also thought to have medicinal value like pollen. It is therefore used in certain expensive preparations.

vi) Bee venom

This is used by bees as a defensive weapon to protect their territory. Bees are naturally embraced with this venom. The venom has two medical uses, namely:

- As a desensitizer for those who are allergic to bee stings.
- In the treatment of arthritis. It is applied directly or by injection.

vii) Pollination

The most important service bees render to mankind is the pollination of fruit crops. It has been stated that the value of the bees in pollination exceeds by 10 – 20% times their value in the production of honey and beeswax.

TYPES OF BEEHIVES

The types of beehives used in beekeeping are categorized into traditional and modern hives.

1. **Traditional hives**

These include the following:

a) **The grass hive**

Dry grass is woven in a basket or cylindrical form, usually with entry points at both ends. The hive is installed high in treetops to avoid termites. At harvesting time, the hive is lowered carefully. The disadvantage with this method is that its lifespan is only one year because it is only for seasonal beekeeping.

b) **Log hive**

A tree is felled and cut into pieces which are carefully scooped out to form hollows. They are then sealed leaving small holes for entry and exit. In Tanzania the hive is spilt into halves which are attached together before baiting and installation. At harvest time, the hive is spilt open and the honey combs removed.

c) **The clay-pot hive**

The pot is similar to the type generally used to carry water or other liquids. However, it is modified to provide a wider mouth and a small mid-section hole for both exit and entry. Before the pot is used, it is fired for curing and the inner part smoked as part of the baiting.

It is then baited with cow dung or other waste and installed on the ground or on pegs in trees. The disadvantage is that:

- Combs are fixed to the hive bond.
- Combs cannot be inspected.
- Detached combs cannot be replaced easily.
- Thousands of bees are killed during honey harvesting.

The design of all modern beehives is based on the discovery of Lorenzo Lorraine Langstroth that when bees build their combs, they always leave exactly the same amount of space (bee space) between them.

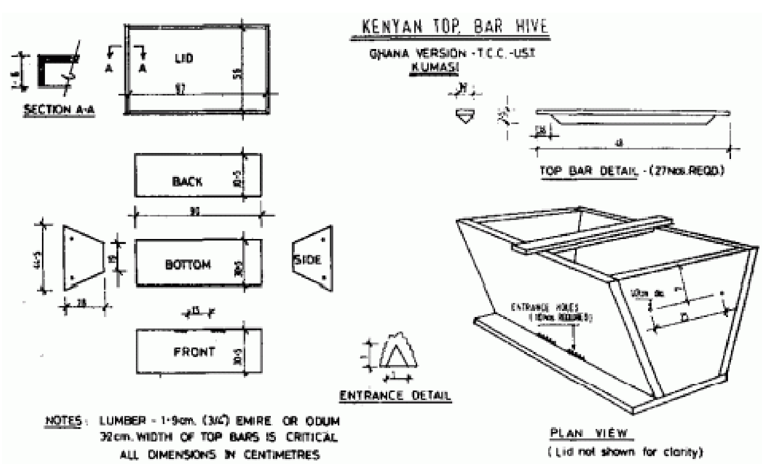
On this basis Langstroth invented a hive with frames separated by this bee space in which bees could build their combs. The frames are so arranged that they can be removed individually:

- Without disturbing other combs.
- Without crushing bees.
- The sides and bottom of the frame provides very good support for the comb.
- Several hive boxes can be stacked one above the other.
- The queen can be confined to the lowest or brood chamber by means of a queen excluder.

- The upper chambers (supers) can only be reached by worker bees and therefore contain only honey combs.
- Hives inspection and many other management practices are possible and easy unlike in the traditional hives.

The top bar hive

The top bar hive is constructed of wood and basically consists of small wooden bars at the top for bees to attach their combs. The top may be covered with an iron sheet reamed with wood. The width of the wood (for the top bars) must be exactly 3.2 cm (very crucial). The tropical honeybee builds a comb which has a thickness of 2.5 cm. The combs are usually attached to the centre of the top bar. A space of 3.5 mm is left on either sider of the comb. When two or more top bars fixed with combs are placed side by side, the inner space becomes 7 mm (ie 3.5 mm). This space, which is vital to the bees, is usually referred to as "bee space". These bee spaces are also found between the combs and hive body. They serve as paths for the bees in which they pass freely. A wire loop is fixed at each end of the hive and the hive is suspended up in a tree or on a rack.



There are different types of top bar hives and their names refer to their shape. Examples are:

(i) The V-shaped top bar

This is usually used by the beginning beekeeper who has no bees wax or comb foundation to serve as a guide for the bees.

- It is easy to be built by any local carpenter with simple basic tools.
- Bees are naturally guided to follow the top bars ridge fixing their comb along the line.

Disadvantages

- New honeycombs can easily break away from the bar. Therefore, top bars with combs should be handled carefully although given enough time, bees will reinforce the combs fixing them firmly to the bars.

(ii) The groove top bar

- This can be built more quickly than the V-shaped but its manufacture requires the use of electrically powered machines to cut the groove in the centre of the bar. The beekeeper fixes strips of wax, about 6 mm thick, into the groove to form a guide for the bees. The bees will then glue this wax foundation firmly into the groove and begin to build their combs along it.

(iii) The pointed starter

Like the groove top bar, the pointed starter cannot be produced cheaply and easily by a village carpenter. It requires electric machine tools for production. It does not require any foundation as for the groove top bar hive.
However, wax can be rubbed along the edge to show the bees where to fix the comb. Bees find this with ease and combs built are always firmly attached. The pointed edge must be placed at the centre of the tip bar.
The Kenyan Top-Bar hive (KTBH), developed by Professor G.F. Townsend and his team of Kenyan bee students at Gvelp University in Canada, is recommended for use in East Africa. It is an ideal accommodation for aggressive tropical bees and is highly recommended for beginners.

(iv) The rectangular hive

This can be fitted with either top bars or frames or both at the same time. A rectangular hive built according to Kenyan top bar hive specifications can utilize the standard top bars. However, if the hive's width is modified, the top bar length must reflect this change.

(v) The Tanzanian transitional long hive

- This is a single box rectangular hive that uses **frames** instead of top bars.

- It usually contains 23 – 27 frames. All the frames are patterned after the Longstroth type but the dimensions differ to suit the tropical African bee.

Advantages of the Frame top bar hives

(i) The comb is fixed firmly to the four sides of the frame. This facilitates easy harvesting and there is no fear of damaging the comb.

(ii) The strength of the built in comb allows easy transportation even on very bad roads. This controls the colony without fear of breakage before arrival at the new destination.

(iii) Honey is harvested without damaging the comb and empty combs are returned to the hive for bees to refill with honey. This means the bees don't waste time and energy on constructing replacement combs.

(iv) During hive manipulations, very few bees are crushed between frames.

(v) The hive is designed with queen excluder and supers (upper chambers) such that the queen and brood are confined to the lower chambers. Supers contain only honey and the lower brood chamber cannot be disturbed when harvesting honey.

(vi) Stealing a double or triple storey hive with a colony is difficult for a thief, unlike the Kenya top bar hive which can be carried away easily.

(vii) A swarm of bees can be hived with ease because bees can easily pass through the numerous spaces between the frame and at the top of the hive.

(viii) Hive boxes can be stacked easily. This makes it easy to expand and contract the hive to meet the needs of the bee colony.

(ix) Drugs can be applied with ease through the openings.

Disadvantages of the frame hive in Tropical Africa

(i) A frame hive with two supers (upper chambers) is very expensive.

(ii) It needs a high degree of craftsmanship to build. This is because frame dimensions must be precise and so village carpenters are not skilled enough for the job and suitable tools for large-scale production of frame parts may not be available.

(iii) Wood for frame construction must be seasoned for at least a year but most carpenters cannot invest their capital in this.

(iv) The need to keep stock of frames to replace those removed during honey harvesting creates an additional cost.

(v) The need to import centrifugal honey extractors, decapping knives, trays and other sophisticated equipment cannot be ruled out.

(vi) If frames are unguided, honeybees find it difficult to start the combs correctly on the frame.

(vii) A hive with supers (upper chambers) is heavy and difficult to carry on the head. Therefore, a vehicle may be required to move colonies if the need arises.

(viii) Because frames do not fit together as the tip bars do, it is very difficult to control the numerous bees which pass through the spaces between the frames and the tip of the hive.

Advantages of the top-bar hive

i) It is cheaper and easier to make because any semi-skilled carpenter can make it as it requires a few simple tools to make.

ii) All materials needed to make it are locally available and so there is no need for their importation.

iii) The hive can be opened easily and quickly because there is no need to employ a hive tool.

iv) Top bars occupied by combs can easily be detected so that the hive can be opened from the empty side. This avoids crushing the bees between the top bars when lifting the first combs.

v) The top bar hive is lighter to carry even when the colony is inside.

vi) More bees wax can be produced and this increases the beekeeper's earnings.

vii) There is need to employ the queen excluder because bees keep their brood chamber separate from the honeycomb. Clean honey is harvested leaving combs undisturbed.

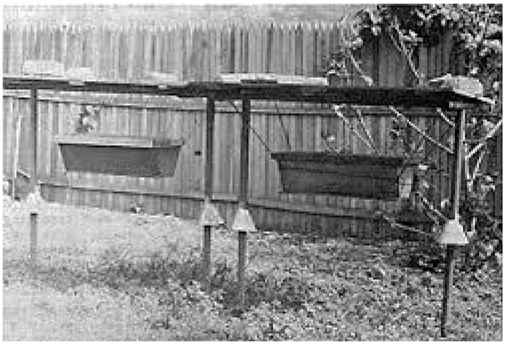
viii) Bees in the top bar hive can be easily controlled when harvesting or inspecting the combs.

ix) Honey production is high because a well-managed hive with a good strong colony can produce between 50 and 120 kg of honey annually.

x) Only a few extra top-bars need be held in stock to replace worn-out or damaged bars.

xi) Honeycombs adulterated with pollen are of high value because pollen is a nutritious food supplement. The only way the nutrition is passed on is through honey harvested from such combs.

Disadvantages of the top-bar hive



i) Top bar hives with newly constructed combs and combs filled with honey are not easily transported on lorries along bad roads with potholes.

ii) Bees are often crushed between top bars as the farmer rearranges the bars after removing them from the hive body, especially when colonies are manipulated at night.

iii) A top bar-hive is easier to steal as it is light and compactly designed.

iv) Honey can only be extracted by destroying honeycombs either by using the solar wax melter to dissolve the comb cells or by crushing them and squeezing out honey. Bees have to build up new combs which involves time, material and resources of the honey.

EQUIPMENT REQUIRED BY THE BEEKEEEPER

a) **The smoker**

This is next in importance to the beehive since no honeybee will ever allow anyone to harvest its honey without a fight. No honey harvesting should be done without a smoker because bees are very aggressive. The smoker is made of two parts, namely:

i) The container: This is a metallic can, big enough to carry enough dry material to last at least 40 minutes.

ii) Bellows section: This puffs air into the container to drive the smoke out of the can. The container is loaded with wood shavings, smoldering cow dung or any dry material which provides white smoke (No oil or kerosene should ever be used in a smoker). The smoke renders bees docile so as not to disturb the beekeeper.

b) **Hive tool**

This is used to remove the frames from the beehive. The Kenyan top-bar hive may not need a hive tool but a knife instead.

c) **Knife**

The knife may be used to pry open top bars or frames which are usually glued to the hive body by the bees. The knife is also used to cut the portion of the comb that is attached to the hive body, for separating two combs that are joined together and for cutting out the honeycomb from the top bar during honey harvesting. A knife can perform almost all the functions of the hive tool but the hive tool cannot be used to cut bee combs as neatly as is required.

d) **The brush or quill**

This is used for brushing bees off gently from the comb to the hive. It must have soft hairs. A strong large quill like an ostrich or turkey feather does it better than a brush.

e) **The feeder**

This is a container turned upside down and so arranged that water trickles slowly from it for the bees to drink.

f) **Protective clothing**

This is for keeping bees from accessing the flesh of the beekeeper. This includes a bee suit (overall), gloves, veil and a pair of boots that must be acquired before any work involving the opening of the hive is undertaken. When working with bees during daylight hours, light coloured clothing, preferably white, yellow or green should be worn. For night work, dark clothes are better.

The bee suit: This is sewn to cover all parts of the body except the head, hands and feet.

- **The veil:** This is the most important clothing item. It can be made out of straw to make a hat. Netting is sewn firmly around the hat and attached at the back by a piece of cloth. The veil protects the head, face and neck from attack.
- **Bee gloves:** These must be sewn with good flexible white leather to protect the

hands and fingers from stings and they help the beekeeper to scoop up bees with his hands if the need arises.

- **A pair of long boots:** These protect the feet from stings. When boots are not available, a pair of light shoes and thick white socks can be worn. Dark or black socks should only be worn at night when bees' vision is poor.

BEEHIVE MANAGEMENT

The Apiary

An apiary (bee farm) is a place where beehives are kept. In Africa, an apiary should contain only about 10 hives per km^2. In bee keeping the farmer can make a good living without necessarily becoming a landowner.

Site selection

Because bees are aggressive, hives should not be placed on the farm but about 100 – 200 metres away from crops. Hives should be away from fertile spots of the farmland. They should be placed on the poorest portions of the farm for which the farmer has little or no other use. An ideal apiary site should be:

i) A way from public places, e.g. playground, noisy commercial or industrial areas, dwelling places, livestock sheds or roads.

ii) Near a fresh water supply, e.g. a stream or river, lake, fishpond or any other appropriate source.

iii) Near food sources, e.g. citrus, avocado, coconut, neem or eucalyptus plantations waste area or marshy land.

iv) Fairly dry land, away from swampy or flooding valley or any low land with stagnant water. This is because humid areas promote fungal diseases and prevent proper honey curing.

v) Accessible to good roads. This is because honey is heavy and good roads facilitate easy transportation of the produce.

vi) Protected from bad weather, especially wind. Hives should be sited on the leeward side of a hill with rainfall not exceeding 1,250 mm a year.

vii) Away from smoke and fire, clear of danger from vandalism and unfriendly neighbours.

How to bait bees

Baiting can be done using the following:

i) **Bee wax**

This is the best bait because it can quickly attract a swarm of bees. It is the most reliable bait as it retains its properties for a long time unlike other baits that must be replenished or replaced when the old supply gets exhausted or destroyed.

A small piece of bees wax is rubbed against the inner walls of the hive. This encourages bees to visit the hive. Bees wax can also be rubbed against the tip of the v-shaped or ridge portion and the wooden starter top bars. This will guide bees to build their combs along it. Otherwise the bees may build combs across the top-bars that makes brood nest control impossible.

ii) **Syrup**

Sweet juices and syrup can be used to bait bees. These can be put in a container. Provide sticks as landing boards to avoid bees drowning. Special care must be taken to restrain other insects from visiting the syrup.

iii) **Granulated sugar**

This may be sprinkled on the floor of the hive.

iv) **Lavender**

Spray or sprinkle a few drops of lavender in the hive. The smell will attract honeybees to visit the bee hive.

v) **Lime**

One or two lines of lime can be placed inside or outside the hive. Lime juice left in the hive may help attract bees.

vi) **Lemon grass**

This can be rubbed on the inner sides of the hive.

vii) **Cow dung**

Dry cow dung is usually burned to glaze the inside of the hive.

viii) **Water**

This is mostly used in the dry savannahs where water is scarce but not in areas with plenty of water.

NOTE:

After baiting the hive and treating the top bars, the latter must be neatly arranged, leaving no gaps in between them. Check whether the tip bars fit the hive body. Do not leave any gaps anywhere because they will cause problems when the colony is being moved. Let the bees only use the entrance if possible.

Beehive maintenance

i) Use a wood preservative like creosote to treat the outside of the beehive. This protects wood from decomposition.

ii) In absence of a preservative, paint the outside of the beehive before placing it in position.

iii) Cover the top with corrugated iron sheet whose sides are rimmed with wood. This is to prevent rainwater from entering the hive and spoiling the honey as well as to preserve the wood.

Installation of the beehive

A beehive can be suspended between two trees or on sturdy branches of big trees. It can also be installed on a platform or a rock. Hanging beehives has the following advantages and disadvantages:

Advantages

i) It is cheaper than installing the hive on a platform.

ii) The lizard, an important beehive predator does not become a serious problem.

iii) Cattle and other grazing animals cannot tip the hive over.

iv) Running water cannot carry the hive away.

v) It is easier to prevent ants from reaching the hive than when it is installed on a stand.

vi) The hive is not easy to be stolen by thieves if suspension wires are properly attached.

Disadvantages of hanging beehives

i) A suspended beehive can easily swing. This makes the bees alert and they are prepared to pounce on anyone who is around.

ii) Honey harvesting and brood-nest control are difficult to execute during the day.

iii) It is not easy to change the location of the hive. This is because removing it from the tree may result in tipping it over and spilling the whole contents. Sometimes the only way to remove it from the tree is by cutting the suspension wires.

How to install a beehive

- To hang a beehive in a tree, select a suitable branch and test its strength because some hives can be as much as 60 kg in weight.
- Inspect the tree to ensure it is ant-free.
- The hive should tilt slightly, with the entrance down so that any water entering the hive can trickle out. It should be parallel with and one metre above the ground.

❖ ***Some common practices in apiary management***

Bee colony examination

Bee colony examination should be done to establish how the colony is progressing. This is by opening the hive and inspecting each comb. This tells the farmer whether:

- Honey is being prepared and capped regularly.
- The colony is getting ready to swarm.
- The hive has been attacked by parasites.

General rules for hive inspection

i) Wear protective clothes for example overalls, veil, hat, boots, etc to protect the whole body. It is better to have an assistant with you during the operation.

ii) Work in pairs; one operating the smoke and the other working the tip-bars and combs.

iii) Get a good smoker with large bellows. The fuel container must be large enough to carry enough fuel to last through the whole operation. Use wood shavings and take a knife with you.

iv) Puff some smoke gently around the hive then puff continuously through the main operation. Wait about 1-2 minutes for the bees to rush in and gorge themselves.

v) Using the hive tool or knife, pry open the lid of the hive. If it has been propolised (top bar hives have no problem with propolising). With the tip-bar hive, knock at the top bar to determine which are without combs, the empty side makes the most noise. The frame hive does not need to be knocked) using the hive tool or knife, pry up the top-bars from the empty side. Then puff some smoke gently to drive bees to the other side of the hive.

vi) Remove the first comb and inspect it. If it is a brood comb, check to see if the cells are regularly filled and well sealed, especially if the comb contains queen and drone cells as well as worker cells. This is a sign that the colony is preparing to swarm. If it is a honeycomb, look to see whether the cells are fully capped (containing ripe honey) or uncapped or partly capped (containing unripe honey).

vii) Replace the comb even if it is full of ripe honey. It can be removed and taken away later during honey harvesting operations that call for special equipment.

viii) Replace the comb, give a puff of smoke, go on to the next comb and repeat the operation until all the combs have been inspected.

ix) If more than 10 brood combs are found, remove the excess because if too much brood is allowed to emerge, the hive will become overcrowded and the colony may abscond. These brood combs can be placed in another hive to strengthen its colony if necessary.

Bee stings

- If a sting is inserted into the skin, it must be scraped away with the finger nail or knife.
- When it is pulled out, more poison will be injected into the flesh.
- If the result is itching and swelling, do not rub the spot because this will cause more pain and swelling.
- Treat bee stings by applying cold cloths.
- In extreme cases, send the victim to the hospital.
- For first aid, administer ephedrine.

Causes of bees to sting

- Visiting the hive during the warm part of the day.
- Disturbing them without smoke.
- Breathing into the hive, especially if one has been drinking alcohol.
- Making noise or drumming when bees are nearby.
- Wearing a cosmetic item that contains bees wax.
- Standing in bees' flight path.
- Wearing dark clothes near the hive during the day.
- Making jerky movements near the hive.
- Crushing a bee near the hive or squashing a bee body and smearing the juice on one's body.
- Swatting with the hand to drive away a bee.

How to avoid stings

Remember a queen-less colony is very aggressive during it's early days.

- Every bee that stings dies afterwards, therefore if bees are enticed to strike, it means they are being killed. As these field bees die, there is a reduction in output and so less honey will be obtained.
- If not protected, run away after the first sting. The attacker may chase the victim but he should not be afraid of a second sting by the same bee.
  The bee can be killed so that she cannot return to the colony to pass on information.

Management of frame hives

The African frame hive may have 10-13 frames. The number of supers to be stacked on the brood chamber depends on the strength of the colony. The queen excluder in this hive enables the beekeeper to only harvest clean honey which is not adulterated by pollen and brood. Easy handling of combs also facilitates quick manipulation.

Baiting

The following points should be noted when baiting a frame hive:

i) Frame must be wired and he comb foundation fixed to help bees build a foundation comb.

ii) Frame hive should not be hang but should be placed on special stands about 30 cm high. Hive stands must be protected against ants and weeds.

iii) Only the brood chamber should be installed on the first day. The super is stacked on the brood chamber only when the colony needs more space to build more combs.

iv) A queen excluder may be inserted on top of the brood chamber or between the super and the brood chamber.

v) A swarm of bees can be hived except that the swarm can be passed through the top of the hive between the frames before the lead is replaced.

vi) When bees and their combs are removed for the new hive, honey and empty combs should be placed side by side next to the brood combs to provide he needed warmth for brood rearing.

Water for bees

- Regular fresh water supply helps bees to make honey very quickly during the honey flow season which coincides with the beginning of the dry season. Water is very important for honey bees as it is used to dilute brood food and cool the hive by evaporation.
- If colonies are not located near any water source the bee keeper must provide some.
- Water dripping gradually from a stand pipe is ideal for feeding bees.
- Any water meant for bees should contain straws or other floating material that the bees can use as landing boards so that they do not drown.

Record Keeping

There are two important records kept in beekeeping, namely: the colony and operational records.

1. **The Colony Record**

➢ The climatic condition of the locality in association with the colony's progress must be studied. The rainfall and temperature pattern in relation to flowering and movement of bees should be studied. This alerts the farmer on when swarming takes place, best time to split colonies to make them increase or collect wild bees for hiving, harvesting season etc.

- Seasonal arrival of pests and disease development is recorded, e.g. arrival of the wax moth, wild ants, beetles etc.
- Individual colony records should be kept, e.g. when the hive was colonized, whether the bees moved in voluntarily or if a wild colony was captured.
- Weigh the individual hive when it is colonized and every month or two weeks, check the weight again to find whether progress has been made. This can be by lifting the hive to feel the weight. The general progress assists the farmer to know the condition of the queen.
    - Record when the bees carry pollen into the hive, observing them at different times and occasionally estimating the number of bees bringing in pollen. If they are many, it means the brood is being reared and the queen is laying more eggs. If the number decreases, find out why and if there is decrease in weight, the bees may have swarmed or the queen is failing to lay eggs an must be replaced.
    - Crayons may be used to mark individual records on the top cover of the hive while general records are kept in a notebook.

2. **Operational Record**

- Keep a notebook recording information on visits to the apiary site, purchases, labour, transport costs, servicing equipment and all other expenses as well as incomes generated.
- Material that will be required on the next visit should be listed and prepared.
- At the end of the year, the success or failure of the operation should be assessed and it is best to reduce costs and maximize returns on investment. Actual profits should be determined.

COLONY MANIPULATION
(Honey and beeswax harvesting and extraction)

Honey Harvesting

- Wear protective clothes. Take along with you a good knife or hive tool, brush (quill) and a good container which should be rustproof
- Smoke the hive and open it.
- Remove combs one by one (give a puff of smoke before removing each one) and look at them carefully.
- Empty combs, brood combs and uncapped honey should all be returned to the hive. Only full combs of ripe honey should be taken away. When such a comb is found, brush any bees on it into the hive and use a knife to cut off the comb honey.
- Leave about one cm on the tip-bar to guide the bees to work on the next honey crop.
- Carry on with the harvest until a dark comb is reached. This comb usually contains both honey at the top and brood below.
- Some combs may not be easy to remove because bees may have attached them to each other, especially where space has been left between the tip bars. Use a knife to separate them.
- If the hive entrance is in the mid-section, there will be honey in both sides. Replace all the top bars and treat the other side in the same manner, but leave 10 combs in the middle. This will assist (entice) bees to work faster to produce the next honey crop than if all the honey combs were taken away.
- After removing the surplus honey, rearrange the top bars carefully in the same manner as before.
- If bees are rushing out between top-bars, drive them back with smoke but avoid crushing them unnecessarily.

- Close the hive carefully making sure the lip is firmly placed on the hive.
- Cork the smoker after work is done do not throw left over fuel into the bush as it
can cause bush fires.

Honey Harvesting in daylight

- The farmer brings to the site an empty hive and a container with a lid for carrying the harvested honey.
- Smoke the hive heavily from outside to force the "security guards" and any other bees of the colony that are waiting outside the hive to return to it. Continue smoking until the bees have lost all their aggressiveness.
- Carry away the hive from the site to the direction opposite to the flight runaway and place it on a platform or on the ground at least 50m away from the nearest hive in the apiary. The empty hive is left at the hive site to serve as a temporary home for any returning foragers or those that escaped from the hive when it was moved for harvesting.
- Work as quickly as possible to avoid robber bees that can cause trouble. Carry out harvesting or another operation in the normal manner.
- When work is over, close the hive and return it to its original position and remove the empty hive. Any bees in it or those waiting outside will then rejoin the hive.

Advantages of harvesting during daylight

- It ensures proper execution and efficient harvesting without the attacking bees chasing nearby inhabitants.
- Diseases can easily be detected.
- Hive predators can be found and eliminated.
- Crushing of combs and bees between top-bars is avoided or minimized.
- Top bars can be easily restored to their proper position.

- Work can be done throughout the day in a pleasant atmosphere without rushing.

Honey and beeswax extraction

Traditional methods

Honey is extracted by squeezing with hands. This seems to be the quickest method for the average honey-tapper who cannot afford a solar wax-melter.

HOWEVER:

- The hand contaminates the honey
- Unripe honey ferments within a few days after extraction.

The combs including brood, unripe and capped honeycombs are all stacked on a wire mesh, and a container is put underneath the pile of combs. The fire begins to consume the combs and honey and was flow down into the container until all bombs are completely consumed by the fire. The material collected in the container is left untouched until next morning. The bee's wax which has hardened at the top of the honey is removed and honey is poured into bottles.

Disadvantages

- Honey loses its nutritional value and quality when exposed to high temperatures.
- The smoky fire employed is full of ashes, charcoal and dust which contaminates the honey.
- The brood combs also add water to the honey and so it cannot be stored for long or enter international market.

The solar wax melter

This is a simple device which can be made by local craftsmen. The melter is made of wood and lined with a galvanized metal plate and has a glass or clear plastic cover. The base is airtight. The melter can be painted black to absorb more heat. On a sunny day the wax extractor is capable of generating a temperature of $61^{0}C$, enough to melt down a bee comb so that both honey and bees wax flow into a container inside the box.

Molding bees wax

Collected bees wax can be molded in the following ways:

i) Use of a container with a rounded bottom and a mouth wider than the bottom with a very smooth inner surface. Many plastic containers are suitable.

ii) Place a small quantity of water (about a table spoonful) in a cooking pot and put on fire (don't melt beeswax in a dry container) it should not be exposed to fire because it burns easily and can be damaged by too much heat. Melt bees wax and all be combs outdoors.

iii) Add all the beeswax and watch carefully as wax melts down. Remove it from the fire immediately after the last lump of wax has melted.

iv) Pour melted beeswax into the mold and place in a dry place to cool.

v) Remove the cakes of bees wax the next morning.

vi) The dark material collected at the bottom can be removed with a knife and can be sold to a shoemaker. The clean bees wax is ready for the market.

Uses of honey

i) It is mostly used as human food, locally and internationally.
  - It is used in certain alcoholic beverages where honey substitutes sugar, in cooking and baking, in child feeding.
  - It is used as a supplement for athletic and strenuous activities and diabetics.

ii) It is used as an ingredient in drugs like cough syrup, a sweetening agent in drugs, especially for children.

iii) It is used for animal feeding, like in dairy cows to increase milk production, donkeys and race horses for extra energy, an additive to poultry mash and feed for fish farms.

iv) In veterinary medicine, it is used in the treatment of certain diseases like acetonemia.

v) In cosmetics, it is used as a facial cleanser and in hand lotions.

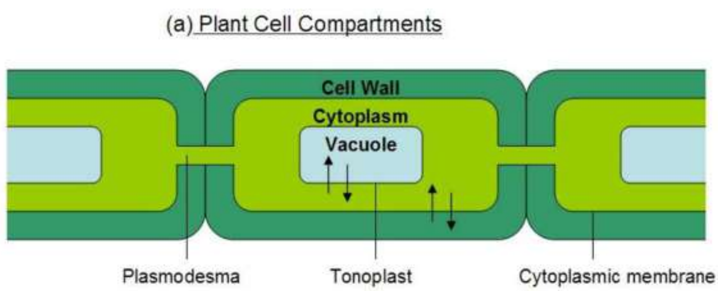
vi) It is used in mice and rat-repellant compounds.

CHAPTER IV

PLANT PHYSIOLOGY

PHYSIOLOGY Comes from the word *physis* (Greek) means "nature" or "origin" *logos* (Greek) means "study"
The scientific study of function in living systems. A sub-discipline of biology, its focus is in how organisms, organ systems, organs, cells, and bio-molecules carry out the chemical or physical functions that exist in a living system.

Plant physiology is a branch of study in Botany dealing with the physiological processes or functions of plants. ... It helps us analyze plant processes such as mineral nutrition, photosynthesis, transportation, respiration and finally plant development and growth which are characteristics exhibited by living entities



Plant functions: in terms of its physiological process and the water and nutrient balance in the plant

Plant –water relations

A) Permeability- on the basis of permeability, there are four types of cellular structures as referred below.

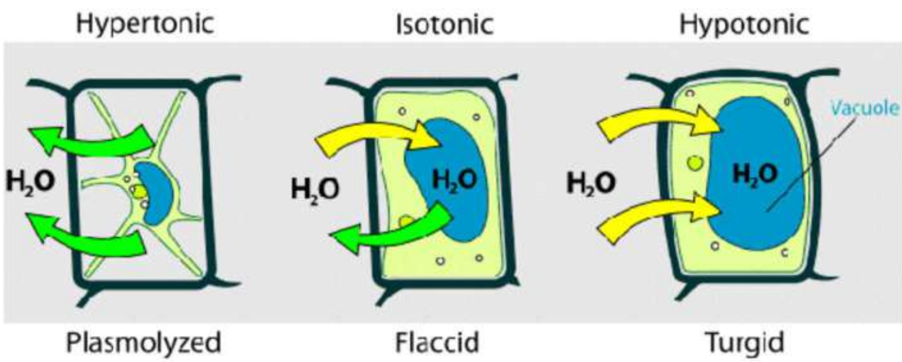
Impermeable structures: they inhibit the movement of both solvent and solute molecules through them, Eg- Lignified, Cutinised or Suberised cell wall of the plant.

Permeable structures: they allow diffusion of both solvent and solute molecules through them. Eg- Cellulose cell wall.

Semi-permeable membranes: Such membranes allow diffusion of solvent molecules but do not allow passage of solute molecules. Eg- Parchment paper

Differentially permeable membrane: All bio-membranes allow some solutes to pass in addition to the solvent molecules. Eg- Plasmalemma, tonoplast and membrane surrounding the organelles. They are sometimes called as selectively permeable.

B) Concentration of solutions:



On the basis of solute in solution, there are 3 types of solutions.

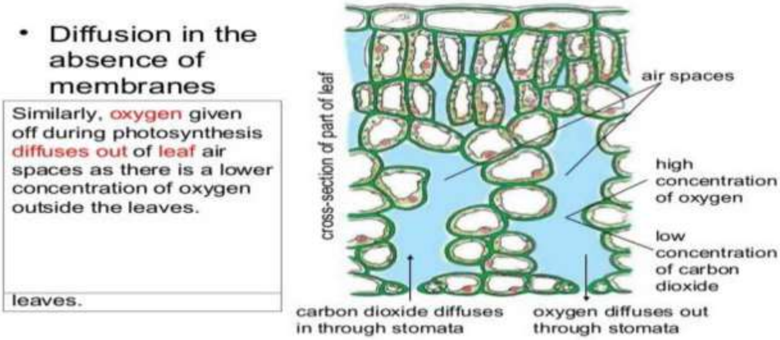
Isotonic solution: if a solution in which a cell is placed has solute concentration equal to that of the cell sap, the two solutions are termed isotonic.

Hypertonic solution: if the solute concentration of outer solution is more than that of the cell sap, the outer solution is known as hypertonic solution

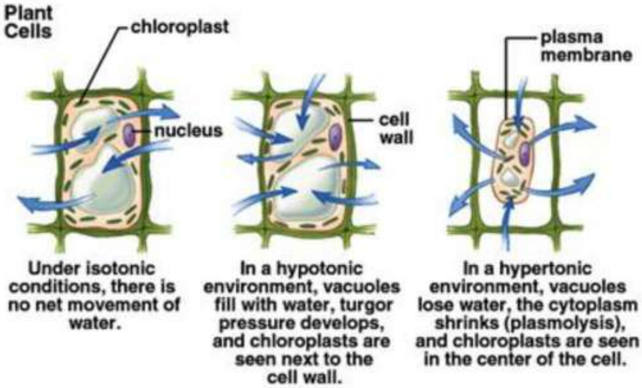
Hypotonic solution: if the solute concentration of the outer solution is less than that of the cell sap, the outer solution is called hypotonic.

C) The different processes:

Diffusion- The movement of the molecules of gases, liquids or solutes from their region of higher concentration to the region of lower concentration until the molecules is evenly distributed throughout the available space is known as diffusion. The exchange of gases like CO2 and O2 between the aerial organs of the plant and the outer atmosphere as well as the movement of gases, liquids and solutes inside the plant body are accomplished largely by the process of diffusion. The rate of diffusion is determined by factor like relative density, temperature, concentration gradient and concentration of medium.



Osmosis: Osmosis is essentially a special type of diffusion of liquid. When two solutions of different concentrations are separated by means of a semi-permeable membrane, the diffusion of water or the solvent from the solution of lower concentration to the solution of higher concentration, until a state of dynamic equilibrium is attained is known as osmosis. Actually the diffusion of the solvent takes place both ways across the membrane but the diffusion of the solvent is more from the solution of lesser concentration to that of the higher concentration.



There is a relevance to osmotic pressure and osmotic potential in this state of diffusion that happens in osmosis.

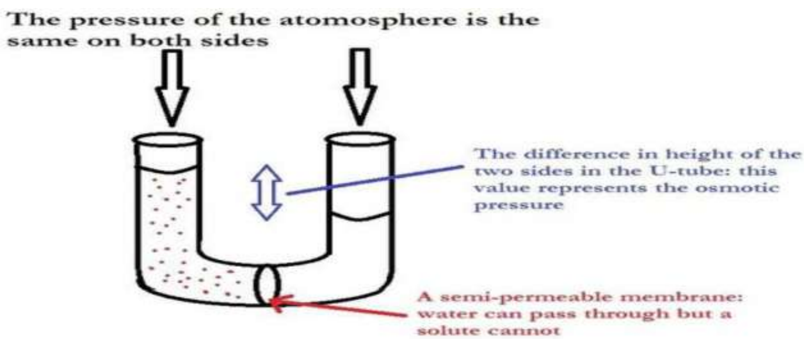
In a classic example of osmosis, plants use osmosis to absorb water and nutrients from the soil. The solution in the roots of the plants is hypertonic, drawing in water from the surrounding hypotonic soil. Roots are designed as selectively permeable membranes, admitting not only water, but some useful solutes, such as minerals the plant needs for survival. Osmosis also plays a critical role in plant and animal cells, with fluids flowing in and out of the cell wall to bring in nutrients and carry out waste.

Fluid passes both in and out of the semi-permeable membrane in osmosis, but usually there is a net flow in one direction or another, depending on which side of the membrane has a higher concentration of solutes. It is possible to alter the process of osmosis by creating pressure in the hypertonic solution. When the pressure becomes so intense that the solvent from the hypotonic solution cannot pass through the membrane, it is known as osmotic pressure, and it will prevent the attainment of an isotonic state.

The potential of water molecules to move from a hypotonic solution (more water, less solutes) to a hypertonic solution (less water, more solutes) across a semi permeable membrane is called osmotic potential.

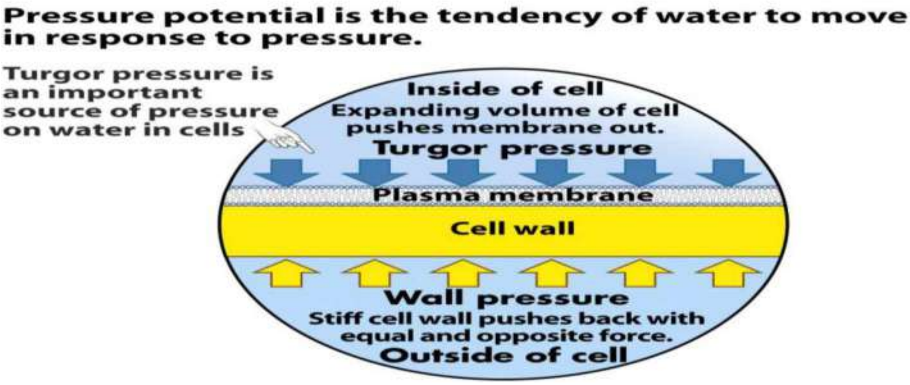
Hence can be deduced as below:

The potential with which the water molecules diffuse through the membrane is called osmotic potential. The osmotic potential is otherwise called water potential (or) chemical potential. The water potential of pure water at 25°C is zero. When a solute (sugar or salt) is added to pure water, the water potential is decreased and it becomes negative as the free energy decreases. Always water moves from a region of higher water potential to a region of lower water potential. The symbol for water potential is Ψ and the unit is pascal.



Turgor Pressure, Wall Pressure and Pressure Potential

The diffusion of water into a cell by endosmosis (diffusion into the living cell from outside) creates a positive hydrostatic pressure on the rigid cell wall. This is termed as **turgor pressure**. The cell wall reacts on this water with equal and opposite force and is termed as **wall pressure.** The wall pressure forces the water out of the cell into the external chamber or the adjacent cell. The terms turgor pressure and wall pressure have been replaced by **pressure potential**



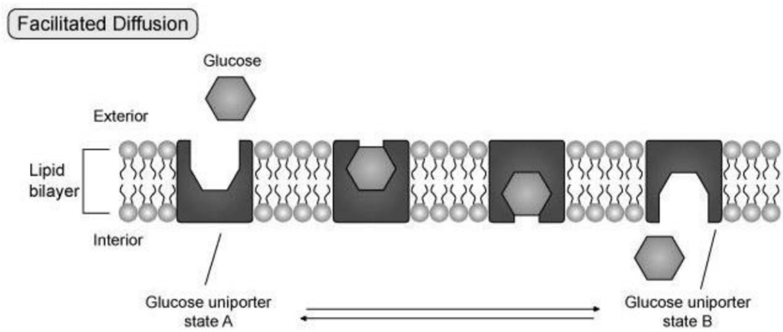
Facilitated Diffusion: A gradient must already be present for diffusion to occur. The diffusion rate depends on the size of the substances; obviously smaller substances diffuse faster. The diffusion of any substance across a membrane also depends on its solubility in lipids, the major constituent of the membrane. Substances soluble in lipids diffuse through the membrane faster. Substances that have a hydrophilic moiety, find it difficult to pass through the membrane; their movement has to be facilitated.

Membrane proteins provide sites at which such molecules cross the membrane.

They do not set up a concentration gradient: a concentration gradient must already be present for molecules to diffuse even if facilitated by the proteins. This process is called facilitated diffusion.

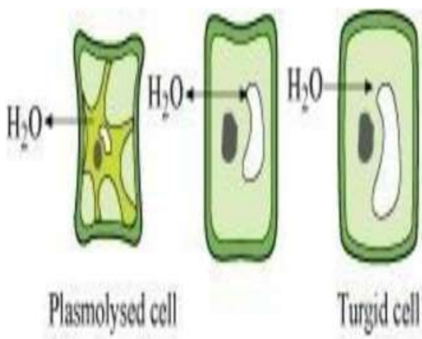
In facilitated diffusion special proteins help move substances across membranes without expenditure of ATP energy. Facilitated diffusion cannot cause net transport of molecules from a low to a high concentration – this would require input of energy. Transport rate reaches a maximum when all of the protein transporters are being used (saturation). Facilitated diffusion is very specific: it allows cell to select substances for uptake. It is sensitive to inhibitors which react with protein side chains.

Passive symports and antiports: Some carrier or transport proteins allow diffusion only if two types of molecules move together. In a symport, both molecules cross the membrane in the same direction; in an antiport, they move in opposite directions. When a molecule moves across a membrane independent of other molecules, the process is called uniport.



Plasmolysis

If a plant cell is placed in a hypertonic solution, the plant cell loses water and hence turgor pressure, making the plant cell flaccid. Plants with cells in this condition wilt. Further water loss causes plasmolysis: pressure decreases to the point where the protoplasm of the cell peels away from the cell wall, leaving gaps between the cell wall and the membrane. Eventually cytorrhysis – the complete collapse of the cell wall – can occur. There are some mechanisms in plants to prevent excess water loss in the same way as excess water gain, but plasmolysis can be reversed if the cell is placed in a weaker solution (hypotonic solution). Stomata help keep



Process of plasmolysis

water in the plant so it does not dry out. Wax also keeps water in the plant. The equivalent process in animal cells is called crenation.

The liquid content of the cell leaks out due to diffusion. The cell collapse and cell membrane pulls away from the cell wall (in plants). Plasmolysis only occurs in extreme conditions and rarely happens in nature. It is induced in the laboratory by immersing cells in strong saline or sugar solutions to cause exosmosis, often using Elodea plants or onion epidermal cells, which have coloured cell sap so that the process is clearly visible.

Water Potential:

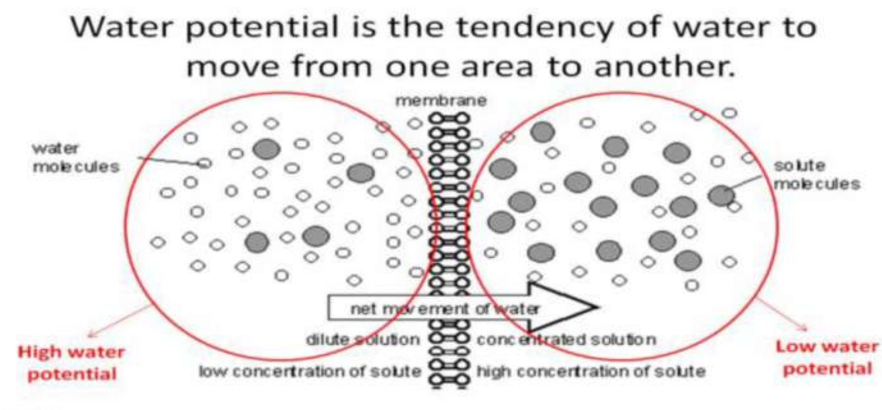
Water is essential for all physiological activities of the plant and plays a very important role in all living organisms. It provides the medium in which most substances are dissolved. The protoplasm of the cells is nothing but water in which different molecules are dissolved and (several particles) suspended.

Distribution of water within a plant varies – woody parts have relatively very little water, while soft parts mostly contain water. Terrestrial plants take up huge amount water daily but most of it is lost to the air through evaporation from the leaves, i.e., transpiration.

Because of this high demand for water, it is not surprising that water is often the limiting factor for plant growth and productivity in both agricultural and natural environments.

Water molecules possess kinetic energy. In liquid and gaseous form they are in random motion that is both rapid and constant. The greater the concentration of water in a system, the greater is its kinetic energy or ‗water potential'. Hence, it is obvious that pure water will have the greatest water potential. If two systems containing water are in contact, random movement of water molecules will result in net movement of water molecules from the system with higher energy to the one with lower energy.

Thus water will move from the system containing water at higher water potential to the one having low water potential. This process of movement of substances down a gradient of free energy is called diffusion. Water potential is denoted by the Greek symbol Psi or ψ and is expressed in pressure units such as pascals (Pa). By convention, the water potential of pure water at standard temperatures, which is not under any pressure, is taken to be zero.



Solute Potential

If some solute is dissolved in pure water, the solution has less free water and the concentration of water decreases, reducing its water potential. Hence, all solutions have a lower water potential than pure water; the magnitude of this lowering due to dissolution of a solute is called solute potential or ψs. ψs is always negative. The more the solute molecules, the lower (more negative) is the ψs. For a solution at atmospheric pressure

(water potential) ψw = (solute potential) ψs.

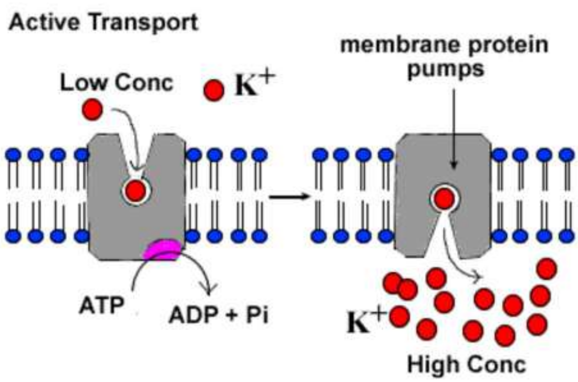
Pressure Potential

If a pressure greater than atmospheric pressure is applied to pure water or a solution, its water potential increases. It is equivalent to pumping water from one place to another. Pressure can build up in a plant system when water enters a plant cell due to diffusion causing a pressure built up against the cell wall, it makes the cell turgid; this increases the pressure potential. Pressure potential is usually positive, though in plants negative potential or tension in the water column in the xylem plays a major role in water transport up a stem. Pressure potential is denoted as ψp.

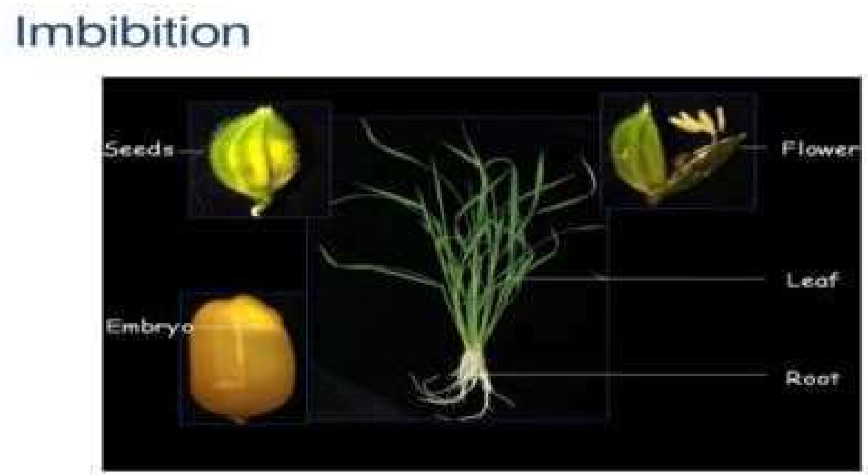
Water potential of a cell is affected by both solute and pressure potential. The relationship between them is as follows:

$\Psi w = \psi s + \psi p$

Active Transport: Active transport uses energy to pump molecules against a concentration gradient. Active transport is carried out by membrane-proteins. Hence different proteins in the membrane play a major role in both active as well as passive transport. Pumps are proteins that use energy to carry substances across the cell membrane. These pumps can transport substances from a low concentration to a high concentration (‗uphill' transport). Transport rate reaches a maximum when all the protein transporters are being used or are saturated. Like enzymes the carrier protein is very specific in what it carries across the membrane. These proteins are sensitive to inhibitors that react with protein side chains.



Imbibition: Imbibition is a special type of diffusion when water is absorbed by solids – colloids – causing them to enormously increase in volume. The classical examples of imbibition are absorption of water by seeds and dry wood. The pressure that is produced by the swelling of wood had been used by prehistoric man to split rocks and boulders. If it were not for the pressure due to imbibition, seedlings would not have been able to emerge out of the soil into the open; they probably would not have been able to establish.



Imbibition is also diffusion since water movement is along a concentration gradient; the seeds and other such materials have almost no water hence they absorb water easily. Water potential gradient between the absorbent and the liquid imbibed is essential for imbibition. In addition, for any substance to imbibe any liquid, affinity between the absorbent and the liquid is also a pre-requisite.

Root Pressure: is the pressure exerted by the cortical cells of the root upon their liquid contents under a fully turgid condition, forcing a quantity of them into the xylem vessels and through them upwards into the stem. Effects of root pressure is also observable at night and early morning when evaporation is low, and excess water collects in the form of droplets around special openings of veins near the tip of grass blades, and leaves of many herbaceous parts. Such water loss in its liquid phase is known as guttation.

Root pressure can, at best, only provide a modest push in the overall process of water transport. They obviously do not play a major role in water movement up tall trees. The greatest contribution of root pressure may be to re-establish the continuous chains of water molecules in the xylem which often break under the enormous tensions created by transpiration. Root pressure does not account for the majority of water transport; most plants meet their need by transpiratory pull. Conditions affecting root pressure are temperature, oxygen and moisture in the soil.

Guttation: is the loss of water in the form of liquid droplets. It occurs through hydathodes. Hydathodes occur at the vein endings on the margin of leaves. A hydathode consists of a pore in the epidermis, a large space containing loosely arranged parenchyma cells called epithem and ending of xylem elements. The process is common during warm, humid conditions. When absorption of water is more than transpiration, hydrostatic pressure is developed in the xylem elements of the veins, due to which water is pushed up the xylem elements and it comes out of hydathodes. The water droplets coming out have various minerals and it may form incrustation on the surface of the leaf when water gets evaporated.

Exudation: is the release of watery sap from an injured part of the plant. If an incision is made in the stemm upto the xylem, xylem sap oozes out. It occurs due to root pressure, phloem pressure, local pressure developed in the stem

Absorption of required substances for plant growth occurs through the part in contact with the soil, namely roots. The most specific region of absorption is the root hair region. A single root hair is a simple extension of the epidermis of a root cell, and reaches into the soil to absorb water. It exists to increase the surface area and therefore the rate at which water can be absorbed. These fine roots help in absorbing nutrients from the soil for the plant. Water moves into the root hair cells because it is moving down a water potential gradient, since a root cell has relatively low water potential due to its inorganic ions and organic substances. Water will enter through the membrane and into the cytoplasm and vacuole.

So the plants take in water from the soil through the root hairs. The water is carried in the xylem vessels to all parts of the plant. One fact to understand while learning this concept of transportation is that the distance between soil containing organs-roots and chlorophyll containing organs-leaves plays an important role.

Pathway of water across root cells:

The responsibility of absorption of water and minerals is more specifically the function of the root hairs that are present in millions at the tips of the roots. Root hairs are thin-walled slender extensions of root epidermal cells that greatly increase the surface area for absorption. Water is absorbed along with mineral solutes, by the root hairs, purely by diffusion. Once water is absorbed by the root hairs, it can move deeper into root layers by two distinct pathways:

- ***apoplast pathway***
- ***symplast pathway***

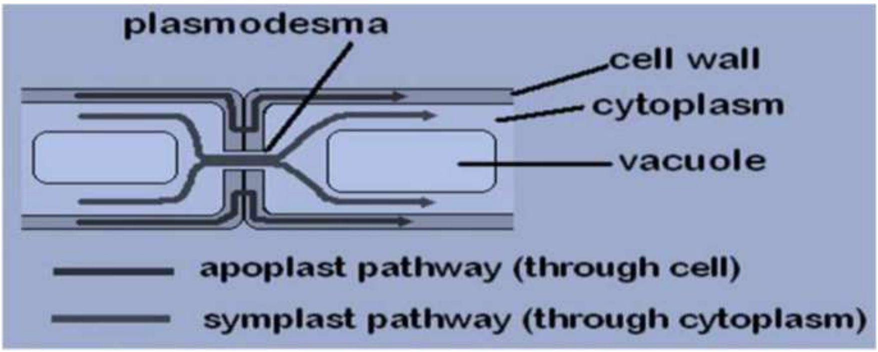
Within a plant, the apoplast is the free diffusional space outside the plasma membrane. It is interrupted by the Casparian strip in roots, air spaces between plant cells and the cuticule of the plant.

Structurally, the apoplast is formed by the continuum of cell walls of adjacent cells as well as the extracellular spaces, forming a tissue level compartment comparable to the symplast. The apoplastic route facilitates the transport of water and solutes across a tissue or organ. This process is known as apoplastic transport.

The symplast of a plant is the inner side of the plasma membrane in which water (and low-molecular solutes) can freely diffuse.

The plasmodesmata allow the direct flow of small molecules such as sugars, amino acids, and ions between cells. Larger molecules, including transcription factors and plant viruses, can also be transported through with the help of actin structures.

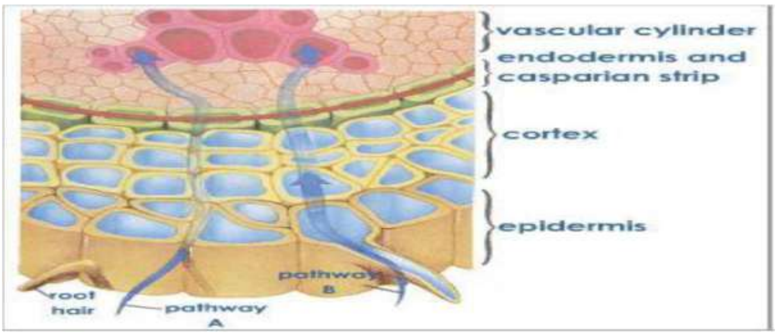
This allows direct cytoplasm to cytoplasm flow of water and other nutrients along concentration gradients. In particular, it is used in the root systems to bring in nutrients from soil. It moves these solutes from epidermis cells through the cortex into the endodermis and eventually the pericycle, where it can be moved into the xylem for long distance transport. It is contrasted with the apoplastic flow, which uses cell wall transport.



The process of water transfer: Water gets into the root hair by Osmosis. The cytoplasm and cell sap inside it are quite strong solutions. The water in the soil is normally a weaker solution. Water therefore diffuses into the root hair, down its concentration gradient, through the selectively permeable cell membrane.

The root hairs are on the edge of the root. The xylem vessels are in the centre. Before the water can be taken to the rest of the plant, it must travel to these xylem vessels. The path it takes is shown in the diagram above. It travels by osmosis through the cortex, from cell to cell.

The water moves up xylem vessels by suction pull. The pressure at the top of the vessels is lowered, while the pressure at the bottom stays high. Water therefore, flows up the xylem vessels. At the same time, when the pressure on top increases, it is automatically reduced due to transpiration.

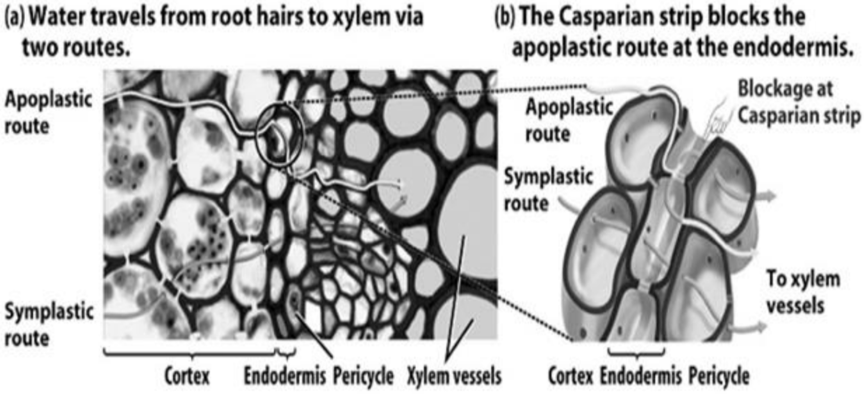


Being specific: From the root hair cells, water again moves down a concentration gradient toward the xylem, and can take one of three paths - apoplast and symplast and vacoular.

The apoplast pathway is where water takes a route going from cell wall to cell wall, not entering the cytoplasm at any point. The symplast pathway is where water moves between cytoplasm/vacuoles of adjacent cells. However, the apoplast pathway can only take water a certain way, near the xylem, the Casparian strip forms an impenetrable barrier to water in the cell walls, and it must move into the cytoplasm to continue. This gives the plant control over the ions that enter its xylem vessels, since water must cross a plasma membrane to get there.

The vacuolar pathway moves molecules through the vacuoles only of the plant. Water on reaching the xylem tissue moves through vessels and tracheids of the root, stem and leaves that are interconnected to form a continous system of water conducting channels reaching all parts of the plant.

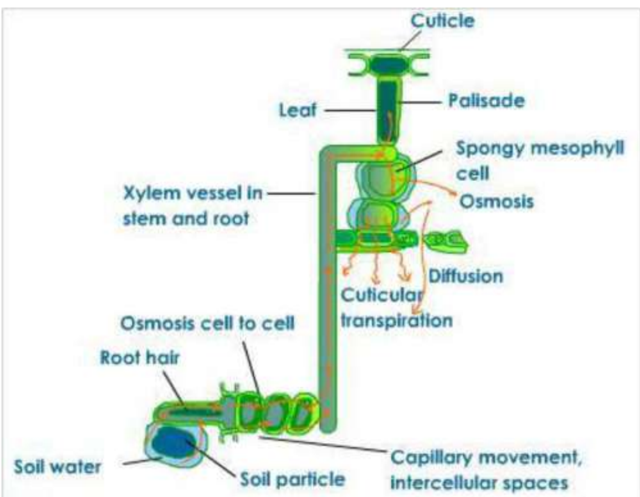
At the roots, the cells in contact with the soil actively takes up ions. This creates a difference in the concentration of these ions between the roots and soil. Water, therefore moves into the root from the soil to eliminate the difference.This means that there is steady movement of water into root xylem, creating a column of water that is steadily pushed upwards



Transpiration: is the process of letting out excess water as water vapour from the internal tissues of living plants through the aerial parts of the plant under the influence of sunlight.

Transpiration is the evaporative loss of water by plants. It occurs mainly through the stomata in the leaves. Besides the loss of water vapour in transpiration, exchange of oxygen and carbon dioxide in the leaf also occurs through pores called stomata (sing. : stoma). Normally stomata are open in the day time and close during the night.

The immediate cause of the opening or closing of the stomata is a



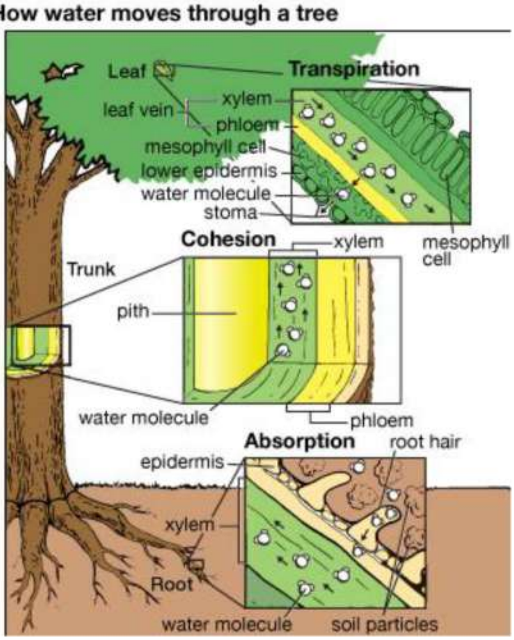
change in the turgidity of the guard cells. The inner wall of each guard cell, towards the pore or stomatal aperture, is thick and elastic. When turgidity increases within the two guard cells flanking each stomatal aperture or pore, the thin outer walls bulge out and force the inner walls into a crescent shape.

The opening of the stoma is also aided due to the orientation of the microfibrils in the cell walls of the guard cells.

Cellulose microfibrils are oriented radially rather than longitudinally making it easier for the stoma to open. When the guard cells lose turgor, due to water loss (or water stress) the elastic inner walls regain their original shape, the guard cells become flaccid and the stoma closes.

Ascent of Sap: The water absorbed from the soil by the root hairs is conducted upwards to the leaves and the growing regions of the stem and the branches. The movement of water from the roots to the upper parts of the plant is called ascent of sap or transport of water. Xylem is the path of the ascent of water.

How water moves through a tree



There are factors responsible for the ascent of sap- it is believed that root pressure forces up the water to a certain height, and that transpiration exerts a suction force on this column of water from above. In short, it may be said that root pressure gives a push from below and transpiration a pull from above. In this respect, transpiration is a more powerful factor.

The transpiration pull results in a continuous stream of water called the transpiration stream. It is a continuous stream of water extending from the xylem of the leaves to the xylem of the roots. In fact, transpiration pull can occur only when there is a continuous column of water. This continuity is maintained by the cohesive and adhesive properties of water.

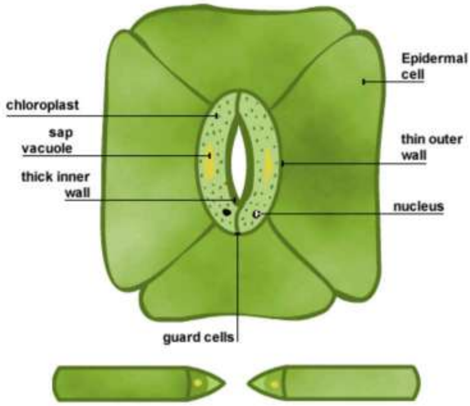
Adhesion causes the water molecules to adhere to the xylem walls and because of cohesion, the water molecules remain together and move up as a stream. Any break in this column, makes ascent of sap difficult. When a stem is cut, the water column moves away from the cut end of the xylem making conduction of water from the cut end difficult.

Stomata- structure and mechanism of opening and closing:

Stomata (singular-stoma) are small microscopic openings present on the surface of all leaves in quite a very large number. Stomata are present not only on the surface of leaves but also present on the surface of stem, branches, flowers, fruits etc. except on roots but in a little number. The number of stomata present on the surface of a leaf varies from 1,000 to 10,000 per square centimeter area of a leaf.

Stomata are present more in number in the lower surface (Ventral) of a leaf than on the upper surface (Dorsal) of a Dicot leaf. Stomata play a vital role in conducting a physiological process called transpiration and also helps in **exchange of gases** through stomata for photosynthesis as well as for respiration.

Each Stoma (sing.) is formed by two kidney shaped or Bean shaped cells called Guard Cells. These two kidney shaped cells enclose a small microscopic space in between them called Stoma. The guard cells which form the stoma are modified epidermal cells. Unlike other cells of epidermis, guard cells additionally possess chloroplasts in them which aid in the opening and closing mechanism of stomata. The outer convex surface of guard cell is elastic and thin in nature. The inner concave surface of the guard cell is highly thick and non-elastic in nature. The guard cells on their outer surface are covered



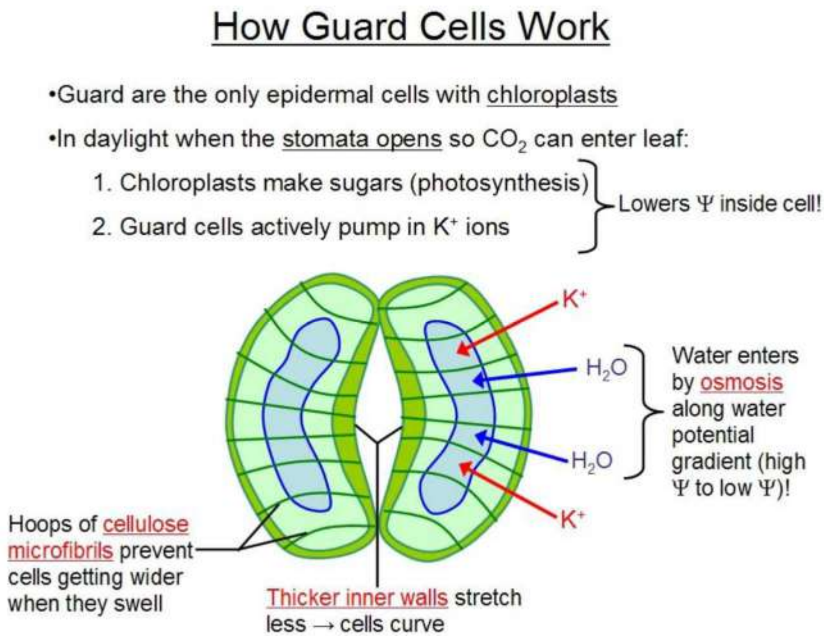
and protected by parenchymatous subsidiary or complementary cells or supporting cells which aid in opening and closing of stomata.

How does the stoma work under normal conditions?

Under normal conditions, the stomata remain closed at night, in the absence of light. They remain open during the day time, in the presence of light. In most plants they open fully in bright light, but in certain plants the stomata do so in diffuse light. Usually they open fully in the morning and close towards the evening.

They may close at daytime, when very active transpiration takes place from the surface of the leaf under certain conditions such as drynesss of water in the soil. The intensity of light markedly affects the degree of stomatal opening. The guard cells become turgid, full of water, expanding and bulging outwards, the stoma opens. When the guard cells become flaccid by losing water, the stoma closes.

The turgidity and flaccidity of the guard cells is due to the presence of sugar or starch in them. In light, the sugar manufactured by the chloroplasts of the guard cells accumulates in them and being soluble, increases the concentration of the cell sap. Under this condition, the guard cells absorb water from the neighboring cells and become turgid, opening the stoma. In darkness, on the other hand, the sugar present in the guard cells becomes converted into starch- an insoluble compound.



The concentration of the cell sap is lower than that of the neighboring cells. Under the condition, the guard cells lose water and shrink the closing stoma. The transformation of sugar into starch at night and vice versa at daytime is due to the acidity and alkalinity of the cell sap of the guard cells. In the absence of photosynthesis at night, the carbon di oxide accumulates in the guard cells and the cell's content becomes weakly acid. Under this condition, sugar is converted into starch. During the daytime, carbon-di-oxide is utilized in photosynthesis, and thus the cell contents become slightly alkaline. Under this condition, starch is converted into sugar.

Basing on these steps of working principles, the stomata play an important role in balancing the water content as well as help in preparation of food in plants.

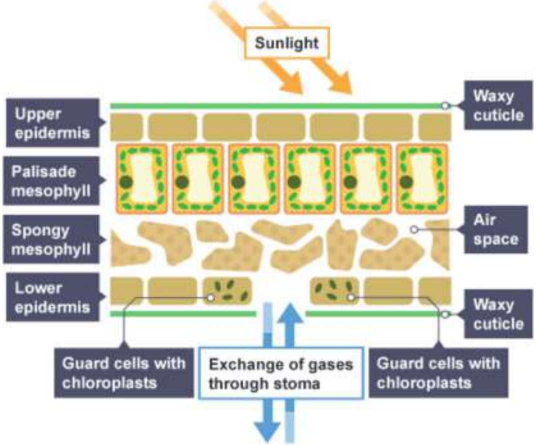
Diffusion in the leaves

One of the main functions of leaves is as a major site of **photosynthesis** – to produce glucose from water and carbon dioxide with the input of energy from sunlight.

To perform this function effectively, leaves are adapted to maximising the absorption of carbon dioxide and sunlight.

Adaptation	Purpose
Flattened shape	Larger surface area to absorb light and carbon dioxide
Thin	Short diffusion distance for carbon dioxide to diffuse into leaf cells, and oxygen to diffuse out of leaf cells
Stomata	Can open to allow diffusion of carbon dioxide into the leaf from the atmosphere, and the diffusion of oxygen and water vapour out of the leaf

The internal structure of leaves is also adapted to maximise the efficiency of exchange



Internal structure of a leaf

Adaptation	Purpose
Adaptation	**Purpose**
Internal air spaces in spongy mesophyll layer	Increases surface area of leaf to absorb more carbon dioxide

Note that the guard cells open and close the stomata depending upon the amount of potassium ions present in the fluid in the cell.

The more potassium ions that are present, the more the cells become turgid (swollen) and the bigger the opening.

The size of the opening is used by the plant to control the rate of transpiration and therefore limit the levels of moisture in the leaf which prevents it from wilting.

Photosynthesis

This name was first proposed by Barnes in1898. Photosynthesis means Photo-light; Synthesis-building up. It consists in the building up of simple carbohydrates, such as sugars, in the green leaf by the chloroplasts in the presence of sunlight along with carbon-di-oxide and water absorbed from air and soil. This process is a form of autotrophic nutrition and is accompanied by liberation of oxygen.

The volume of oxygen liberated has been found to be equal to the volume of carbon-di-oxide absorbed. By this process, not only simple carbohydrates are formed, but a considerable amount of energy is also transformed by the green cells into chemical energy and stored up as such in the organic substances formed.

Means of Autotrophic nutrition:

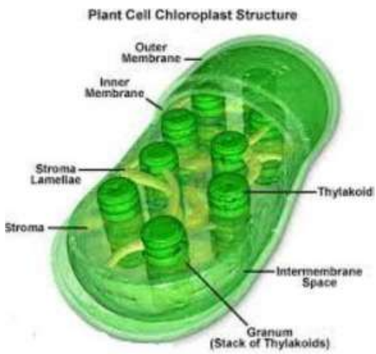
All living organisms need food. They need it as a source of raw materials to build new cells and tissues as they grow. They also need food as a source of energy. Food is a kind of ―fuel‖ which drives essential living processes and brings about chemical changes. So, nutrition is the process of acquiring energy and materials.

Plants need energy and raw materials for their growth. The plants take in the raw materials to prepare food of their own. Thus, building up of complex food molecules from simpler substances is called a synthesis and it needs enzymes and energy to make it happen. The enzymes are present in the plant‘s cells and energy for the first stage in the synthesis comes from sunlight.

The green pigments present in the chloroplasts of the leaves, works along with the energy synthesized, combining with the absorption of gaseous carbon-di-oxide from atmosphere and water from soil surface to prepare food of its own. This state is said to be autotrophic. The nutrition so derived is said to be autotrophic nutrition.

Specific sites of Photosynthesis: Leaves are the most important organs of photosynthesis. Leaves are said to be the food factory of the plants. This basic concept of food preparation in plants has complex systems, with the involvement of many smaller units of the plant body. The major site of photosynthesis occurs inside **the chloroplast**, a cell organelle, containing the green coloring pigment, the Chlorophyll.

Hence, Chloroplasts are the actual sites for photosynthesis. All green parts of a plant having chloroplasts are involved in photosynthesis.



There is evidence to suggest that the green substance chlorophyll, in the chloroplast of plant cells, plays a part in photosynthesis. Chlorophyll absorbs sunlight and makes the energy from sunlight available for chemical reactions. Thus, in effect, the function of chlorophyll is to convert light energy tochemical energy.

- ➢ Chloroplasts are surrounded by two membranes, which form the chloroplast envelope.
- ➢ They always contain chlorophyll and other photosynthetic pigments located on a system of membranes.
- ➢ The double layered membrane encloses a space filled with a ground substance called Stroma.
- ➢ The membrane system is the site of the light-dependent reaction in photosysnthesis.
- ➢ The membranes are covered with chlorophyll and other pigments, enzymes and electron-carriers.
- ➢ The system consists of many flattened, fluid-filled sacs called thylakoids which form stacks called grana.
- ➢ Each granum resembles a pile of coins and the lamellae are often sheet-like. Generally a chloroplast contains 40 to 60

grana. Grana are just visible under the light microscope as grains.

- The stroma is the site of the light-independent reactions of photosynthesis.
- The structure is gel-like containing soluble enzymes and other sugars and organic acids.
- Excess carbohydrates from photosynthesis is sometimes seen stored as grains of starch.
- The stroma contains circular DNA, RNA and enzymes for starch synthesis.
- As a matter of fact, as students of biology , we need to understand the structure of a leaf. A transverse section of a leaf will have the following parts:
- Upper epidermis
- Mesophyll layer Closely packed, single layered Palisade Parenchyma cells
- Loosely packed many layered Spongy Parenchyma cells
- Vascular bundle with xylem and phloem cells in the middle of spongy parenchyma.
- Lower epidermis with stomata at regular intervals.

Photosynthetic pigments: The photosynthetic pigments of higher plants fall into two classes, the chlorophylls and carotenoids. The role of the pigments is to absorb light energy, thereby converting it to chemical energy. These pigments are located on the chloroplast membranes-thylakoids, and thechloroplasts are usually arranged within the cells so that the membranes are at right-angles to the light source for maximum absorption

Features to know with reference to the process of photosynthesis:

The Biophysics of Light. The energy in sunlight occurs in ―packets‖ called photons, which are absorbed by pigments.**Chlorophylls and Carotenoids.** Photosynthetic pigments absorb light and harvest its energy.

Organizing Pigments into Photosystems. A photosystem uses light energy to eject an energized electron.

How Photosystems Convert Light to Chemical Energy.

Some bacteria rely on a single photosystem to produce ATP. Plants use two photosystems in series to generate enough energy to reduce NADP+ and generate ATP.

How the Two Photosystems of Plants Work Together.

Photosystems II and I drive the synthesis of the ATP and NADPH needed to form organic molecule

Details on Chlorophyll: Chlorophylls absorb mainly red and blue-violet light, reflecting green light and therefore giving plants their characteristic green color. The chlorophyll molecule has a flat, light absorbing head which has a magnesium atom in the centre. This explains the need for magnesium by plants and the fact that magnesium deficiency reduces chlorophyll production and causes yellowing. The chlorophyll molecule also has a long hydrocarbon tail which is hydrophobic-water-hating. The interior of the membrane is also hydrophobic, so the tails project into the thylakoid membranes and act like anchors. The heads are hydrophilic and lie flat on the membrane surface like solar panels.

Different chlorophylls have different side chains on the head and this modifies their absorption spectra, increasing the range of wavelengths of light absorbed.

Chlorophyll a is the most abundant photosynthetic pigment. It exists in several forms, depending on its arrangement in the membrane. Each form differs in its light absorption peak.

Carotenoids: Carotenoids are yellow, orange, red or brown pigments that absorb strongly in the blue-violet range. They are called accessory pigments because they pass the light energy they absorb on to chlorophyll. Carotenoids have three absorption peaks in the blue-violet range of the spectrum and apart from acting as accessory pigments, they may also protect chlorophylls from excess light and from oxidation by oxygen produced in photosynthesis. They are usually masked by green chlorophyll but can be seen before leaf fall because chlorophylls break down fast.

Photosystem- excitation of chlorophyll by light: When a molecule of chlorophyll or other photosynthetic pigment absorbs light it is said to be excited. The energy from the light is used to boost electrons to a higher energy level. The energy of the light is now trapped in the chlorophyll and has been transferred to chemical energy.

Light reaction: It is called as Hill's reaction. (In 1939, Robert Hill discovered that isolated chloroplasts were capable of releasing oxygen in the presence of an oxidizing agent-electron acceptor.)

During the reaction solar energy is absorbed by chlorophyll molecules and is converted into chemical energy-ATP. This production of ATP (Adenosine Tri Phosphate) is called photophosphorylation. ATP is made when energy is used to bond another phosphate to ADP.

With the absorption of sunlight, chlorophyll molecules come to an excited state from the ground state and these results in the transfer of an electron from the chlorophyll which leads to the reduction of NADP to NADPH2. This process is calledreduction. The hydrogen comes from water. This also requires energy which is provided by light. A role of ATP and reduced NADP is simply to carry the energy and hydrogen into the light-independent reactions which follow. When light shines on photosystems I and II, high energy electrons are released by the chlorophyll molecules in the photosystems. It is the energy from these electrons that is used in making ATP and reduced NADP.

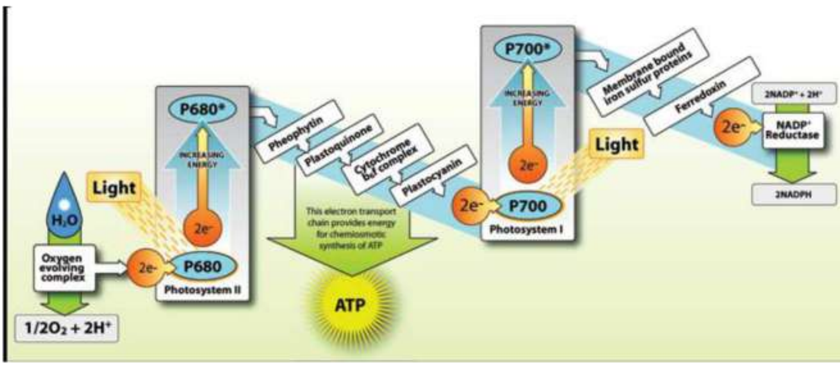
The initial and essential part of photosynthesis lies in Photolysis-splitting of water molecule into its two components. This is essentially a light reaction taking place in the body of the chloroplast. Water is the specific hydrogen donor and the oxygen released is by the photolytic splitting of water. Oxygen escapes to the atmosphere, while hydrogen combines with a reducing agent, Nadp formed in the chloroplast.

The salient feature of light reaction other than Photolysis is the process of flow of electrons from P680 and P700. Light provides the energy that causes this flow.

It is always better to remember this equation:

Chlorophyll → Chlorophyll+ + e-

(Reduced form) (Oxidized form) (Electron)



First, an electron from P680 or P700 is boosted to a higher energy level that is it acquires excitation energy. Instead of falling back into the photosystem and losing its energy it is captured by an electron acceptor (X or Y) as shown in the diagram. This represents the important conversion of light energy to chemical energy. The electron acceptor is thus reduced and a positively charged- oxidized chlorophyll molecule is left in the photosystem.

The electron then travels downhill, in energy terms, from one electron acceptor to another in a series of oxidation-reduction (redox) reactions. The energy lost during this electron flow is coupled to the formation of ATP. The pathway followed by the electron can be cyclic returning to where it began, or non-cyclic, ending at NADP. When electrons are added to NADP it is changed to reduced NADP

Reactions in reference:

The excited chlorophyll removes an electron from the hydroxyl ion derived from the water molecule.

$H_2O \rightleftharpoons H^+ + OH^-$

$OH^- \longrightarrow OH + e^-$

$4(OH) \longrightarrow O_2 + 2H_2O$

$NADP + 2H^+ + 2e^- \longrightarrow NADPH_2$

During this reaction ATP and NADPH2 is produced, which in turn, is utilized in the dark reaction.

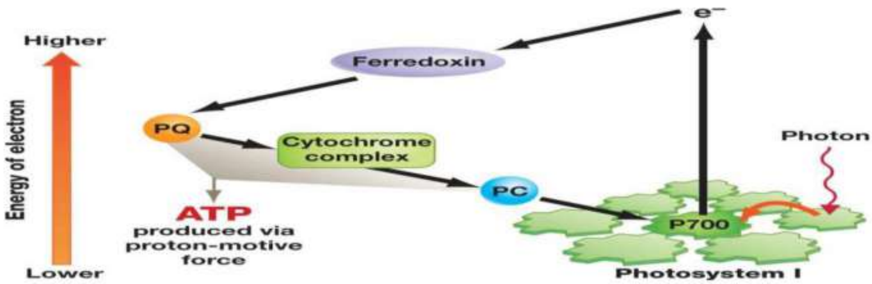
Electron Transport System:

The light driven reactions of photosynthesis are referred to as electron transport chain

The chlorophyll molecule which has lost an electron during this process regains its electron from the water molecule through an electron transport system and returns to its ground state. During the electron transfer Adenosine diphosphate gets converted to Adenosine triphosphate in the form of which some energy is conserved. This production of ATP associated with photosynthetic electron transport is called Photophosphorylation. It is of two ways:

Cyclic and Non cyclic Photophosphorylation.

In Cyclic Photophosphorylation, Photosystem I is involved. The electron released by excited P700 photocentre returns to this after passing through a series of electron carriers and is recycled after gaining solar energy trapped by PSI. Electron while passing through various electron carriers, loses energy which is used in the formation of ATP



The excited chlorophyll molecule P700 is oxidized and releases the electron. The released electron is received by primary acceptor X which passes it on to ferredoxin(Fd) either directly or through ferridoxin reducing substrate(FRS). Ferrodoxin transfers the electron to cytochrome b6 through plasto-quinone (PQ). The energy released in this step is used in the synthesis of one molecule of ATP. The electron ultimately returns to oxidized P700 molecule to repeat the same process.

Cyclic photophosphorylation supplements ATP production for dark reaction. ATP molecules produced may be utilized for providing energy for other energy requiring processes. It is not involved in CO2 fixation as it is not utilized in the production of NADPH needed for assimilation of CO2 to sugars during dark reactions.

In reference to the Z diagram of photosystems I and II. Two photosystems work sequentially.

First, a photon of light ejects a high-energy electron from photosystem II; that electron is used to pump a proton across the membrane, contributing chemiosmotically to the production of a molecule of ATP. The ejected electron then passes along a chain of cytochromes to photosystem I. When photosystem I absorbs a photon of light, it ejects a high-energy electron used to drive the formation of NADPH.

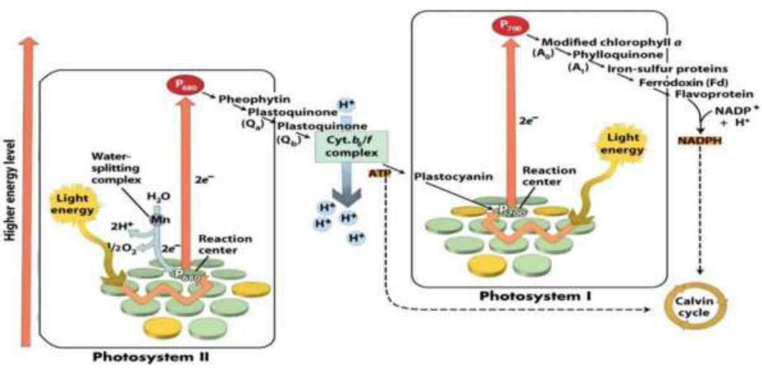
The non-cyclic photophosphorylation is explained as below:

Both the pigment systems,PSI and PSII are involved in this process. Electron released from the photocentres of PSI and PSII do not return to the site of release. Electron released during photolysis-splitting of water, is picked up by P680 photocentre of PSII. Pigment system II absorbs solar energy and electron is extruded from P680 and it passes through a series of electron carriers like Quinone, Plastoquinone, Cytochrome complex and Plastocyanin. Electron passing through Cytochrome complex releases sufficient energy to synthesize one molecule of ATP.

From Plastocyanin, electron is passed on to PSI which also absorbs sunlight. In excited state P700 extrudes the electron which passes through X, Ferredoxin and NADP reductase and ultimately NADP+ gets reduced to NADPH through H+ released during photolysis of water. Photolysis of water occurs at PSII in the presence of **Z enzyme complex** and cofactors like Mn++ and Cl-.

The energy released by electrons is basically used for pumping H+ ions across thylakoid membrane. Proton gradient is established which triggers the coupling factor to form ATP from ADP and ionic phosphate.

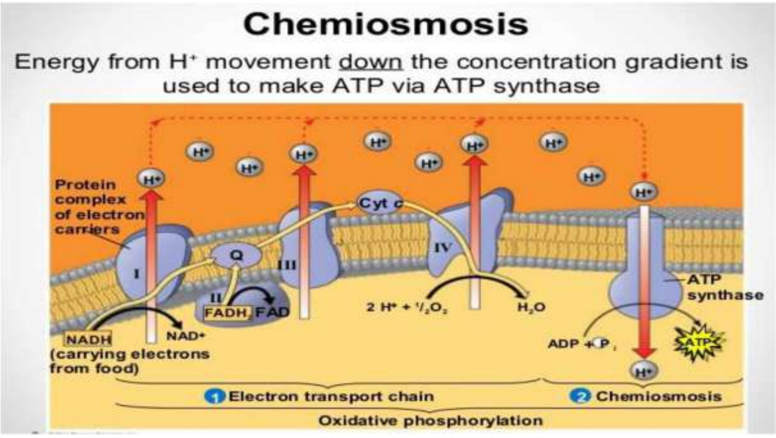
Non-cyclic phosphorylisation:



Making ATP: Chemiosmosis- Chemiosmotic hypothesis:

Chemiosmosis is a process that takes place in the membranes of the chloroplast.

The protons that accumulate on one side of the membrane now flow back across the membrane through specific protein complexes where chemiosmotic synthesis of ATP takes place



just as it does in aerobic respiration. The excited electron is shuttled along a series of electron-carrier molecules embedded within the photosynthetic membrane. Several of them react by transporting protons across the membrane, generating agradient of proton concentration. Its arrival at the pump induces the transport of a proton across the membrane. The electron is then passed to an acceptor.

Process as it happens in a thylakoid:

Each thylakoid is a closed compartment into which protons are pumped from the stroma by the *b6-f* complex. The splitting of water also produces added protons that contribute to the gradient. The thylakoid membrane is impermeable to protons, so protons cross back out almost exclusively via the channels provided by *ATP synthases.*These channels protrude like knobs on the external surface of the thylakoid membrane. As protons pass out of the thylakoid through the ATP synthase channel, ADP is phosphorylated to ATP and released into the stroma, the fluid matrix inside the chloroplast.

The stroma contains the enzymes that catalyze the reactions of carbonfixation.

Dark Reaction/Light Independent reaction:- Calvin Cycle.

Basic Information:

The key step in Calvin cycle:

Melvin Calvin and his coworkers at the University of California worked out the first step of what later became known as the Calvin cycle. They exposed photosynthesizing algae to radioactive carbon dioxide (14CO2). By following the fate of a radioactive carbon atom, they found that it first binds to a molecule of ribulose 1, 5-bisphosphate (RuBP), then immediately splits, forming two molecules of phosphoglycerate (PGA).One of these PGAs contain the radioactive carbon atom. In 1948, workers isolated the enzyme responsible for this remarkable carbon-fixing reaction: Rubisco.

The reactions of dark reaction where understood based on this concept of Calvin. It is also called as Biosynthetic phaseThe reactions that catalyze the reduction of CO2 to carbohydrates with the help of the ATP and NADPH2 generated by the light reactions are called the dark reactions. The enzymatic reduction of CO2 by these reactions is also known as carbon fixation. These reactions that result in CO2 fixation take place in a cyclic way and were discovered by Melvin Calvin. Hence, the cycle is called Calvin cycle.

Fixation of carbon during photosynthesis takes place in three stages: Fixation, Reduction and Regeneration of RuBP

a) Fixation:

The acceptor molecule of CO2 is a 5C compound called ribulose-1,5-bisphosphate (RuBP). Fixation of a molecule of CO2 to RuBP is catalyzed by the enzyme RuBP carboxylase. The resulting 6C compound is highly unstable and gets cleaved to form two molecules of 3C compounds called phosphoglyceric acid (PGA).

This process is called carboxylation. The 3-Phosphoglyceric acid(PGA) is the first stable product of photosynthesis.

b) Reduction:

The two molecules of PGA are further reduced to glyceraldehyde-3-phosphates in two steps. First, two PGA molecules are converted to 1,3 -bisphosphoglyceric acids by the enzyme PGA kinase. This reaction consumes two molecules of ATP in the ratio of one ATP for each molecule
of 1,3-bisphosphoglyceric acid formed.

In the second step, the two molecules of 1,3-bisphosphoglyceric acid are reduced to glyceraldehyde-3-phosphates by the enzyme glyceraldehyde-3-phosphate dehydrogenase with the help of the light generated reducing power NADPH2. So, two molecules of NADPH2 will beconsumed during this reaction. To reduce one molecule of CO2 upto reduction two ATP and two NADPH2 are consumed.

Glyceraldehyde-3-phosphate is the most important intermediate compound of the cycle as it is involved in the synthesis of fats and carbohydrates.

$$2\,moles\ of\ PGA + 2\,ATP \xrightarrow{PGA\,kinase} \begin{matrix} 2\,moles\,1,3-bisphospho- \\ glyceric\ acid \end{matrix}$$

$$\begin{matrix} 2\,moles\,1,3-bisphospho \\ glyceric\,acid \end{matrix} + 2NADPH_2 \xrightarrow[]{\begin{matrix} G-3-P \\ dehydrogenase \end{matrix}} 2\,moles\,G-3-P$$

c) Regeneration of RuBP

The glyceraldehyde 3-phosphate molecules are converted to RuBP through a series of reactions, which generate 4C, 6C and 7C phosphorylated compounds as intermediates.

For better and easy understanding of these reactions, a simplified scheme of Calvin cycle considering three CO2
molecules fixation reactions is shown below.

The reactions of regeneration of RuBP are as follows:

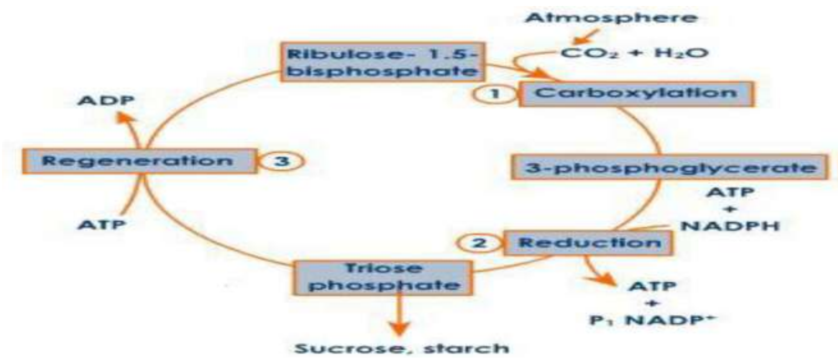
- Some of the Glyceraldehyde 3-phosphate molecules are converted to dihydroxy acetone phosphates.
- Glyceraldehyde 3-phosphate combines with dihydroxy acetone phosphate to form fructose1,6-bisphosphate.
- Fructose 1,6-bisphosphate undergoes dephosphorylation to form fructose 6-phosphate.
- Fructose 6-phosphate combines with glyceraldehyde 3-phosphate obtained from the fixation of second molecule of CO2 to form Ribose 5-phosphate (R5P) and Erythrose 4-phosphate (Er4P).
- Erythrose 4-phosphate combines with DHAP obtained from the second CO2 fixation, to form sedoheptulose 1,7-bisphosphate.
- Sedoheptulose 1,7-bisphosphate undergoes dephosphorylation to form sedoheptulose 7-phosphate.
- Sedoheptulose 7-phosphate combines with glyceraldehyde 3-phosphate obtained by the third CO2 fixation, to form two molecules of 5C compounds – ribose 5-phosphate and xylulose 5-phosphate (Xy5P).
- Ribose 5-phosphate and xylulose 5-phosphate molecules are transformed to ribulose 5-phosphate (Ru5P).
- Ru5P molecules are then phosphorylated by ATP to form RuBP molecules, which again enter into the cycle of CO2 fixation.

$$RuBP + CO_2 \xrightarrow{2ATP + 2NADPH_2} 2\, moles\, of\, G-3-P$$

$$Ru5P \xrightarrow{ATP} RuBP$$

In the above illustration, three CO2 molecules are fixed and the net gain is a 3C called DHAP. These triose phosphate molecules combine to form hexose phosphates, which are used to form sucrose. For every carbon fixation 3ATP and 2 NADPH2 are consumed.

Dark reaction of Photosynthesis is the C3 pathway.



Plant Nutrition:

Transport of food: Phloem translocates organic food.

Leaves make carbohydrates by photosynthesis. They also use some of these carbohydrates to make amino acids, proteins, oils and other organic substances.

Some of the organic food materials, especially sugar, that the plant makes is transported in the phloem tubes. It is carried from the leaves to whichever part of the plant needs it. This is called translocation. The carbohydrates made in the leaf during photosynthesis are converted to sucrose and carried out of the leaf to the stem.

From here, the sucrose may pass upwards to growing buds and fruits or downwards to the roots and storage organs. All plants of plant which cannot photosynthesize will need a supply of nutrients brought by the phloem. It is quite possible for substances to be travelling upwards and downwards at the same time in the phloem.

Mechanism involved in transport of food through phloem vessels:

A variation is observed with regards the cell sap of plants. The xylem sap is always a vey dilute solution, but the phloem sap may contain up to 25 per cent of dissolved solids, the bulk of which consists of sucrose and amino acids. There is a good deal of evidence to support the view that sucrose, amino acids and many other substances are transported in the phloem.

The movement of water and salts in the xylem is in upward direction, but in the phloem, the solutes may be travelling up or down the stem. The movement of the solutes in the phloem is bidirectional. Phloem, as is known, is continuous from the leaf to the root. There is a difference in turgor pressure between the leaves and the roots.

Turgor pressure is high in leaves and low in roots. Because of difference in turgor pressure, there is mass flow of the solutes and the solvent from the region of higher concentration-leaf to the region of lower concentration-root through the phloem.

The cytoplasmic strands extending through the sieve-plates are supposed to facilitate the movement.

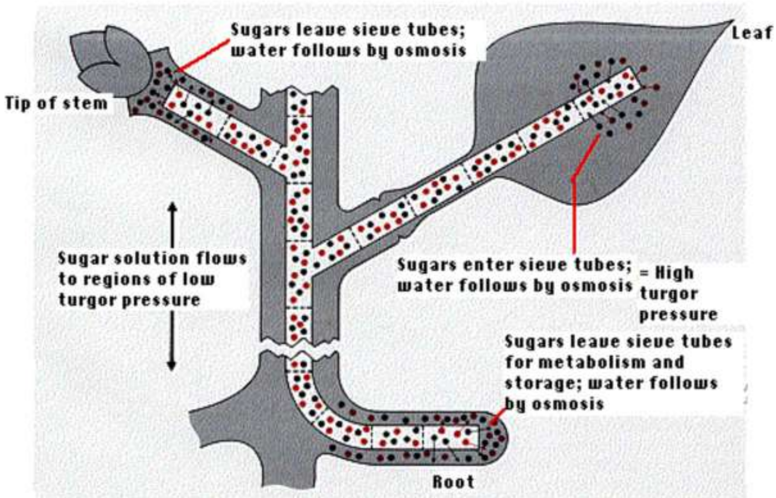
Further, the excess food left in the plant after usage by the plant cells, is stored in parenchymatous cells of different parts of the plant. The food may be in the form of carbohydrates, proteins, fats or oils.

Hence, the transport of mineral salts and food in plants is called translocation and the theory to understand based on this particulate movement is explained in Mass Flow Hypothesis.

Mass Flow Hypothesis:

Mass flow is the theory that explains solute transport in plants. Any area where sucrose is produced in a plant is known as a *source*, and any area where it is taken out is known as a *sink*.

This is the major hypothesis used to explain movement in phloem though it has its limitations.



The flow of solute through the phloem tubes is represented in the diagram, wherein the flow from the source of production to the storage areas can also be identified.

Sucrose is actively transported into the sieve tubes of the phloem at the source, lowering the water potential inside the sieve. So water enters the tubes via osmosis, creating a higher pressure inside the sieve tubes at the source.

At the sink, sugars leave the phloem to be used up, increasing the water potential inside the sieve tubes, so water leaves via osmosis, lowering the pressure inside the sieve tubes.

The result is a pressure gradient between source to sink, pushing sugars to where they are needed.

The major steps in the mass flow theory are as follows:

- Active transport/active movement of sugar (sucrose) at the source into phloem cells
- It causes the water potential of phloem contents to become more negative.
- Therefore water flows by osmosis from adjacent cells.
- This means that the hydrostatic pressure in phloem increases

- This causes mass flow within the plant body.

At another part of the plant (a sink e.g. the roots) the sugars are removed from the phloem by active transport, so the gradient is maintained within the plant body.

Mass can be understood with the help of an experiment as referred below:

Mass flow or bulk flow of solutes in sieve elements was first proposed by the German Scientist Munch (1931). Munch visualises a pumping action in mesophyll cells. According to Munch's hypothesis, the sieve tubes are connected to one another by means of cytoplasmic connections, forming a con-tinuous system called symplast. The symplast is impermeable on the outerface as it a system of interconnected protoplasts inthe plant.

Mass flow of solutes as per this hypothesis is as follows. A very high concentration of nutrients is present in the mesophyll cells due to two reasons:

a) Water is transpired continuously from the mesophyll cells and

b) Food is continuously synthesised.

Solutes are actively loaded into the phloem thus increasing their osmotic potential.

This increased potential draws water from the xylem vessels by means of osmosis. A hydrostatic pressure is built up in the sieve tubes. In the cells of the root, food material is continuously utilized reducing their osmotic potential as well turgor pressure. Thus a turgor Pressure gradient is established resulting in the mass flow of solution from supply end (leaf) to consumption end (root).

At the consumption end water diffuses into the xylem to be transported up to the leaves. Thus a circulatory system is established within the plant body.

The principle of mass flow may be illustrated with the help of a simple experiment. Two chambers A and B with selective permeability are connected by tube T containing water.

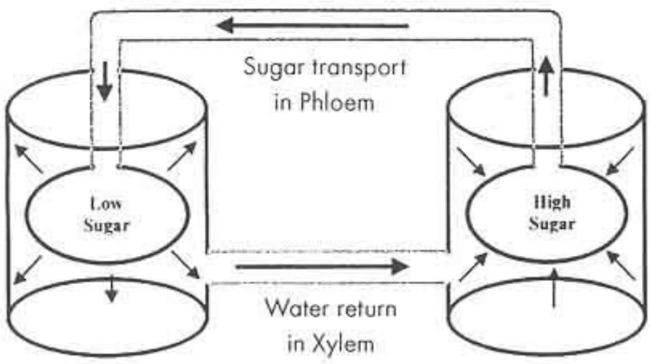


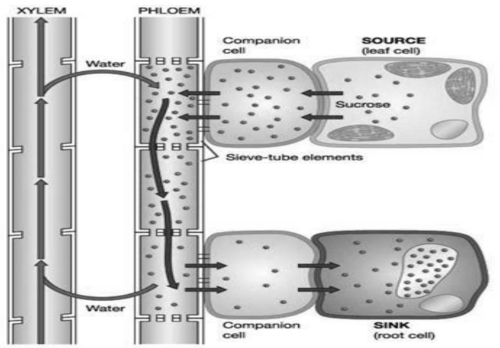
Diagram of Münch mass flow in phloem.

Here chamber A is Comparable to mesophyll cells, chamber B to the root cells. Tube T is comparable to phloem. This forms a closed system similar to what is seen in plants.

Chamber A contains a highly concentrated sugar solution, while in chamber B its concentration is low. The system is dipped in a water filled vessel. In this experimental set up A corresponds to supply end, B to consumption end and T to longitudinal sieve tube system. The outer vessel having water corresponds to xylem. The concentration at A causes rapid diffusion of water into it resulting in a high turgor pressure.

The solution from A therefore flows en masse to B until turgor pressure gradient is maintained. The flow stops, when turgor pressure both in A and B are equal. However if a high turgor pressure is maintained at A, there is a continuous flow from A to B This is possible in the plant by the continuous synthesis of food On reaching chamber B the water will flow into the outer vessel (xylem).

Experimental evidence to mass flow hypothesis



The main aspect of mass flow is that it requires a positive hydrostatic pressure in the seive tubes and a continuous supply of sugars in the leaves to generate enough pressure. Experimental evidences have clearly pointed to the presence of a positive pressure flow in phloem. Evidence in favour of this theory is that growth substances or viral particles are transported rapidly in sieve elements, when the leaves are illuminated. This suggests that sugars produced during photosynthesis will help generate the pressure gradient

Supporting evidence to the hypothesis:

- When the phloem is cut, sap oozes out, showing a pressure gradient.
- Suitable water potential gradient between leaves and other plants, in theory.
- Phloem sap has a high pH, which is to be expected since hydrogen ions are actively transported out of the cell.
- ATP is present in phloem sieve elements in high numbers since it is required for active transport of hydrogen ions.

Evidence against

- Sugar travels to many different sinks.
- Sieve plates are a barrier to mass flow.
- Does not require living cells, but phloem cells are alive

Mechanism of transport of food in phloem:

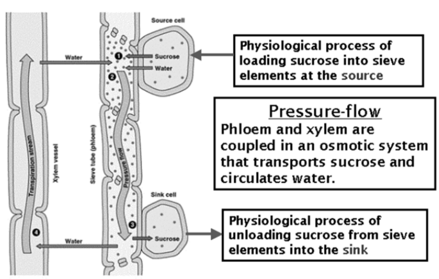
While considering the mechanism of translocation, it is pertinent to consider the various aspects of translocation and translocation structures. Translocation structures are sieve tubes which are living cells in which the protoplasm shows all cellular activities including streaming of particulate matter. The longitudinal columns have sieve plates through which plant proteins pass through and extend the entire length of the cell forming a continuum between the cells. Companion cells are in close contact with sieve cells. Most of the energy demand of sieve cellsis met with by companion cells which contain a large number of mitochondria.

It can be evaluated that mass flow theory called as pressure flow theory, where the concept is based on the extreme concentration gradient between the source and the sink. The transport of water as done by xylem and transport of food as done by phloem, in xylem the driving force is transpiration and root pressure while in phloem, it is active transport and osmosis.

To summarize, the movement of sugars in the phloem begins at the source, where sugars are loaded (actively transported) into a sieve tube. Loading of the phloem sets up a water potential gradient that facilitates the mass movement in the phloem

The diagram given below will give a clear understanding to the hypothesis:

The Pressure-Flow Hypothesis



CHAPTER V

MANAGEMENT OF NATURAL SCIENCES

Environment literally means the surroundings of an object.

Environmental science or ecology can be defined as the study of organisms in relation to their surroundings. Ecology is one of the most popular areas in biology. Mankind is greatly interested in ecology in view of the problems of over population, environmental pollution, human survival, pest control and conservation of natural resources. The solutions to all these problems involve ecological principles. Hence knowledge of environmental science is necessary for the survival of human race

Natural Resources are obtained from earth and its environment. Natural resources are classified as-

Renewable resources which are continuously available for use. They do not get exhausted with time. **For Example**, Sunlight, Wind, Water etc.

Non-renewable Resources are those which gets exhausted with time. They are present in limited amount on the earth. **For Example**, Minerals.

Natural Resources are also classified as biotic and abiotic resources.

Biotic Resources can be obtained from forests, animals etc. **For Example**, Fossil Fuels.

Abiotic Resources are those that come from non-living and non-organic material.

There are three important terminologies used which are as follows-

Refuse: Say no to things that are offered to an individual. **For Example**, an individual say no to buy plastic products.

Reduce: Minimize the use of anything. **For Example**, minimize the use of fans, tubelights etc.

Reuse: To use the things again and again is defined as reuse.

Repurpose: When a particular thing cannot be used for a purpose, it can be used for another purpose.

Recycle: When the material can be used to make the needed things.

Why do we need to manage the resources?

We need to manage the resources because they are present in limited quantity. With the increase in population, the demand for resources are increasing. So, there is a need to manage the resources to minimize their use and preventing the exploitation of resources.

Forests and Wildlife

Forests are biodiversity hotspots. Biodiversity is defined as different types of organism present on the earth. The main aim of conservation is to preserve the biodiversity. The loss of biodiversity will lead to loss of ecological stability.

Stakeholders

Stakeholders who are-

- They are the people living around the forests are dependent on forest and its products.
- Forest department of the government owns the land and also control the resources from forests.
- Industries that use forest produce .**For Example** Timber, Paper, Resin, Gum medicines, Sports equipment industries.
- Wildlife and natural enthusiast who want to conserve the nature.

Bamboo is used to manufacture huts, baskets and also for food storage. Implements used in agriculture, fishing is largely made up of wood. The government of India has recently instituted an Amrita devi bishnoi national award for wildlife conservation in the memory of an Amrita Devi bishnoi who sacrificed her life to protect the trees in 1731.

Management of Forest

Local communities have been working traditionally for conservation of forests and trees. Magsaysay Award recipient Sunderlal Bahuguna gave momentum to the Chipko Andolan. The Chipko Andolan was started in Reni in Garhwal. It was started by villagers especially by women at Reni village who tried to stop the commercial wood contractors from cutting the tree by hugging the trunk of the trees.

People Participation in the Management of Forests

The acceptance of locals who live in harmony with natural resources is vital for forest conservation measures. In 1972, the West Bengal forest department found that they have failed in maintaining the degraded Sal forests. Surveillance and policing had led to complete alienation of the people which led to clashes between forest officials and villagers. So, to overcome this, department was forced to changed the strategy. Forest officer A.K. Banerjee involved villagers in protection of 1272 hectares of badly degraded Sal forests in Arabari forest range of Midnapore district. In return he allowed villagers to collect fuelwood and fodder on payment of nominal fee. Also 25% of final harvest was given to village community.

Methods of Forest Conservation

- One of the most common method of forest conservation is silviculture. It is a method in which trees are grown and cultivated.
- Social forestry deals with the management and protection of the forest.
- Agroforestry includes land management for the cultivation of trees or shrubs.

Red Data Book

It is a document for recording the list of the endangered and rare species of animals, plants, fungi as well as some local species also.

Water for all

Water is required for fulfilling the basic needs of individuals. Human activities have altered the availability of water in various regions. Rain in India are due to monsoon. Common irrigation methods such as dams, canals and tanks are used in various parts of India. These methods are maintained by local people. This helps in storing water which can be used in agriculture. Not only in agriculture, daily needs of the common people can be met through this water.

Ganga Action Plan

This plan was launched by Shri Rajeev Gandhi in 1986. It is to improve the water quality of ganga by treatment, diversion and interception etc. It also includes treatment of domestic sewage and industrial effluents before releasing them into water bodies.

Dams

Large dams are made to store water that can be used in irrigation, in generating electricity etc. Indira Gandhi canal in Rajasthan areas has helped a lot in bringing greenery in different regions.

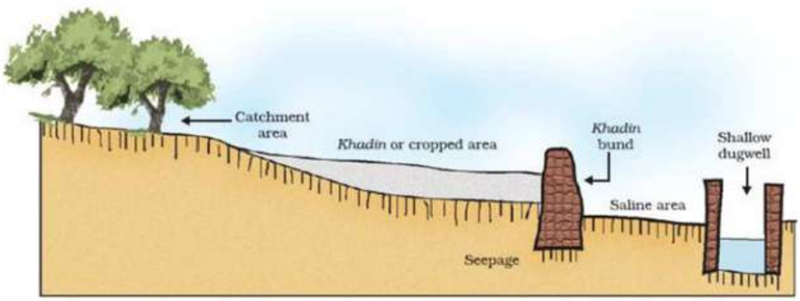
Dams control floods, provide water supply, electricity, waste management, recreation and wildlife habitat etc.

Criticism about large dams addresses three problems in particular- social problems, economic problems and environment problems

Construction of dams causes problems such as excessive sedimentation, water logging, sudden floods, soil erosion, large scale deforestation, health hazards, loss of livelihood etc.

Ancient Method of Watershed Management System

Different methods of watershed management system are known since ancient times. One of the method known as **Khadins** in Rajasthan which consists of a long earthen embankment built across the lower hill slopes. The area enclosed by the embankment is called as '**bund**' which collects huge amount of rainwater which flows down the slopes. Subsequently this water saturated land is used for crop production.



It stores water for drinking and household consumption purposes. Others include kulhs in Himachal Pradesh,, Ahar and Pynes in Bihar, Eris in Tamil Nadu, Bundhis in Madhya Pradesh, Surangams in Kerala etc.

Coal and Petroleum

- They are the non-renewable natural resources.
- Coal is formed by the remains of the trees buried inside the earth.
- Petroleum is formed by the bacterial decomposition of dead plants and dead animals. High pressure and temperature are needed for the formation of petroleum.
- Both coal and petroleum are fossil fuels.
- They are getting used up at higher rate, so there are more chances that they get exhausted soon.

Disadvantages of Fossil Fuels - Burning of fossil fuels release large amount of carbon-dioxide, sulphur dioxide and other harmful gases.

This causes air pollutions and the harmful effects of air pollution. This also raises the earth temperature and thus leads to global warming.

Steps to minimize the pollution from Fossil Fuels

- Reduce the use and burning of fossil fuels.
- Use of CNG in transport vehicles to reduce pollution.
- Alternative sources of energy such as Hydroelectricity, nuclear, solar, wind power and biogas should be used.

Conservation and Judicious Use of Resources

Natural resources are conserved for their biological, economic and recreational values. The use of natural resources in excess and unplanned way leads to imbalance in the environment.

Natural resources are conserved for their biological, economic and recreational values. The use of natural resources in excess and unplanned way leads to imbalance in the environment. A judicious balance should be maintained between exploitation of resources and its replenishment. Proper utilization and management of nature and its resources is termed as **conservation**.

We have to build a sustainable world, which should last forever. Some of the ways to sustain continuous use of resources are practices to utilise energy efficiently, avoid wastage of water, avoid usage of plastics and other non-biodegradable materials and to take care for the environment we live. It is important that we manage and use our resources carefully so as to preserve for the future generations.

Forest and its Importance

Forests are an important component of our environment and are dominated by microorganisms, flowering plants, shrubs, climbers, dense trees and provide a vast habitat for wild animals. Forests also contribute to the economic development of our country. Forests are vital for human life, it is a source for a wide range of **renewable natural resource**. They provide wood, food, fodder, fibre and medicine.

Forests are major factor of environmental concern. They act as carbon sink, regulate climatic conditions, increase rainfall, reduce global warming, prevent natural hazards like flood and landslides, protect wildlife and also act as catchments for water conservation. They also play a vital role in maintaining the ecological balance.

1. Deforestation and its Effects

Deforestation is the destruction of large area of forests. This happens for many reasons like intensive agriculture, urbanization, construction of dams, roads, buildings and industries, hydroelectric projects, forest fires, construction of mountain and forest roads. It is a threat to the economy, quality of life and future of the environment. India is losing about 1.5 million hectares of forest cover every year.

Effects of Deforestation

Deforestation gives rise to ecological problems like floods, drought, soil erosion, loss of wild life, extinction of species, imbalance of biogeochemical cycles, alteration of climatic conditions and desertification.

2. Conservation of Forests

India has an area of 752.3 lakh hectare classified as **reserved forests** and 215.1 lakh hectare as **protected forests**. The important measures taken for conservation of forests are as follows

Afforestation: Activities for afforestation programme (**Van Mahotsav**) includes planting and protecting trees with multiple uses which help in restoration of green cover. Destruction of trees should be curtailed.

Social forestry programme: It should be undertaken on a large scale with active participation of the public and utilization of common land to produce firewood, fodder and timber for the benefit of the rural community. This relieves pressure on existing forests and to safeguard future of tribals.

Forest Conservation through Laws: Adopting stringent laws and policies to conserve and protect forests are through National Forest Policy, (1952 and 1988) and Forest Conservation Act, 1980.

Wildlife and its Conservation

Wild life refers to the undomesticated animals living in their natural habitats (forests, grasslands and deserts) an area without human habitation. They are needed for maintaining biological diversity. It also helps in promoting economic activities that generates revenue through tourism. Conservation of forest and wildlife is interrelated with each other.

1. Decline in Wildlife Population

Wildlife of India is a great natural heritage. Exploitation of wildlife resources has decreased global wildlife population by 52% between 1970 and 2014. Over exploitation and shrinking of forest cover areas has resulted in animals becoming extinct, some are threatened and some are on the verge of extinction. In recent years, increase in human encroachment has posed a threat to India's wildlife.

2. Aims of Wildlife Management

The main aim of wildlife conservation are:

- To control and limit exploitation of species.
- To preserve the plants and animals from extinction.
- Maintenance of threatened species and protect species which are on the verge of extinction.
- Preserve the endangered species.
- To study the ecological relationship of the plants and animals in natural habitat.
- Hunting and poaching should be prohibited.
- Establishment of National parks, Wildlife sanctuaries, protected areas and Biosphere reserves.

The Wildlife protection Act was established in **1972.** The provisions of the act are

- Prohibit killing and hunting of specified animals.
- Constitute sanctuaries, national parks, and closed areas for wildlife conservation.
- Special schemes for preservation of endangered species.
- Constitute Central Zoo Authority and recognition of zoos.
- Restrict, regulate or prohibit trade in wild animals and products obtained from them.

CONSERVATION AND FOREST MANAGEMENT IN THE MAFINGA HILLS PRIORITY KEY BIODIVERSITY AREA OF ZAMBIA

The Mafinga Hills are located in the North Eastern part of Zambia. They host the source of the Luangwa River, the largest tributary of the Zambezi river and one of the four main watersheds of the country. Over the years, the Luangwa has come under threat from anthropogenic activities such as extending agricultural activities into the fragile riparian margins and unsustainable shifting cultivation (known locally as *Chitemene*).

The Luangwa river and the Mafinga Hills form part of what is known as the Eastern Afromontane biodiversity hotspot.

The term Afromontane refers to the plant and animal species common to the mountains of Africa. Other than being a source of the Luangwa river, the Mafinga Hills are home to a variety of endemic flora and fauna species (e.g Nyika Dwarf Frog).

A research done by the Wildlife and Environmental Conservation Society of Zambia (WECSZ) in 2015, revealed that the critical ecosystem in Mafinga has come under growing threat of degradation, especially with regard to the Luangwa river headwaters. As earlier mentioned, the threats were largely arising from human activity. In order to address the identified threats, WECSZ with support from the Critical Ecosystem Partnership Fund, in September 2016, commenced a project dabbed "Conservation and Forest Management in the Mafinga Hills Priority Key Biodiversity Area of Zambia."

The project would aim at not only conserving the critical Afromontane ecosystem but also empower local people through enhancing their participation in conservation activities and improving their livelihood through beekeeping. The target communities are namely Sichitambule, Malungule, Mulekatembo and Nachisitu villages, which all lie astride the Mafinga Hills in Mafinga District of Zambia.

As of January 2017, the project had trained a minimum of sixty people from Malungule, Mulekatembo and Nachisitu villages. The people in the three villages are mostly traditional pastoralists who also act as guardians of biological diversity. They play a critical role in the preservation of the headwaters of the Luangwa River.

Commenting on the project, chief Mwenichifungwe said his people had received the project with excitement and would commit to ensuring its success. WECSZ has made strides to help communities in the critical ecosystem of Mafinga to come up with nurseries for trees which are indigenous to the area. The resulting seedlings are expected to be planted along degraded riparian zones of the Luangwa river headwaters. This initiative is being carried out with the help of experts from Forestry Department and the Department of Agriculture.

As an environmental action group, the Wildlife and Environmental Conservation Society of Zambia seeks to work with communities in all areas around the country. As not for profit organisation, WECSZ endeavours to supplement national efforts to promote healthy environments and sustainable livelihoods.

Renewable and Non-Renewable Energy Resources

Energy is an important input for development. The expansion of possible energy resources has been directly related with the pace of agricultural and industrial development in every part of the world. Energy resources can be classified as non-renewable and renewable.

Non-renewable (Exhaustible) energy resources

Energy obtained from sources **that cannot renew themselves** over a short period of time is known as non-renewable energy. These are available in limited amount in nature. They include coal, petroleum, natural gas and nuclear power. These **conventional energy resources** account for 90% of the world's production of commercial energy and nuclear power account for 10%.

Renewable (Inexhaustible) energy resources

These energy resources are available in unlimited amount in nature and they can be **renewed over a short period of time**, inexpensive and can be harvested continuously. These comprise the vast potential of **non-conventional energy resources** which include biofuel, biomass energy, geothermal energy, water energy (hydroelectric energy and tidal energy), solar energy, wave energy and wind energy.

1. Fossil Fuels

Fossil fuels are found inside the earth's crust and are energy rich substances formed by natural process, such as **anaerobic**

decomposition of buried dead organisms, over millions of years. As the accumulating sediment layers produce heat and pressure, the remains of the organisms are gradually transformed into hydrocarbons. e.g. petroleum, coal and natural gas.

2. Coal and Petroleum

Coal and Petroleum are **natural resources**. They are called **fossil fuels** as they are formed from the degradation of biomass buried deep under the earth millions of years ago.

Coal is used for **generation of electricity** at Thermal power plants. **Petroleum** also known as **crude oil** is processed in oil refineries to produce **petrol** and **diesel** which are used to run automobiles, trucks, trains, ships and airplanes etc. **Kerosene** and **LPG** (Liquefied Petroleum Gas) obtained from petroleum is used as domestic fuel for cooking food.

The coal and petroleum reserves can get exhausted if we continue using them at a rapid rate. The formation of these fossil fuels is a very slow process and takes very long period of time for renewal.

3. Steps to Conserve Coal and Petroleum Resources

It is necessary to conserve or save coal and petroleum resources for the future use, which can be done by reducing their consumption.

- If electricity is saved, it will inturn reduce the use of coal
- Using bicycle for covering short distances instead of using cars, scooters or motorcycles
- Using pressure cooker can reduce the consumption of kerosene and LPG while cooking food. Solar cooker and solar heaters can be used wherever possible
- Motor vehicles should be designed with fuel efficient engines to increase efficiency and also reduce air pollution

PEOPLE'S PARTICIPATION IN FOREST CONSERVATION: CONSIDERATIONS AND CASE STUDIES

Many people of a great variety of cultures and land-use practices live in or around tropical forests. Although these people are all in some way dependent on forests, they have little else in common. In recent years, however, it has become much harder for forest-dependent people to use local forests and their products, owing to deforestation, logging, population pressure or legal initiatives such as the declaration of state forests, national parks or wildlife reserves. In many countries, plans to protect forest ecosystems have failed to address the needs and knowledge of local forest-dependent communities . Participation by local people is essential to any conservation effort.

In forest conservation, participation is often associated with community forestry, which refers to forest management or co-management by people living close to the forest. Legal, political and cultural settings for community forestry vary widely, and the term covers a wide range of experiences and practices. Community forestry is often associated with South and Southeast Asia, but it is also common in other regions .

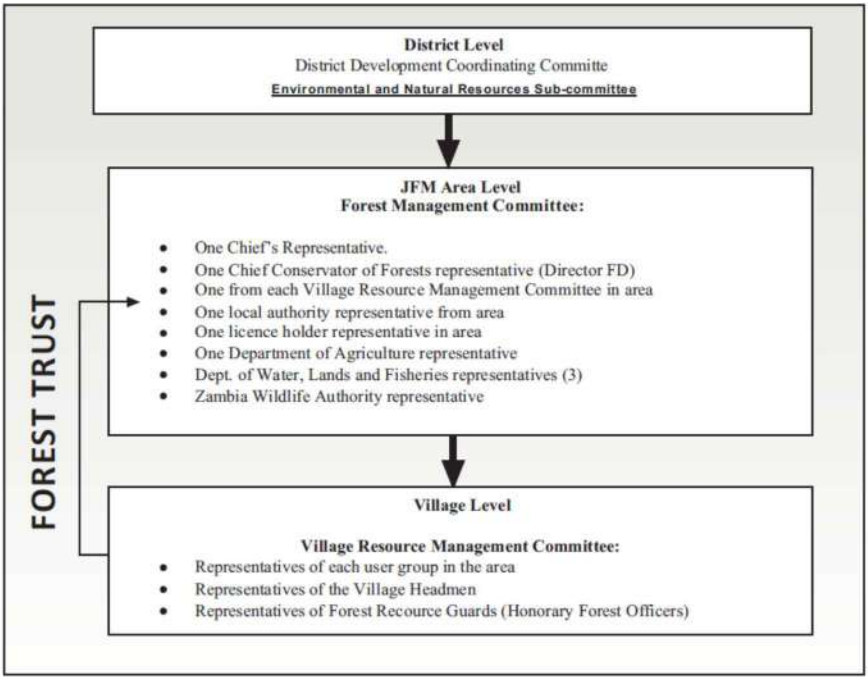
Although local participation is important in forest conservation, there are circumstances in which it is absolutely necessary, for example high population pressures and resource use conflicts, communal ownership and in smaller and more vulnerable protected areas. In such cases, conservation without local participation is doomed to failure. Nevertheless, participation in itself provides no guarantee of success. The outcome of participatory processes often depends on additional factors such as institutional or legal frameworks, and the education or interests of local people and other stakeholders. As the case studies in this paper show, governments and their agencies play a significant role in participatory processes by providing-or not providing-an 'enabling environment'.

This paper deals with different perspectives of participatory processes and, briefly, the key elements of enabling environments, for example institutional and regulatory frameworks, land tenure regimes and various forms of capacity building. This paper is based on an earlier paper by Isager and Theilade (2001), which provides a more detailed discussion of participation and forest conservation. Our intention is to give an overview of political and cultural contexts in which participatory processes will inevitably take place. We also offer some practical suggestions for improving these processes.

What is participation?

The concept of participation originally grew out of radical criticism of mainstream development projects in the 1960s and 1970s. Critics who asked why development projects often failed to meet their objectives came to the conclusion that a lack of participation was the reason. Too many projects, they argued, were designed and implemented without consultation or cooperation with the people whose lives they affected. Since then, participation has become one of the buzz words of development. It now seems that every project description or plan adopts a 'participatory approach', often because this is required by donor organizations for political reasons. Unfortunately, project planners and implementers frequently use the word 'participation' while continuing a traditional style of management that does not involve local people (Wily 1997). Nevertheless, true participation may lead to more effective conservation of forest resources .

JOINT FOREST MANAGEMENT IN ZAMBIA Joint Forest Management (JFM) in Zambia is organized vertically according to central, district, area and village levels . The Environmental and Natural Resources Sub-Committee of the District Development Coordinating Committee coordinates all natural resource management issues at district level including JFM activities. At the JFM area level the Forest Management Committee (FMC) has substantial representation from the state and some representation from local levels. At the village level there is the Village Resource Management Committee (VRMC) with a representative on the FMC. The Katanino community thus formally participates in JFM decisionmaking processes through representation on the VRMCs and the FMC.



It has been argued that a major reason behind the transition to JFM was the state's need to reduce forest management costs by delegating work to the localcommunities and not necessarily to give more rights to communities . An important question is then how far central government will go in devolving powers, resources and authority; and the appropriateness of the resulting property regimes in local contexts. The prescribed composition of JFM committees in the Forest Act does not cater for handling dynamic complexities at community levels ; nor does the Act specify explicit roles for chiefs and their local institutions. This is clearly an aberration, considering the authority commanded by chiefs in Zambia's
traditional society . The benefits that local communities may derive from jointly managed forests are mainly revenues from forest permits, which are shared with the central government

What is an Ecosystem?

The ecosystem is the structural and functional unit of ecology where the living organisms interact with each other and the surrounding environment. In other words, an ecosystem is a chain of interaction between organisms and their environment. The term "Ecosystem" was first coined by A.G.Tansely, an English botanist, in the year 1953.

Read on to explore the types, structure, components, types and functions of the ecosystem in the ecosystem notes provided below.

Types of Ecosystem

An ecosystem can be as small as an oasis in a desert, or as big as an ocean, spanning thousands of miles. There are two types of ecosystem:

- Terrestrial Ecosystem
- Aquatic Ecosystem

Terrestrial Ecosystems

Terrestrial ecosystems are exclusively land-based ecosystems. There are different types of terrestrial ecosystems distributed around various geological zones. They are as follows:

1. Forest Ecosystems
2. Grassland Ecosystems
3. Tundra Ecosystems
4. Desert Ecosystem

Forest Ecosystem

A forest ecosystem consists of several plants, animals and microorganisms that live in coordination with the abiotic factors of the environment. Forests help in maintaining the temperature of the earth and are the major carbon sink.

Grassland Ecosystem

In a grassland ecosystem, the vegetation is dominated by grasses and herbs. Temperate grasslands, savanna grasslands are some of the examples of grassland ecosystems.

Tundra Ecosystem

Tundra ecosystems are devoid of trees and are found in cold climate or where rainfall is scarce. These are covered with snow for most of the year. The ecosystem in the Arctic or mountain tops is tundra type.

Desert Ecosystem

Deserts are found throughout the world. These are regions with very little rainfall. The days are hot and the nights are cold.

Aquatic Ecosystem

Aquatic ecosystems are ecosystems present in a body of water. These can be further divided into two types, namely:

1. Freshwater Ecosystem
2. Marine Ecosystem

Freshwater Ecosystem

The freshwater ecosystem is an aquatic ecosystem that includes lakes, ponds, rivers, streams, and wetlands. These have no salt content in contrast with the marine ecosystem.

Marine Ecosystem

The marine ecosystem includes seas and oceans. These have a larger salt content and greater biodiversity in comparison to the freshwater ecosystem.

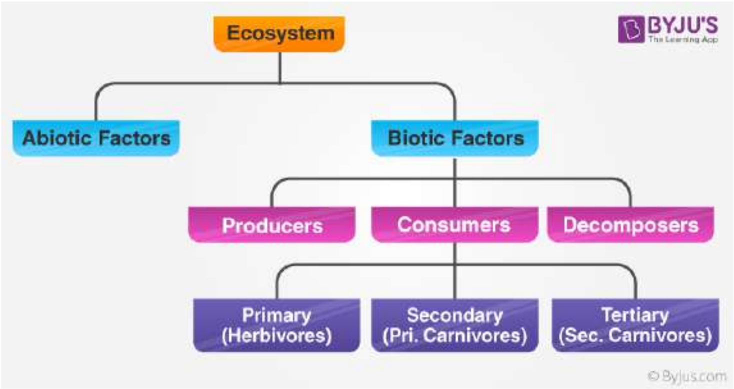
Structure of the Ecosystem

The structure of an ecosystem is characterised by the organisation of both biotic and abiotic components. This includes the distribution of energy in **our environment**. It also includes the climatic conditions prevailing in that particular environment.

The structure of an ecosystem can be split into two main components, namely:

- Biotic Components
- Abiotic Components

The biotic and abiotic components are interrelated in an ecosystem. It is an open system where the energy and components can flow throughout the boundaries.



Biotic Components

Biotic components refer to all life in an ecosystem. Based on nutrition, biotic components can be categorised into autotrophs, heterotrophs and saprotrophs (or decomposers).

- **Producers** include all autotrophs such as plants. They are called autotrophs as they can produce food through the process of photosynthesis. Consequently, all other organisms higher up on the food chain rely on producers for food.
- **Consumers** or heterotrophs are organisms that depend on other organisms for food. Consumers are further classified into primary consumers, secondary consumers and tertiary consumers.
    - ***Primary consumers*** are always herbivores that they rely on producers for food.
    - ***Secondary consumers*** depend on primary consumers for energy. They can either be a carnivore or an omnivore.
    - ***Tertiary consumers*** are organisms that depend on secondary consumers for food. Tertiary consumers can also be an omnivore.
    - ***Quaternary consumers*** are present in some food chains. These organisms prey on tertiary consumers for energy. Furthermore, they are

usually at the top of a food chain as they have no natural predators.

Decomposers include saprophytes such as fungi and bacteria. They directly thrive on the dead and decaying organic matter. Decomposers are essential for the ecosystem as they help in recycling nutrients to be reused by plants.

Abiotic Components

Abiotic components are the non-living component of an ecosystem. It includes air, water, soil, minerals, sunlight, temperature, nutrients, wind, altitude, turbidity etc.

Functions of Ecosystem

The functions of the ecosystem are as follows:

1. It regulates the essential ecological processes, supports life systems and renders the stability.
2. It is also responsible for the cycling of nutrients between biotic and abiotic components.
3. It maintains a balance among the various trophic levels in the ecosystem.
4. It cycles the minerals through the biosphere.
5. The abiotic components help in the synthesis of organic components that involves the exchange of energy.

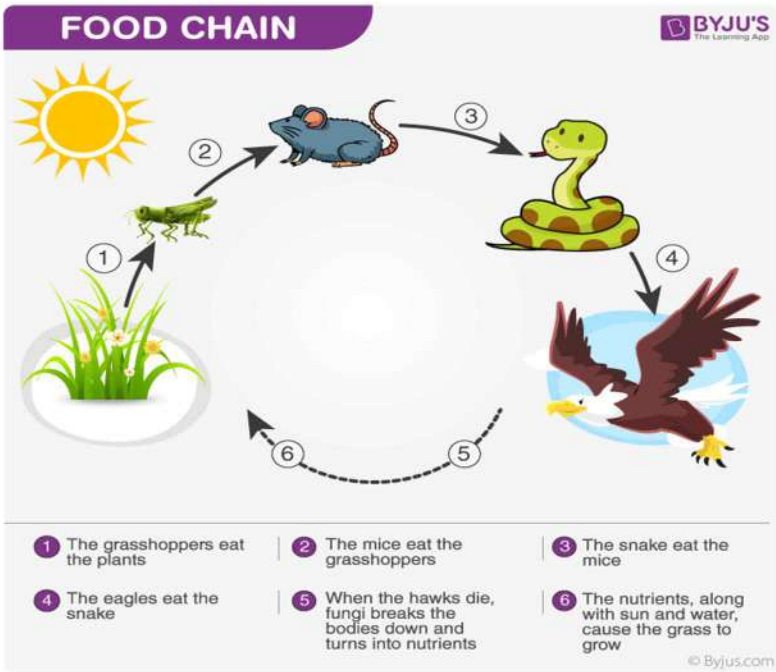
Important Ecological Concepts

1. Food Chain

The sun is the ultimate source of energy on earth. It provides the energy required for all plant life. The plants utilise this energy for the process of photosynthesis, which is used to synthesise their food.

During this biological process, light energy is converted into chemical energy and is passed on through successive levels. The flow of energy from a producer, to a consumer and eventually, to an apex predator or a detritivore is called the food chain.

Dead and decaying matter, along with organic debris, is broken down into its constituents by scavengers. The reducers then absorb these constituents. After gaining the energy, the reducers liberate molecules to the environment, which can be utilised again by the producers.



2. Ecological Pyramids

An ecological pyramid is the graphical representation of the number, energy, and biomass of the successive trophic levels of an ecosystem. Charles Elton was a first ecologist to describe the ecological pyramid and its principals in the year 1927.

The biomass, number, and energy of organisms ranging from the producer level to the consumer level are represented in the form of a pyramid; hence, it is known as the ecological pyramid.

The base of the ecological pyramid comprises of the producers, followed by the primary and secondary consumers. The tertiary consumers hold the apex. In some food chains, the quaternary consumers are at the very apex of the food chain.

The producers generally outnumber the primary consumers, and similarly, the primary consumers outnumber the secondary consumers. And lastly, apex predators also follow the same trend as the other consumers; wherein, their numbers are considerably lower than the secondary consumers.

For example, Grasshoppers feed on crops such as cotton and wheat, which are plentiful. These grasshoppers are then preyed upon by common mice, which are comparatively less in number. The mice are preyed upon by snakes such as cobras. Snakes are ultimately preyed on by apex predators such as the brown snake eagle.

3. Food Web

Food web is a network of interconnected food chains. It comprises of all the food chains within a single ecosystem. It helps in understanding that plants lay the foundation of all the food chains.

Environmental Problems:

Global warming: Green house effect

Global warming refers to an average increase in the earth's temperature, which in turn causes changes in climate. During the past 4.65 billion years of its history, earth has warmed many times. But at present it is facing a rapid warming mainly due to human activities. The average temperature of earth is about 590F (150C). During the last century this average has risen by about 10F. By the year 2100, it is believed that the rise would be between 2.5 and 10.40F. This will cause dramatic changes such as rise in sea level, changes in rainfall patterns, wide range of impacts on plants, wildlife and humans.

Conservation and judicious use of natural resources:

Fossil fuels, like, coal, lignite, petroleum and natural gas are non renewable natural resources. Both have an organic origin and are called hydrocarbon fuels. Coal was formed in nature as a solid from the remains of the trees buried deep inside the earth, some 500 million years ago.

$$\text{Dead wood} \xrightarrow[\text{chemical action}]{\text{bacterial and}} \text{Peat} \xrightarrow[\text{Pressure}]{\Delta} \text{Lignite coal}$$

The more heat and pressure coal undergoes through, the richer becomes the carbon content of it.

.

$$\text{Lignite coal} \xrightarrow[\text{Pressure}]{\Delta} \text{Bituminous coal} \xrightarrow[\text{Pressure}]{\Delta} \text{Anthracite coal}$$

Petroleum also occurs deep inside the earth's crust, as a liquid, and is formed by the bacterial decomposition of marine plant and animal matter and prehistoric forests in the absence of air buried at the bottom of the seas. This decomposition takes place under high pressures and temperatures of about 200oC, with the passage of millions of years of time.

Most of the energy needs that started with the industrial revolution some 250 years ago, and which exponentially increased in the 20th century have been met by the reserves of coal and petroleum. The use of coal and petroleum and their products in the world economy is immense. Coal is an important fuel source as its energy is converted into other forms of energy such as electricity, steam and coal gas.

Thermal Power Station

Many thermal power stations are run on coal. Coal is used for many industrial applications such as fuel for iron and steel foundries, metal extraction plants and steam based turbines. Coal tar, a black liquid, produces a mixture of over 200 carbon compounds which are used to prepare drugs, dyes, paints, explosives, plastics etc. It is a source of aromatic hydrocarbon compounds like benzene, toluene, aniline, phenol, naphthalene, anthracene etc. Coke is an important reducing agent is another by-product containing 98% carbon.

Petroleum is often referred to as liquid gold, due to its importance as a fuel in transportation (Petrol, Diesel, kerosene, gas oil, fuel oil) and as a source of over hundred and fifty important petrochemicals used in industrial and consumer applications. Over 25% of the entire chemical industry is devoted to the extraction of petroleum to get petrochemicals. The prosperity of any country depends upon these petroleum reserves.

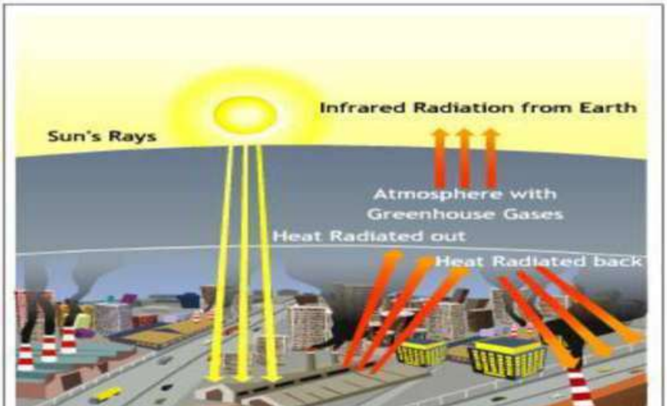
Petroleum Refinery

Hydrocarbon fuels take millions of years to form and because they are depleting at a very fast rate coal and petroleum reserves will be exhausted in the future no matter how carefully we use them. One estimate reckons that at present rate of usage, our known petroleum resources will last us for about forty years and the coal resources will last for another two hundred years.

The management of such non renewable energy sources involves slightly different perspectives from those resources discussed earlier in terms of policy and technology issues. One way of conservation and managing of these resources is to substitute existing technologies so that hydrocarbon fuels are more efficiently used or used less. For example, the use of vehicles with more efficient mileage and exhaust characteristics or a substitution of fuel or raw material. Some technologies in cars now use alternate fuels in combination with petrol (alcohol mixed petroleum) or completely use Bio fuel. Biogas can replace Liquid petroleum fuel (LPG) for cooking in rural areas.

A second route is to affect the policy of finding non-conventional and renewable energy sources. Power generation technologies are being developed by using wind energy through windmills, hydro energy and nuclear energy for generating electricity. Steam turbines are used in industries and solar energy based technologies (solar voltaic cells, solar panels are being used for areas such as for lighting, communications, solar heating etc. to reduce the dependence on hydrocarbon fuels.

A related aspect of management of these resources is the emissions they create in terms of pollution levels and green house gases. The choice of efficient technology or alternate fuel and technologies/products has a direct bearing on this characteristic of managing coal and petroleum based resources. High carbon dioxide levels, oxides of nitrogen and sulphur, lead to dangerous levels of air pollution affecting health and causing smogs, haze, and acid rain. Sulphur containing automobile fuels for example, have been banned



Greenhouse Effect

for automobiles in almost all countries for health reasons.

A second area of concern is the excessive emission of green house gases like carbon dioxide from automobile exhaust; petrochemical based industries power stations etc., which cause a rise in atmospheric temperatures (Global warming). Thus we must exercise judicious choices at a personal and community level while using these resources.

Energy and non-renewable resources discussed have an impact on environment and people need to conserve the environment having understood the impact of the crisis

Energy crisis and its environmental impact

Energy may be defined as any property, which can be produced from or converted into work. In today's world for any development and for all industrial operations, energy is a prerequisite. Life is unthinkable without energy. Energy production and energy utilization are the indicators of a country's progress. Heat, light, electricity are different forms of energy. While energy drives the world, the energy generated and utilised affects environment on a phenomenal scale. More population, rapid industrialisation, increased energy generation, over production, uncontrolled consumption and damages to environment are all inter-linked issues. Major issues are slowly being converted into crisis threatening our survival.

Background history of energy usage:

Fire was probably the first human energy technology. **Charcoal** from fires has been found at sites occupied by our early ancestors. **Wind** and **waterpower** have been used early as long. **Muscle power** provided by domestic animals has been important for agriculture. The invention of the **steam engine**, together with diminishing supplies of wood in industrializing countries caused a switch to **coal** as our major energy source in the nineteenth century. Coal in turn, has been replaced by **oil** in this century due to the ease of shipping, storing and burning liquid fuels. Recently **electricity** and **gas (petrol)** has changed the economic prosperity and lifestyle in many countries.

Renewable and non-renewable energy sources

Energy sources that are being made available continuously are known as renewable energy sources. (Eg). Geothermal energy, wind energy, tidal energy, solar energy, ocean currents, nuclear fusion, gobar gas, biomass and vegetable refuse etc.

Non-renewable sources of energy are natural sources which are being accumulated in nature from a very long time and cannot be replaced if they are exhausted. Examples of natural resources are coal, ores, petroleum, timber, natural gas, electricity etc.

Fossil fuels like **petroleum**, **natural gas** and **coal** are now providing about 95% of all commercial energy in the world.

Energy crisis

Energy crisis is due to the increase in population accompanied by rapid urbanization and industrialization. Our resources of petroleum and natural gas are dwindling day by day. We can hardly expect the oil industry to operate at full capacity until the last drop is removed from the ground. It appears that we will run out of petroleum and natural gas by about 2020 unless domestic supplies are extended by taking one or more of the following steps.

Steps to be taken to resolve energy crisis

1. Reduce the consumption of fuels: The principal target areas are heating and transportation, which account for about 18% and 25% respectively, of our total energy requirements. The consumption of fuel in these areas can be reduced by (a) proper insulation of existing buildings and design changes in new constructions (eg. using less plate glass), (it saves about 33% of energy) (b)improving the fuel economy of automobiles, (c) using more efficient means of transportation.

2. Develop new sources of energy: An example formulated.

The energy crisis has prompted the development of alternate energy sources (alternatives to fossil fuels) other than the heat available from the combustion of fossil fuels.

Wind Energy: The wind power is of great significance across coastal, hill and desert areas where wind energy can be usefully exploited for generation of electricity and water pumping. The harnessing technology of wind energy is simple. The strike of the blowing wind on specially designed blades of a windmill's rotor causes it to rotate. This rotation, which is the mechanical energy, when coupled to a turbine, drives the power generator. The wind energy thus delivers on the spot small quantities of energy.

Advantages of wind power:

i) Power generation is cheaper. Power is procured at 40 paise per unit

ii) Free from pollution and environmental degradation,

iii) Since generation is continuous unlike in diesel power, investment is never idle

A concern of great importance: Green house gases and Green house effect:-

The trapping of energy from the sun by certain gases in the atmosphere leading to the rise in earth's temperature is known as **Green house effect**. Hence these gases are known as green house gases. Some gases such as water vapour, carbon dioxide, nitrous oxide and methane act as the trap. These gases absorb and reflect infra-red waves radiated by earth.

By doing so, these gases conserve heat as the glass in a green house does. Normally all life on earth depends on this green house effect. If it does not exist, earth would be cooled, and ice would cover earth from pole to pole. But if the greenhouse effect becomes strong it could make the earth warmer than usual. Even a little extra warming may cause problems for humans, plants and animals.

Types of Greenhouse Gases:-

In the environment, greenhouse gases occur (i) naturally or (ii) from human activities.

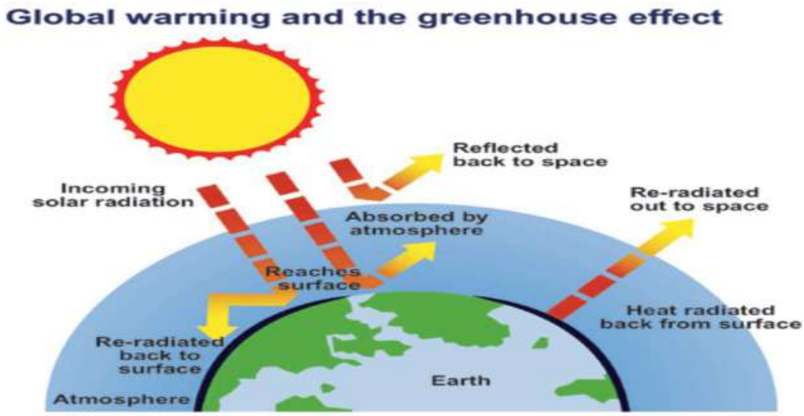
The most abundant greenhouse gas is **carbon dioxide**. It reaches the atmosphere due to volcanic eruptions, respiration of animals, burning and decay of organic matter such as plants. Normally carbon-dioxide is removed by the plants by photosynthesis. Carbon-dioxide is also absorbed into ocean water. But humans by their activities increase the release of carbon dioxide into the atmosphere. Such activities include burning of fossil fuels, solid wastes, wood and wood products to drive vehicles, generate electricity etc. At the same time due to deforestation, the number of trees available to absorb carbon-dioxide through photosynthesis has been greatly reduced.

Human activities have caused carbon-dioxide to be released to the atmosphere at rates much faster than that at which earth's natural processes can recycle this gas. There were about 281 molecules of carbon-dioxide per million molecules of air (i.e., parts per million or ppm) in 1750.

Today atmospheric carbon-dioxide concentrations are 368 ppm, a 31% increase.Methane traps 20 times more heat than carbon-dioxide. It is emitted during the production and transport of coal, natural gas and oil. It is also emitted from rotting organic waste in sand fills, by the cows as a byproduct of digestion. Since 1750, the amount of methane in the atmosphere has more than doubled.

Nitrous Oxide traps 300 times more heat than carbon-dioxide. Burning fossil fuels and ploughing farm soils releases nitrous oxide. Since 1750 its level increased by 17%. **Hydrocarbons** formed from the manufacture of foams, coolants such as **chlorofluorocarbons** used in refrigerators are the other gases responsible for global warming.

In 2000, scientists discovered an alarming increase in the level of a new gas called **trifluoromethyl sulphur penta fluoride**. Even though the gas is rare, it traps more effectively than all other greenhouse gases. The saddest part of it is that the industrial source of the gas is not yet identified.



Effects of Global warming:-

1. Due to the warming of oceans, sea level will rise. Glacier ice will also melt, causing further rise in sea level. As a result in the 21st century sea level will rise from 9 to 88 cm. Such a rise will submerge many parts of countries.
2. Seasons will be longer in some areas.
3. The warmed world will be generally more humid and greater humidity will increases the rainfall.
4. Storms are expected to be more frequent and intense.
5. Some regions of the world would become dry.
6. Wind blows will be harder and in different patterns. Hurricane would be more severe.
7. Weather patterns would be less predictable and more extreme.
8. Crops and forests may be affected by more insects and plant diseases.
9. Animals and plants will find it difficult to adjust to the changed environment. Animals will tend to migrate toward the poles and toward higher elevations.
10. Some types of forests may disappear.
11. More people will get sick or die from heat stress.
12. Tropical diseases such as malaria, dengue fever, yellow fever and encephalitis will spread to other parts of the world.

Efforts to control Global warming:-

Two major ways are there to control global warming:

1. To keep the carbon-dioxide out of the atmosphere by storing the gas or its carbon component somewhere else, a strategy called **carbon sequestration**.

2. To reduce the production of green house gases.

Carbon sequestration:-

The simple technique is to preserve trees and plants more. Trees, take up carbon-dioxide, break it down in photosynthesis, and store carbon in new wood. It need massive reforestation. Carbon-dioxide can also be sequestrated directly into deep ocean water or into oil wells or some aquifer form which it cannot escape.

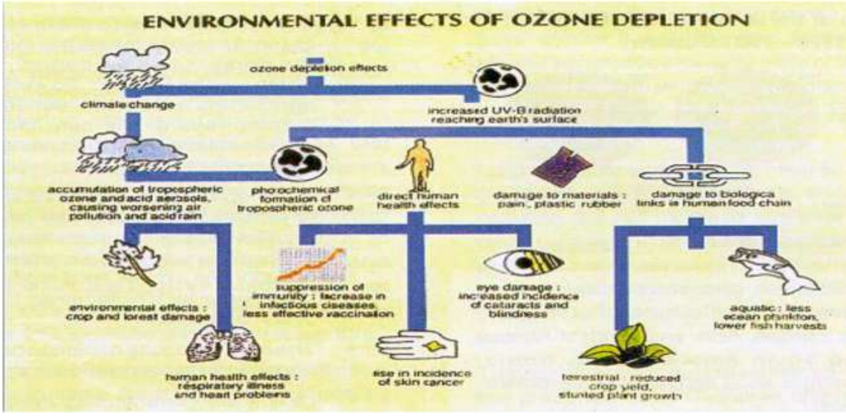
Usage of alternate fuels such as nuclear energy, solar power, wind power and hydrogen fuel cells which emit no greenhouse gases are being considered.

Ozone layer depletion

Ozone is a form of oxygen (O3). In the stratosphere (ozonosphere), ozone blocks out the sun's ultraviolet rays and is a lifesaver.

Ozone as a natural sun block

The electromagnetic radiation emitted from the sun includes ultraviolet radiation, which is potentially harmful to most living things since it can damage DNA. The ozone layer screens out the sun's harmful ultraviolet radiation. Even 1% reduction in the amount of ozone in the upper stratosphere causes a measurable increase in the ultraviolet radiation that reaches the earth surface. If there was no ozone at all, the amount of ultraviolet radiation reaching us would be catastrophically high.



All living things would suffer radiation burns, unless they were underground, or in the sea.

In the stratosphere, small amount of ozone are constantly being made by the action of sunlight on oxygen. At the same time, ozone is being broken down by natural processes. The total amount of ozone usually stays constant because its formation and destruction occur at about the same rate. But unfortunately human activity has recently changed that natural balance. Some manufactured substances such as chlorofluro carbons and Hydro chlorofluro carbons can destroy stratosphere ozone much faster than it is formed.

Ozone hole:

Ozone loss was first detected in the stratosphere over the Antarctic. The part of the atmosphere where ozone is most depleted is referred as —**Ozone hole**‖ but it is not a real hole just a vast region of the upper atmosphere where there is less ozone than elsewhere. Ozone-poor air can spread out from the Polar Regions and move above other areas. In addition, direct ozone depleted is also slowly increasing.

Reasons for the Antarctic Ozone hole:

Scientific observations prove that the ozone hole formed over Antarctic is due to compounds of chlorine and bromine formed in the atmosphere. Nearly all of the chlorine and half of the bromine in the stratosphere come from human activities, the chlorofluocarbons released due to human activities transported up into the upper stratosphere.

The most common Ozone depleting substances (ODS) are chloroflurocarbons (CFC) or freon gases, bromine compounds on halons, nitrogen oxides and methyl bromide. These compounds are liberally released from air-conditioners, freezers, foam insulations, aerosol products, industrial solvents, fire extinguishers and pesticides.

Effect of Ozone depletions:

If the ozone is depleted more ultraviolet radiations (especially Ultraviolet B (UVB) will reach the earth's surface.

Effect on plants: - will affect crop yield and forest productivity.

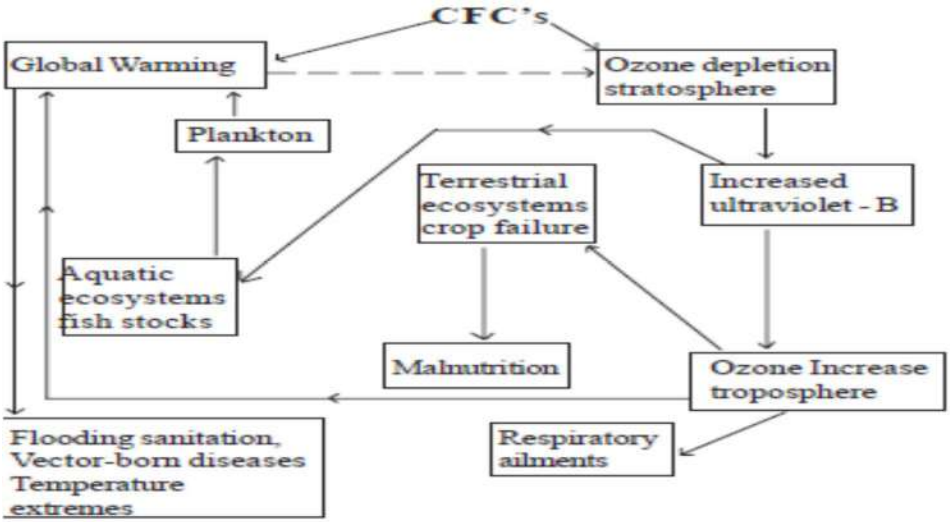
Effect on animals: - will cause damage to fish larvae and other small animals

Effect on human health: - Results in non-melanoma skin cancer and melanoma, acute erythem a (sun burn), ocular abnormalities, cataract, affect immune responses.

Preventing ozone depletion:

1. CFC's (Chloro Fluro Carbons) should be replaced by HCFC's (HydroChloro Fluro Carbons). (If over used could damage ozone), HFC's (HydroFlouro Carbons), Hydrocarbons such as butane and propane. (flammable and poisonous), Ammonia (must be handled carefully), Water and steam.
2. Production, use and emission of ozone – depleting chemicals should be controlled.
3. Re-cycling of these chemicals should be increased.
4. Servicing of refrigerators and air-conditioners should be regulated.
5. Refrigerants should be recaptured and used.
6. Adopt protection measures from sun's radiation.

The general effect of ozone depletion is summed up in the following chart



Concept of conserving by managing different elements of environment:

Water management

On a human time scale, the amount of water on the earth is fixed, for all practical purposes. There is little we can do to make more water. However, there are several ways to increase local supplies.

a) Seeding clouds

Seeding clouds with dry ice or potassium iodide particles sometimes can initiate rain if water laden clouds and conditions that favour precipitation are present.

b) Desalination

Desalination of ocean water is a technology that has great potential for increasing fresh water. The common methods of desalination are distillation (evaporation and re-condensation) or reverse osmosis (forcing water under pressure through a semi-permeable membrane whose tiny pores allow water to pass but exclude most salts and minerals). Although desalination is still three to four times more expensive than most other sources of freshwater, it provides a welcome water supply in such places like Dubai, Oman and Bahrain where there is no other access to fresh water.

c) Dams, Reservoirs, Canals and Aqueducts

It is common to trap run off with dams and storage reservoirs and transfer water from areas of excess to areas of deficit using canals, tunnels and underground pipes.

d) Watershed management

A series of small dams or tributary streams can hold back water before it becomes a great flood. Ponds formed by these dams provide useful wildlife habitat and stock-watering facilities. Small dams can be built with simple equipment and local labour, eliminating the need for massive construction projects and huge dams.

e) Rain water harvesting

The activity of collecting rainwater directly or recharging it into ground to improve ground water storage in the aquifer is called rain water harvesting.

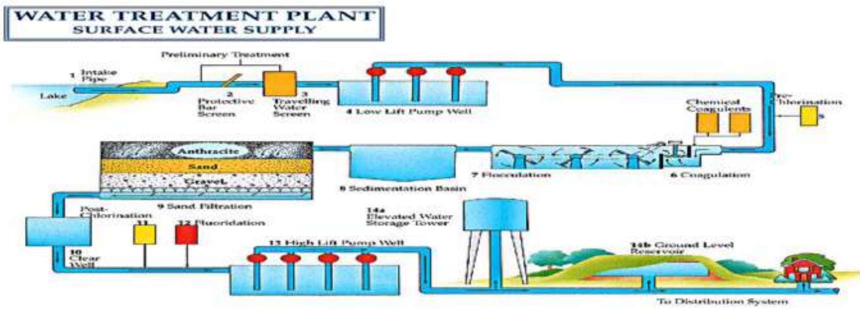
By rainwater harvesting the ground water can be conserved, water table depletion can be reduced and also sea water intrusion in coastal areas can be arrested. To recharge the groundwater rainwater that falls in the terrace of the buildings and in the open space around the buildings may be harvested. Roof top rain water can be diverted to the existing open / bore well. Rainwater available in the open spaces around the building may be recharged into the ground by the following simple but effective methods.

f) Better agricultural practices

Sound farming and foresting practices can reduce runoff. Retaining crop residues on fields reduces flooding. Minimizing ploughing and forest cutting on steep slopes protects watersheds. Wetlands conservation preserves natural water storage capacity and aquifer recharge zones.

g) Domestic conservation

We could save as much as half of the water we now use for domestic purposes without great sacrifice or serious changes in our lifestyles. The use of washing machines, dish washers and low volume shower heads can reduce water loss.



h) Industrial conservation

Nearly half of all industrial water use is for cooling of electric power plants and other industrial facilities. By installing dry cooling systems, this could be avoided. Cooling water can be recharged; some industrial waste water may be treated, recycled and reused.

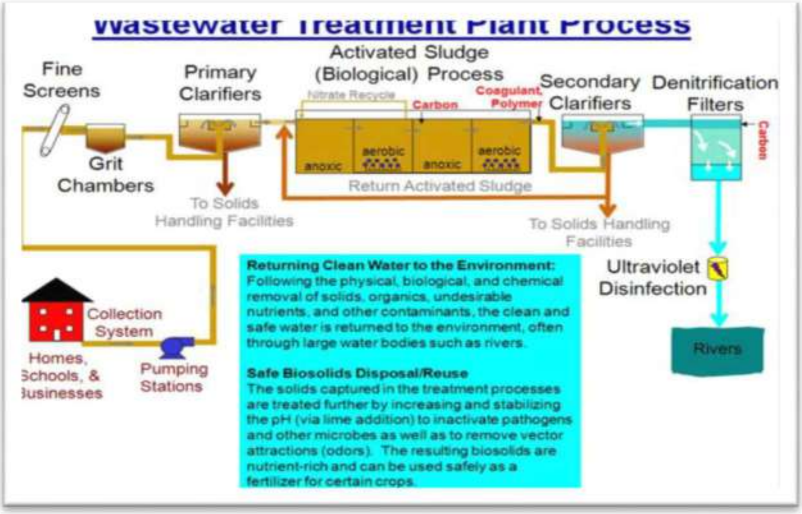
i) Saving water -an individual's role

As an individual you can conserve water by the following methods.

- Take shorter showers.
- Don't wash car and two wheelers often
- Don't allow tap run while washing hands, dishes, food or brushing your teeth unnecessarily.
- In your lawn, consider planting native plants, a rock garden or some xerophytic landscaping.
- Use water conserving appliances: low – flow showers and low –flush toilets.
- Use recycled water for lawns, house plants and car washing
- Check taps for leaks

Waste water treatment and management

The main steps in typical water – treatment plants are coagulation, settling and filtration to remove suspended particles, aeration to remove the volatile substances most responsible for taste and odour, and chlorination to kill pathogenic organisms.



For the treatment of sewage, **primary treatment** consists of mechanical filtration, screening, and settling, followed by chlorination. It removes 50 to 65% of the suspended solids.

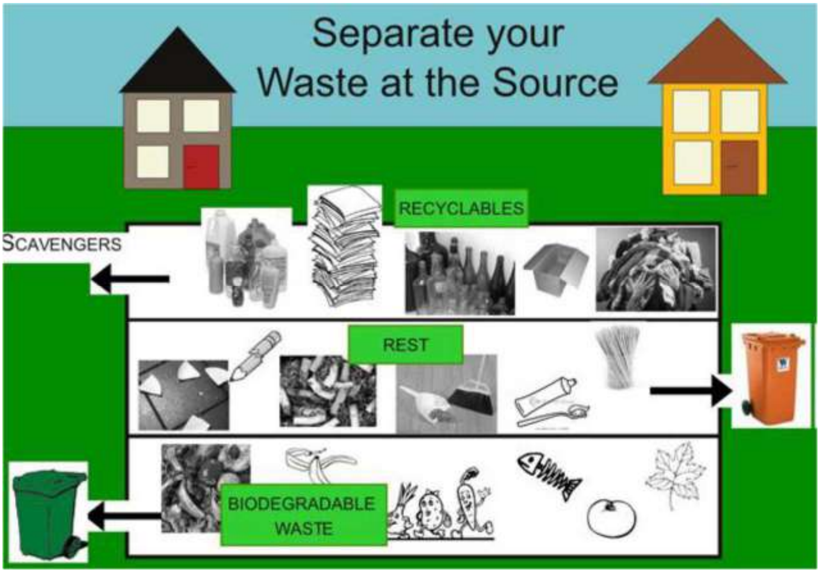
In **secondary treatment** the organic wastes are transformed by bacteria in the treatment plant, where oxygen is provided by aeration, instead of depleting dissolved oxygen in the receiving waters. The sludge from this process, consisting largely of bacterial masses, is concentrated and processed further in an anaerobic digester.

Waste management

Human activities related to livelihood and welfare generates waste. All wastes are pollutants and they create pollution in one way or other. Fundamentally air, land and water pollution results mostly due to improper disposal of wastes.

Pollution, Pollutants

Pollution is the human caused addition of any material or energy (heat) in amounts that cause undesired alterations to water, air or soil. Any material that causes the pollution is called a pollutant.



Classification of wastes

1. Bio – degradable waste

These are wastes capable of being removed or degraded by biological or microbial action. Waste from agricultural products, animal wastes and waste from food processing, leather, fibre, paper and wood etc. come under this group.

2. Non bio-degradable waste

The substances which are normally not acted upon and decomposed by microbes are non-bio degradable wastes. It includes mineral waste, mining waste and industrial waste and non-degradable metallic and plastics substances.

3. Mixture of biodegradable and non-biodegraded wastes

It includes municipal waste and industrial waste. Municipal waste contains household garbage, piles of food scrapes, old newspaper, discarded and throws away materials, glass, cans, old appliances, broken materials, leather shoes, fibres, plastics and others. Construction waste materials, packaging materials, sewage, hospital waste, junk and vehicles are varied types of urban wastes. All these wastes are found in the form of semisolid, solid, semi-liquid, sludge and in fly ash form.

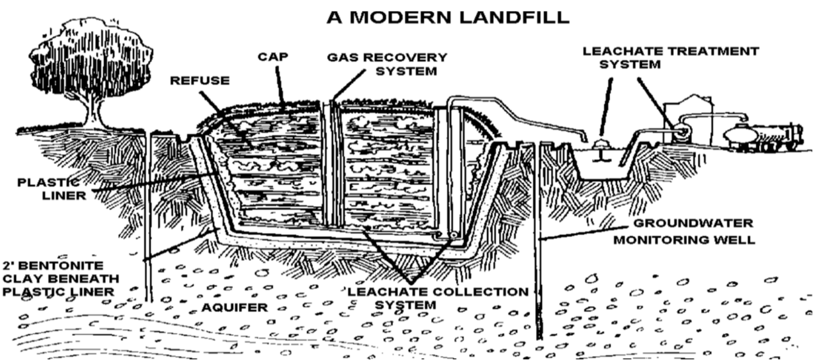
Management of hazardous wastes

Hazardous wastes may remain dangerous for thousands of years. The hazardous waste include radioactive refuse, metallic compounds, organic solvents, acid asbestos, organic cyanides, pathological hospital wastes, disposable medical equipments and tools.

The following methods are adopted for the disposal of hazardous wastes.

1. Landfills: There are permanent storage facilities for military related liquid and radioactive waste materials in secured lands. High level radioactive wastes are stored in deep underground storage.

Wastes are carefully contained to prevent cross – mixing of reactive substances. The land fill is capped with impervious clay to prevent infiltration and percolation of water through the fill. Fill bottom is lined and provided with drainage system to contain and remove any leakage that occurs.



Monitoring the wells provides a final check.

2. Deep well injection: It involves drilling a well into dry, porous material below groundwater. Hazardous waste liquids are pumped into the well. They are soaked into the porous material and made to remain isolated indefinitely. However fractures in the impermeable layer may permit the injected wastes to escape and contaminate ground water.

3. Surface impoundments: This method is used to dispose large amounts of water carrying relatively small amounts of chemical wastes.

Surface impoundments are simple excavated depressions (ponds) into which liquid wastes are drained. Solid wastes settle and accumulate while water evaporates. If the pond bottom is well sealed and if evaporation equals input, wastes may be stored in the impoundment indefinitely.

4. Incineration: The hazardous biomedical wastes are usually disposed by means of incineration. Human anatomical wastes, discarded medicines, toxic drugs, blood, pus, animal wastes, microbiological and biotechnological wastes etc are called **Bio-medical wastes**.

5. Bioremediation: This is another rapidly developing clean up technology. Cleaning the environment with biological options such as microbes and plants is called bioremediation. Some naturally occurring bacteria and other microorganisms have the capability to degrade or absorb or detoxify the wastes such as heavy metals. Many plant materials are successfully used as adsorbents for xenobiotics (phyto-remediation).

Genetically Engineered Microorganisms (GEMS) are currently produced in large scale to remove the hazardous radionuclides and heavy metals such as mercury, chromium, cadmium etc. Certain plants such as *Gibberella fusarium* were able to breakdown cyanide and reduce it to a non-toxic form. The bacteria *Pseudomonas*, nicknamed as ‗super – bug' are capable of degrading variety of toxic compounds and also degrade oil.

Management of non-hazardous wastes- Solid Waste Management

1. Sanitary landfills: The refuse is spread in a hollow land or in a trench and compacted with a layer of clear sand fill. The sanitary landfills are far more desirable than open dumps but the ground water contamination is always a potential problem. Once a land fill operation has been completed the site must be inspected periodically. This land fill is suitable for recreational activities such as parks and play ground.

2. Incineration: Municipal incinerators burn combustible solid waste and melt certain non-combustible materials. Since the high temperature destroys pathogens and their vectors, it is a good method of disposal from health point of view. The incineration can reduce the volume of solid waste by 80 to 90 percent.

3. Reuse and recycling techniques: Resource recovery is a broad term that is used for the retrieval of valuable materials or energy from a waste. The separating out of materials such as rubber, glass, paper and scrap metal from refuse and reprocessing them for reuse is named as reclamation of waste or recycling. Paper (54% recovery) can be re-pulped and reprocessed into recycled paper, card board, and other paper products; finally ground and sold as cellulose insulators or shredded and composted.

4. Glass: It can be crushed, re-melted and made into new containers or crushes used as a substitute for gravel or sand in construction materials such as concrete and asphalt. Some forms of plastics (2.2 % recovery) can be re-melted and fabricated into carpet fiber, fill for insulated apparel, irrigation drainage, tiles and sheet plastics. **Metals** can be melted and re-fabricated (39% recovery). Food wastes and yard wastes (leaves, grass etc.) can be composted to produce humus soil conditioner. Textiles can be shredded and used to strengthen recycled paper products. Old tyres can be re- melted or shredded and incorporated into highway asphalt.

People‘s participation for conservation:
Biodiversity conservation (Biosphere reserves)
Government and non Governmental organizations

What is biodiversity?

Biological diversity means the variability among living organisms from all sources including terrestrial, marine and other aquatic ecosystems and the ecological complexes of which they are parts. It is usually considered at three different levels – genetic diversity, species diversity and ecosystem diversity.

Reasons for Decline of Biodiversity

1. Natural causes of Bio diversity extinction

Studies of the fossil record suggest that more than 99% of all species ever existed are now extinct. Most of them were gone before humans came on the scene. At the end of Permian period about 250 million years ago, a greater disaster wiped 2/3of all marine species and half of all plant and animal families.

2. Human caused reduction

Natural areas are converted to farms, housing subdivisions, shopping malls, marinas and industrial centres. For example, when a forest is cleared, it is not just the trees that are destroyed, but also every other plants and animals that occupy that destroyed ecosystem, either permanently or temporarily also suffers.

Importance Biodiversity conservation?

Biodiversity is the backbone for agriculture, aquaculture, animal husbandry, forestry and a host of other applied branches of biology. Biodiversity is fast becoming the fundamental requirement on which the new industrial developments and innovations are going to be based. Biodiversity will offer in the coming years, new sources of food, medicine and other human requirements.

To save the races of endangered and endemic species the bio-resources should be identified and the hotspots in each country should be given prior importance to conservation. Only then the remaining species at the verge of extinction could be saved.

Consequences of Losing Biodiversity

Many species have already become extinct and we do not know really what we are losing when we lose species. In future we might lose a keystone species, a species whose role is absolutely vital for the survival of many other species in an ecosystem. For example, the Orchid bees play a vital role in tropical forests by pollinating trees. If they disappear, the eventual fall of that ecosystem is evident. This loss may remove and constrict the natural habitats in which wild species live. Recreational, aesthetic and commercial losses will also be inevitable.

Conservation of Biodiversity

The conservation of biodiversity and the growing human population are the two great challenges facing our generation and those to follow.

The following strategies are adapted to conserve biodiversity.

a. International Conservation Strategies

Biodiversity should be preserved as the common heritage of all humans. All species have a right to exist; one strategy considered as a priority is **conserving hotspots** around the globe. These are areas characterized by high concentrations of endemic species and experiencing unusually rapid rate of habit modification loss. There are around 25 hot spots identified from all over the world.

b. National Conservation Strategies

Several measures like legal measures, *in situ* and *ex situ* conservation efforts, documenting of indigenous knowledge and the application of science and technology have been taken up by many countries of the world.

Many countries are a party to the **International Convention on Biological Diversity** (CBD) in May 1994.

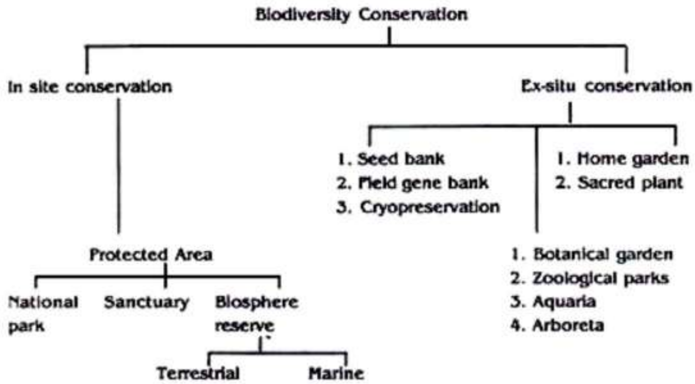
This is being carried out with the help of several other Government and Non-governmental organizations, and individuals.

Forest and wild life conservation:

Establishment of Bio-reserves

A biosphere reserve is a unique concept which includes one or more protected areas and surrounding lands that are managed to combine both conservation and sustainable use of natural resources. **'Biosphere Reserve'** is an international designation made by the United Nations Educational, Scientific and Cultural Organisation (UNESCO). It is based on the basis of nominations submitted by countries participating in the **Man and the Biosphere Program** (MAB).

The MAB was launched in 1971 to catalyse a greater understanding and provision of knowledge and skills to support sustainable relationships between people and their environment. Biosphere Reserves act as a keystone of MAB by providing a global network of sites for cooperative research toward this end. As at the end of November 2002, the World Network of Biosphere Reserves included 495 sites in 95 countries.



Characteristics of a Bio-reserve

It is a land and/or coastal/marine area in which people are an integral component, and which is managed for objectives, ranging from complete protection to intensive yet sustainable production.

It is a regional centre for monitoring, research, education and training on natural and managed ecosystems.

It is a place where government decision makers, scientists, managers and local people cooperate in developing a model programme for managing land and water to meet human needs while conserving natural processes and biological resources.

Finally, each biosphere reserve is a symbol of voluntary cooperation and use resources for the well being of people everywhere.

Organizations involved in Biodiversity Conservation

The organizations involved in biodiversity conservation are

1.World Wildlife Fund: (WWF) 2.Resources for the Future :(RFF)

3.The Nature Conservancy:

4. World Resources Institute :(WRI),

5.IUCN (International Union for Conservation of Nature and Natural Resources),

6.African Wildlife Foundation:(AWF),

7. Genetic Resources Action International: (GRAIN), 8.International Science Foundation,

9.The Biodiversity Support Program :(BSP)

Conservation is not just important for animals but to all living things. Conservation is also very important to prevent floods, fires, new deserts and drought. It is important to protect habitats and natural areas like rainforests. If we allow the destruction of rainforests it will increase the production of greenhouse gases which make the world warm up. This results in melting of Arctic and Antarctic ice caps, rising sea levels and flooding of low lands like the Seychelles.

Another thing that can happen is that new deserts are formed. This happens when the warming earth results in less water and less vegetation like trees and things stop growing and land becomes barren (and by the way, a desert isn‘t just sandy like a beach, it is usually too hot and dry for people‘s comfort, but it is mainly about being dry so you can get deserts in cold areas without sand too).

Conservation needs to be done by humans to prevent damage to the world caused by humans. But what humans don‘t think about is how without conservation our lives will change. Resources, such as water, oil, natural gas, wood and food, become less available as we don‘t protect our planet. When these become less available, countries may get so desperate for it wars can start over who gets the resource. This can also lead to people accidently making that resource even rarer and less plentiful. So let‘s preserve and protect our Mother Earth.

Zambia's biodiversity faces a number of challenges and threats. Wildlife faces the challenge of illegal wildlife trade and poaching. The forests face a challenge of deforestation as a result of land use such as agriculture and human settlements. Forests are also threatened by charcoal burning (by rural people) which is a source of energy for the poor people in urban areas who cannot afford electricity.

Zambia is also highly endowed with abundant water resources from rivers, lakes and wetlands. Biodiversity in freshwater bodies face threats such as pollution, poor fishing methods and overfishing.

The Zambezi river basin, which covers eight (8) riparian states in Southern Africa (Angola, Zambia, Zimbabwe, Malawi, Namibia, Botswana, Mozambique, Tanzania), is a major source of freshwater for the entire region. The greatest challenges are the various competing demands for water usage ranging from energy generation, abstraction for crop irrigation purposes as well as domestic and industrial uses.

Zambia recently discovered uranium deposits in the north western part of the country in upper Zambezi river basin and mining is currently under way. Recognizing that uranium is a highly radioactive material and Zambia being a member of the International Atomic Energy Agency (IAEA), it is incumbent upon the Zambian government to ensure that there is maximum protection at all times. The greatest threat is contamination of the Zambezi river basin, home to about 65 million people.

WWF Zambia has been working to address various threats and other challenges facing biodiversity conservation in Zambia for the benefit of humanity and the environment. With support from various cooperating and implementing partners, WWF Zambia has several programmes across the country aimed conserving Zambia's biodiversity.