BIOLOGY

B.Tech (1st Year)

Notes

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LEARN & GROW

Index

UNIT -1

Concept and definition of Biology:-

Biology Definition

Biology is the branch of science that primarily deals with the structure
, function, growth, evolution, and distribution of organism. As a science, it is a methodological study of life and living things. It determines verifiable facts or formulates theories based on experimental findings on living things by applying the scienctific methode An expert in this field is called a *biologist.*

Basic concepts of biology

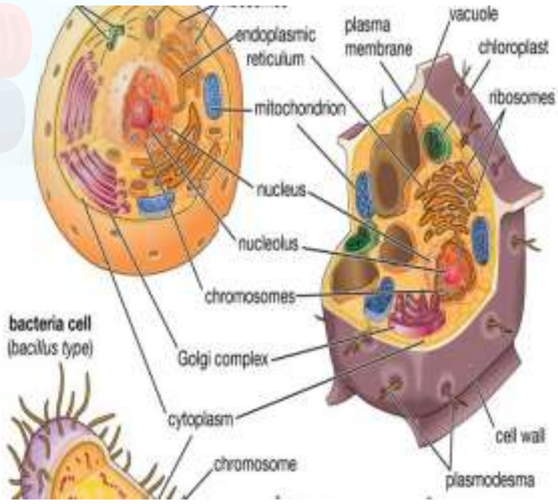
Biological principles

Homeostasis

The concept of Homeostasis—that living things maintain a constant internal environment—was first suggested in the 19th century by French physiologist Claude Bernard, who stated that “all the vital mechanisms, varied as they are, have only one object: that of preserving constant the conditions of life.”

Unity

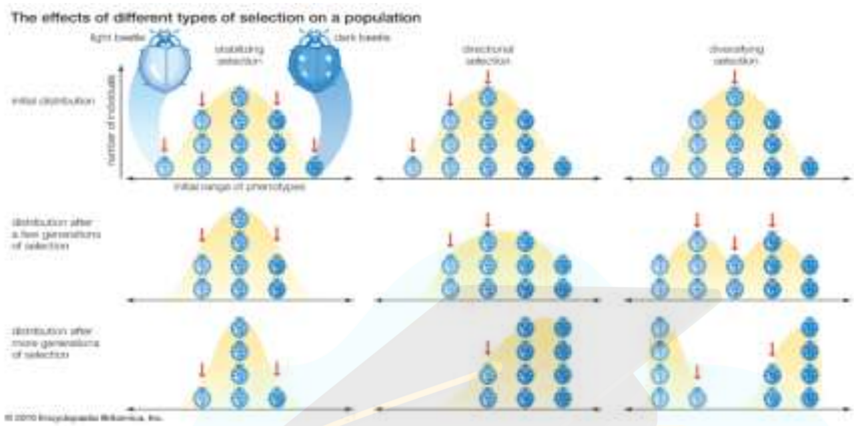
All living organisms, regardless of their uniqueness, have certain biological, chemical, and physical characteristics in common. All, for example, are composed of basic units known as cells and of the same chemical substances, which, when analyzed, exhibit noteworthy similarities, even in such disparte organisms as bacteria and humans. Furthermore, since the action of any organism is determined by the manner in which its cells interact and since all cells interact in much the same way, the basic functioning of all organisms is also similar.



CELLS

Evolution

In his theory of natural selection , which is discussed in greater detail later, Charles Darwin suggested that “survival of the fittest” was the basis for organic evolution (the change of living things with time). Evolution itself is a biological phenomenon common to all living things, even though it has led to their differences. Evidence to support the theory of evolution has come primarily from the fossil record , from comparative studies of structure and function, from studies of embryological development , and from studies of DNA and RNA (ribonucleic acid).



Diversity

Despite the basic biological, chemical, and physical similarities found in all living things, a diversity of life exists not only among and between species but also within every natural population The phenomenon of diversity has had a long history of study because so many of the variations that exist in nature are visible to the eye

Importance of biology in major discoveries of life Characteristic features of living organisms:

Importance of Biology

There are numerous indications of the importance of biology. Biology is primarily concerned with studying life. In addition, it offers a thorough scientific explanation of how all living and nonliving things interact with one another.

It provides information about various life forms. Additionally, biology includes various areas of study concerned with the sustainability of life, such as the study of the human body and the environment, the ecosystem, the quality of food, the causes of disease, and the discovery of new medications.

The study of life has influenced how the world is today. It has also provided a multitude of reliable and credible explanations for why things occur more scientifically.

Here are a few reasons why everyone should understand the importance of biology.

Describes the Changes in the Human Body

Scientifically, humans are known as *Homo sapiens*. They look like apes, yet their bodies, languages, and cognitive abilities are more advanced. Being the most developed species of animal, humans have intricate bodies that are difficult to understand.

However, anyone can learn the causes of changes taking place in the body by studying biology. When children mature early and show physical changes, it means that their systems start releasing hormones necessary for puberty.

Disease Treatment Approaches

Modern medicine and biology share a close relationship, and pharmacology, a branch of biology, is fundamental to modern medicine and healthcare. Pharmacology covers a wide range of activities, from research to producing painkillers and depression medications. Knowing about different diseases, their causes, and the effects they have on the human body is helpful in fields like pathology.

Scientists can now predict diseases in advance, how they are passed down through generations, and even treat them at a microscopic level owing to technological innovation. The application of biology is limitless, especially in areas of medicine and health.

Biology Helps to Understand Nature

The study of various organs and sections of an animal or plant enables us to understand the mechanisms in various functions, including reproduction, metabolism, food gathering, and behaviour. It also improves our understanding of numerous characteristics of animals and plants.

Benefits to Humans

Humans benefit from biology in everyday life. For instance, to produce the best harvest possible, farmers should be completely aware of crops, including how to raise them, how much water and nutrients to feed them, and how much fertiliser to apply. The same is true for animals, which must be bred, fed a certain amount of food, given veterinary treatment, etc.

Provides Solutions to Significant Issues

Biology provides answers to widespread problems that might have an impact on people all over the world. It might even be able to solve environmental issues.

For instance, biology may be used to create efficient and long-term plans to increase food production in nations experiencing food shortages. Another problem is the existence of contaminants. This area of research might be able to offer solutions to this environmental problem.

Furthermore, the importance of biology might hold the secret to creating a healthy biosphere, where all living and nonliving things interact together.

What are Cell Organelles?

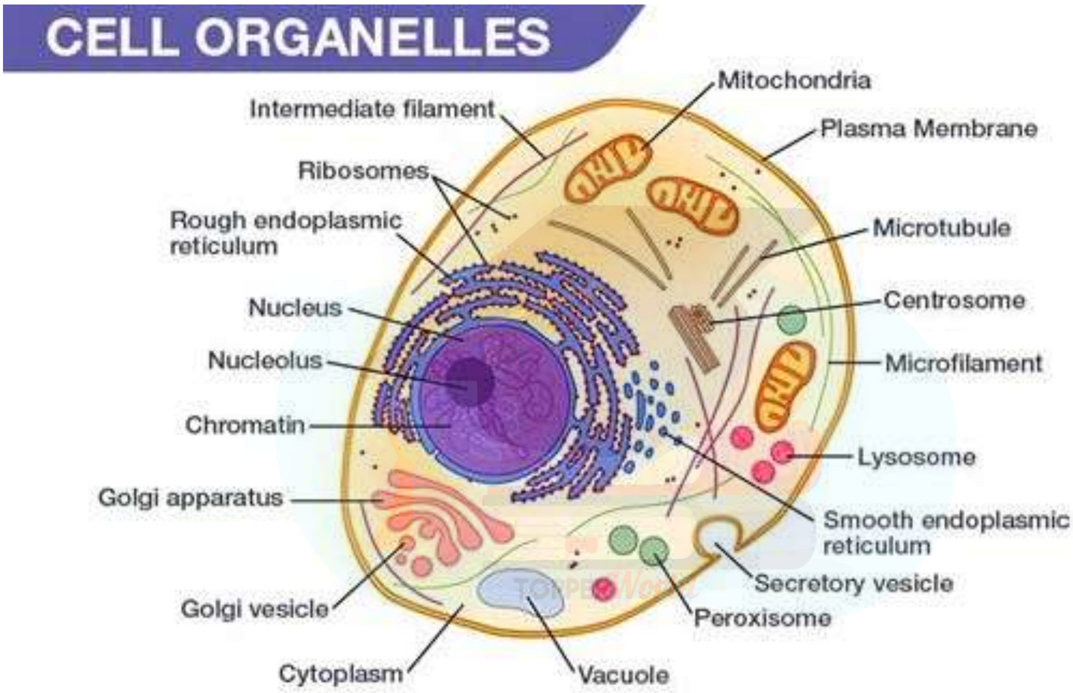
The cellular components are called cell organelles. These cell organelles include both membrane and non-membrane bound organelles, present within the cells and are distinct in their structures and functions. They coordinate and function efficiently for the normal functioning of the cell. A few of them function by providing shape and support, whereas some are involved in the locomotion and reproduction of a cell. There are various organelles present within the cell and are classified into three categories based on the presence or absence of membrane.

Organelles without membrane: The Cell wall, Ribosomes, and Cytoskeleton are non-membrane-bound cell organelles. They are present both in the **prokaryotic cell** and the eukaryotic cell.

Single membrane-bound organelles: Vacuole, Lysosome, Golgi Apparatus, Endoplasmic Reticulum are single membrane-bound organelles present only in a eukaryotic cell.

Double membrane-bound organelles: Nucleus, mitochondria and chloroplast are double membrane-bound organelles present only in a eukaryotic cell.

Let us learn more in detail about the different cell organelles in brief.



List of Cell Organelles and their Functions

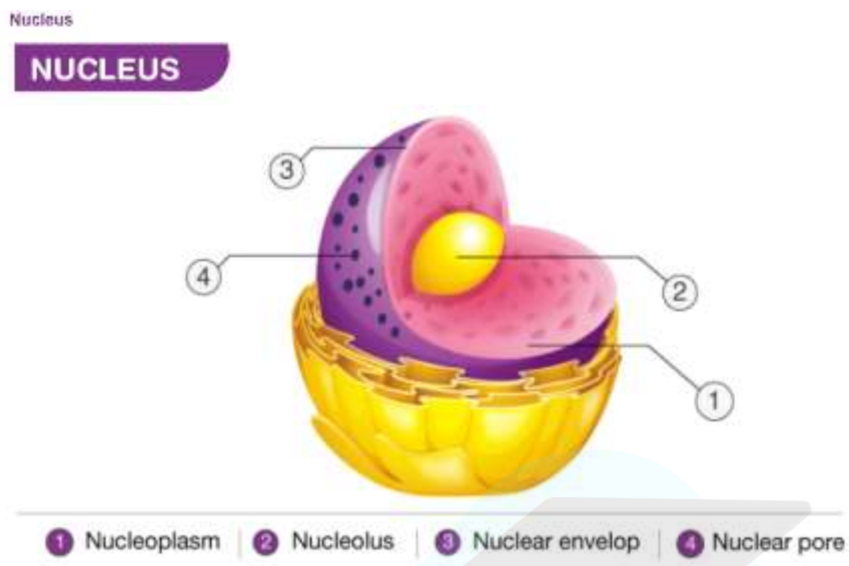
Plasma Membrane

The plasma membrane is also termed as a Cell Membrane or Cytoplasmic Membrane. It is a selectively permeable membrane of the cells, which is composed of a lipid bilayer and proteins.

The plasma membrane is present both in plant and animal cells. It functions as the selectively permeable membrane, by permitting the entry of selective materials in and out of the cell according to the requirement. In an animal cell, the cell membrane functions by providing shape and protects the inner contents of the cell. Based on the structure of the plasma membrane, it is regarded as the fluid mosaic model. According to the fluid mosaic model, the plasma membranes are subcellular structures, made of a lipid bilayer in which the protein molecules are embedded.

Cytoplasm

The cytoplasm is present both in plant and animal cells. They are jelly-like substances, found between the cell membrane and nucleus. They are mainly composed of water, organic and inorganic compounds. The cytoplasm is one of the essential components of the cell, where all the cell organelles are embedded. These cell organelles contain enzymes, mainly responsible for controlling all metabolic activity taking place within the cell and are the site for most of the chemical reactions within a cell.



The nucleus is a double-membraned organelle found in all eukaryotic cells. It is the largest organelle, which functions as the control centre of the cellular activities and is the storehouse of the cell's DNA. By structure, the nucleus is dark, round, surrounded by a nuclear membrane. It is a porous membrane (like cell membrane) and forms a wall between cytoplasm and nucleus. Within the nucleus, there are tiny spherical bodies called nucleolus. It also carries an essential structure called chromosomes.

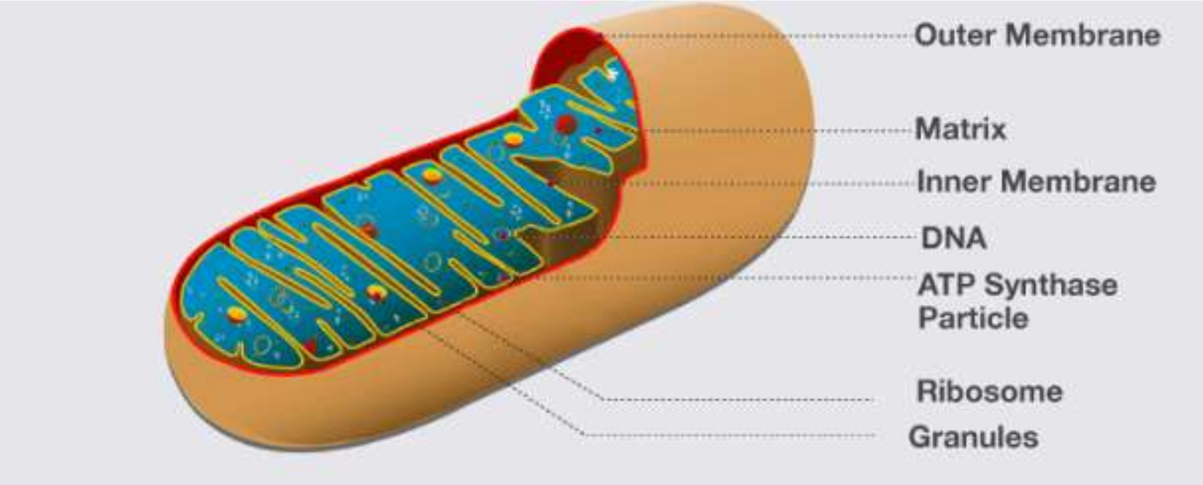
Endoplasmic Reticulum

The Endoplasmic Reticulum is a network of membranous canals filled with fluid. They are the transport system of the cell, involved in transporting materials throughout the cell.
There are two different types of Endoplasmic Reticulum:

1. **Rough Endoplasmic Reticulum** – They are composed of cisternae, tubules, and vesicles, which are found throughout the cell and are involved in protein manufacture.

2. **Smooth Endoplasmic Reticulum** – They are the storage organelle, associated with the production of lipids, steroids, and also responsible for detoxifying the cell.

Mitochondria:



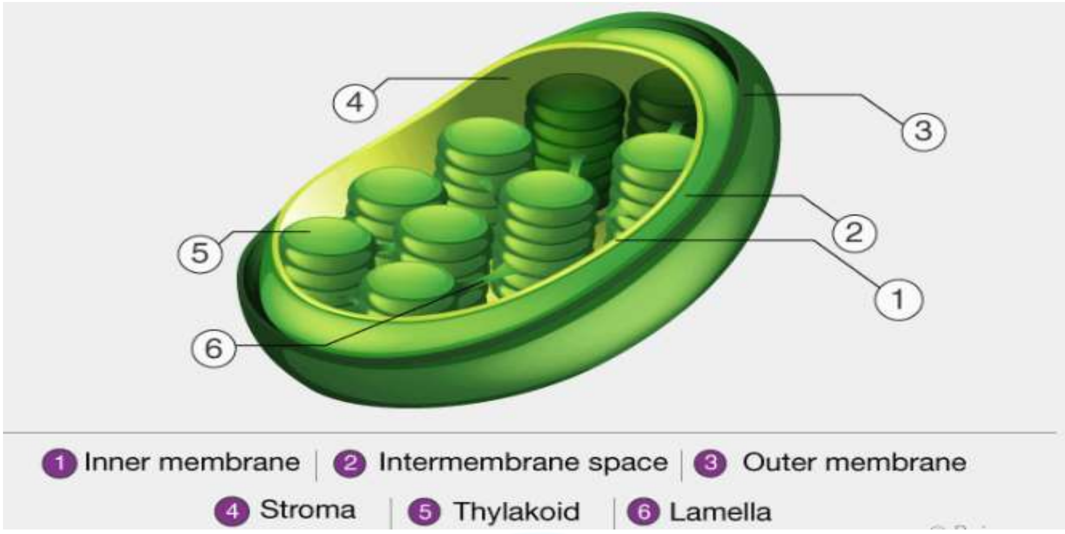
Mitochondria are called the powerhouses of the cell as they produce energy-rich molecules for the cell. The mitochondrial genome is inherited maternally in several organisms. It is a double membrane-bound, sausage-shaped organelle, found in almost all eukaryotic cells.

The double membranes divide its lumen into two distinct aqueous compartments. The inner compartment is called a 'matrix' which is folded into cristae whereas the outer membrane forms a continuous boundary with the cytoplasm. They usually vary in their size and are found either round or oval in shape. Mitochondria are the sites of aerobic respiration in the cell, produces energy in the form of ATP and helps in the transformation of the molecules.

For instance, glucose is converted into adenosine triphosphate – ATP. Mitochondria have their own circular DNA, RNA molecules, ribosomes (the 70s), and a few other molecules that help in protein synthesis.

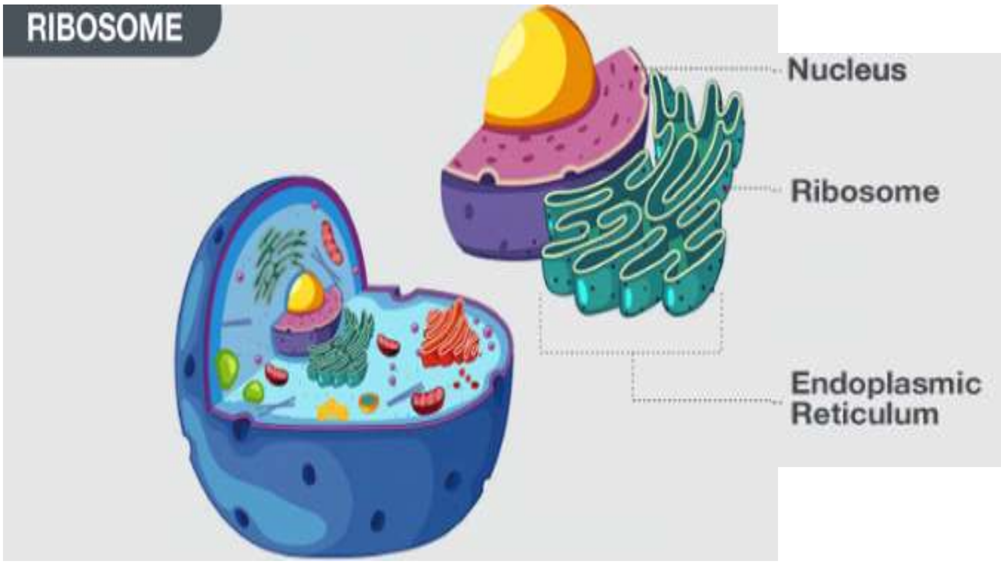
Plastids

Plastids are large, membrane-bound organelles which contain pigments. Based on the type of pigments, plastids are of three types:



- **Chloroplasts** – Chloroplasts are double membrane-bound organelles, which usually vary in their shape – from a disc shape to spherical, discoid, oval and ribbon. They are present in mesophyll cells of leaves, which store chloroplasts and other carotenoid pigments. These pigments are responsible for trapping light energy for photosynthesis. The inner membrane encloses a space called the stroma. Flattened disc-like chlorophyll-containing structures known as thylakoids are arranged in a stacked manner like a pile of coins. Each pile is called a granum (plural: grana) and the thylakoids of different grana are connected by flat membranous tubules known as stromal lamella. Just like the mitochondrial matrix, the stroma of chloroplast also contains a double-stranded circular DNA, 70S ribosomes, and enzymes which are required for the synthesis of carbohydrates and proteins.
- **Chromoplasts** – The chromoplasts include fat-soluble, carotenoid pigments like xanthophylls, carotene, etc. which provide the plants with their characteristic color – yellow, orange, red, etc.
- **Leucoplasts** – Leucoplasts are colorless plastids which store nutrients. Amyloplasts store carbohydrates (like starch in potatoes), aleuroplasts store proteins, and elaioplasts store oils and fats.

Ribosomes:

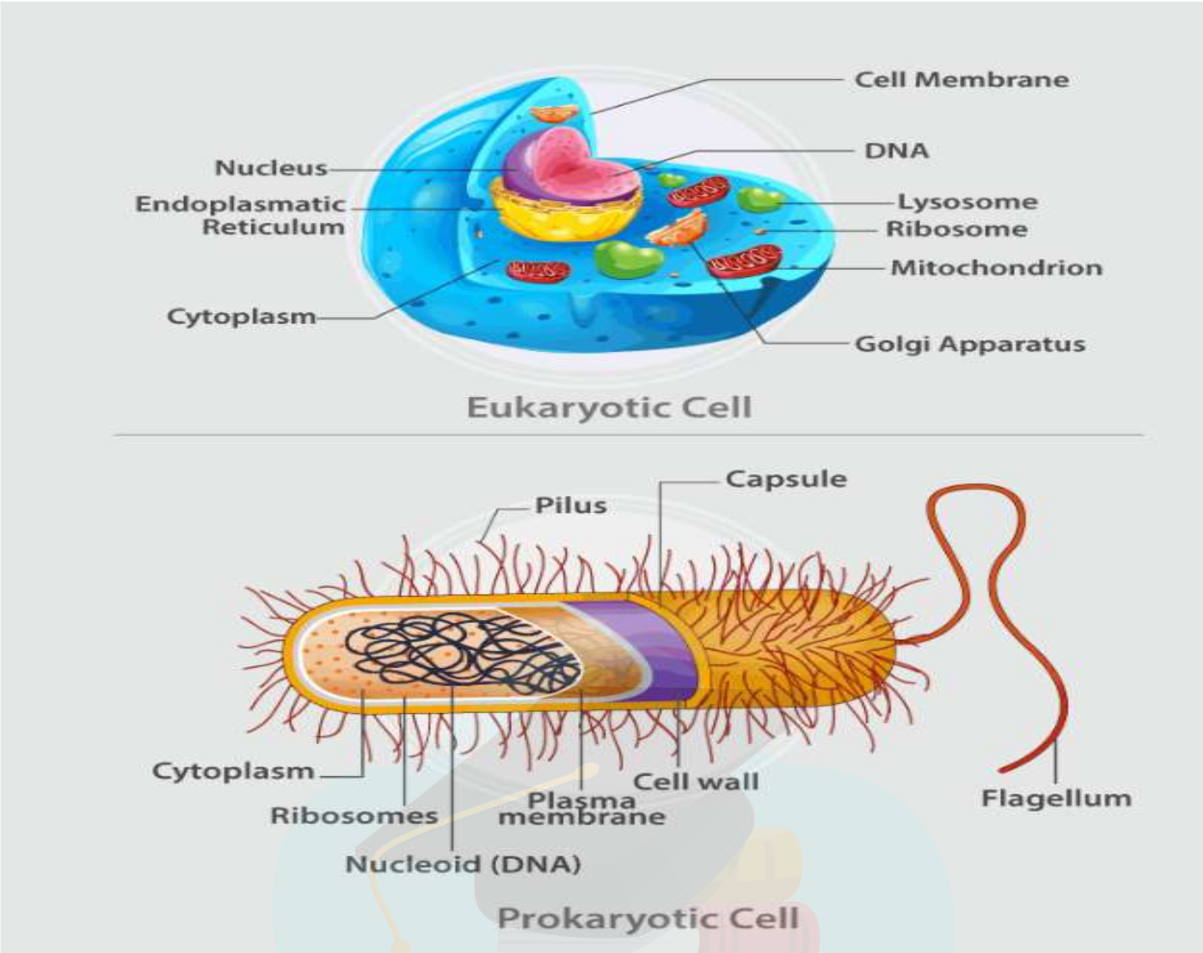


Ribosomes are non membrane-bound and important cytoplasmic organelles found in close association with the endoplasmic reticulum. Ribosomes are found in the form of tiny particles in a large number of cells and are mainly composed of 2/3rd of RNA and 1/3rd of protein. They are named as the 70s (found in prokaryotes) or 80s (found in eukaryotes) The letter S refers to the density and the size, known as Svedberg's Unit. Both 70S and 80S ribosomes are composed of two subunits. Ribosomes are either encompassed within the endoplasmic reticulum or are freely traced in the cell's cytoplasm. Ribosomal RNA and Ribosomal proteins are the two components that together constitute ribosomes. The primary function of the ribosomes includes protein synthesis in all living cells that ensure the survival of the cell.

Difference between prokaryotic and eukaryotic cell:

	Prokaryotes	Eukaryotes
Type of Cell	Always unicellular	Unicellular and multi-cellular
Cell size	Ranges in size from 0.2 μm – 2.0 μm in diameter	Size ranges from 10 μm – 100 μm in diameter
Cell wall	Usually present; chemically complex in nature	When present, chemically simple in nature
Nucleus	Absent. Instead, they have a nucleoid region in the cell	Present
Ribosomes	Present. Smaller in size and spherical in shape	Present. Comparatively larger in size and linear in shape
DNA arrangement	Circular	Linear
Mitochondria	Absent	Present
Cytoplasm	Present, but cell organelles absent	Present, cell organelles present
Endoplasmic reticulum	Absent	Present
Plasmids	Present	Very rarely found in eukaryotes
Ribosome	Small ribosomes	Large ribosomes
Lysosome	Lysosomes and centrosomes are absent	Lysosomes and centrosomes are present
Cell division	Through binary fission	Through mitosis
Flagella	The flagella are smaller in size	The flagella are larger in size
Reproduction	Asexual	Both asexual and sexual
Example	Bacteria and Archaea	Plant and Animal cell

Prokaryotic Vs Eukaryotic Cell

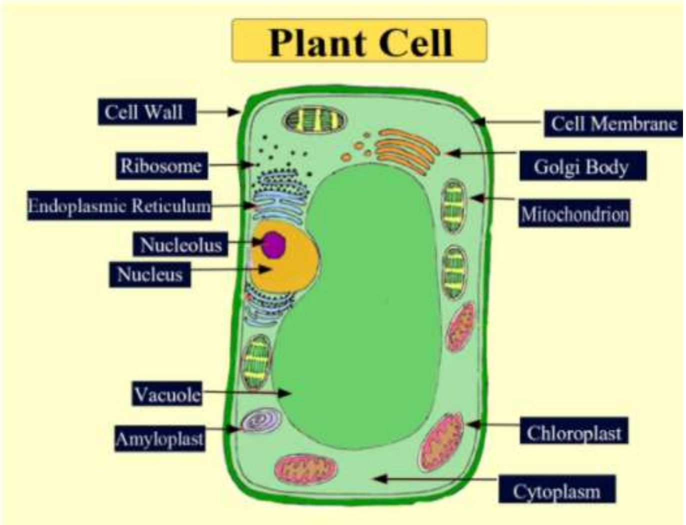


Difference between animal and plant cell:

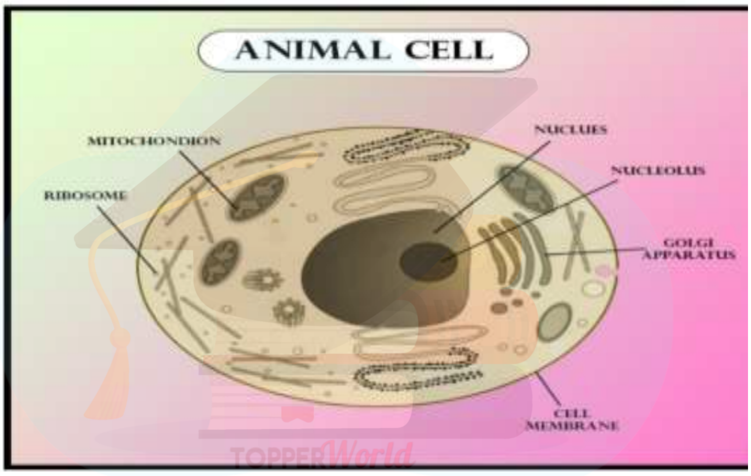
The difference between animal and plant cells are:

Plant cell	Animal cell
1. A plant cell is surrounded by a rigid cell wall.	1. An animal cell does not have a cell wall.
2. Presence of a large vacuole is seen in plant cells.	2. Whereas there are very small vacuoles as compared to plant cells are seen in animal cells.
3. Larger in size.	3. Smaller in size.
4. Plant cells have plastids.	4. Animal cells do not have plastids.
5. Centrosomes are absent in plant cells	5. Animal cells have centrosomes.
6. Plant cells do not have cilia.	6. Animal cells have cilia.
7. Lysosomes are very rare in plant cells.	7. Animal cells have lysosomes.

Plant Cell:



Animal Cell:



Classification of organisms

(a) Cellularity;-Unicellular Organisms

As the name implies, unicellular organisms are made up of a single cell. They are the oldest form of life, with fossil records dating back to about 3.8 billion years ago. Bacteria, amoeba, Paramecium, archaea, protozoa, unicellular **algae**, and unicellular fungi are examples of unicellular organisms. These unicellular organisms are mostly invisible to the naked eye, hence, they are also referred to as microscopic organisms. Most of the unicellular organisms are also prokaryotes.

Examples of Unicellular Organisms

Some of the examples of unicellular organisms are:

- Amoeba
- Euglena
- Paramecium
- Plasmodium
- Nostoc, Salmonella (Prokaryotic unicellular organisms)
- Protozoans, Fungi, Algae (Eukaryotic unicellular organisms)

Also Read: Unicellular Organisms

Multicellular Organisms

Organisms that are composed of more than one cell are called multicellular organisms. **Multicellular organisms** are almost always eukaryotes. However, bacteria can form large interlinked structures such as colonies or biofilms but these can't be classified as multicellular organisms.

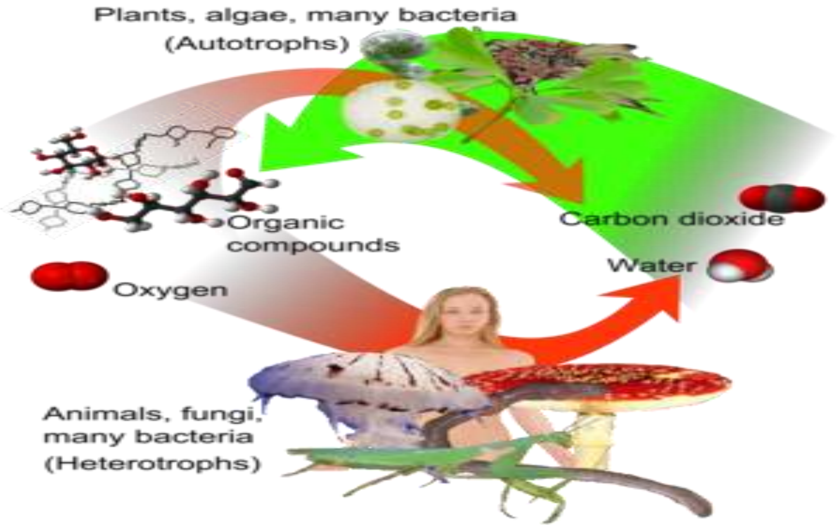
Multicellular Organisms Examples

Some of the examples of multicellular organisms are listed below:

- All vertebrates and invertebrates
- All angiosperms, gymnosperms and higher land plants

(b) Energy and Carbon Utilization:- Autotrophs, Hetrotrophs and Lithotrops:

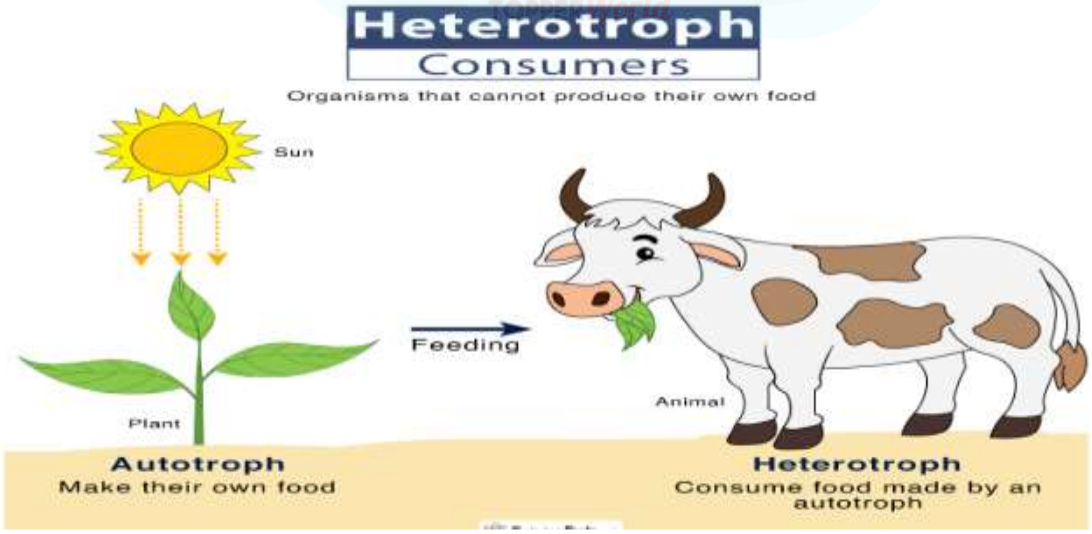
Autotrophs



Autotrophs are organisms that undergo autotrophic mode of nutrition. These are the organisms that can prepare their own food from simple substances like carbon dioxide and water. All green plants are examples of autotrophs. These green plants contain chlorophyll pigment in the plant cell that helps in the synthesis of their own food by absorbing energy from the sunlight. All autotrophs are producers and are placed at the primary level in the food web.

Carbohydrates can be converted to fatty acids to produce lipids. Other elements may be added to synthesize organic compounds such as proteins. Carbohydrates, proteins and lipids can be used as energy sources during respiration by both autotrophs and heterotrophs, recycling carbon dioxide so that it may again be used in photosynthesis.

Heterotrophs



Heterotrophs are organisms which cannot prepare their own food and depend upon producers or green plants and other animals for their food. This mode of nutrition is known as the heterotrophic mode of nutrition.

Heterotrophs rely on autotrophs to provide a continuous supply of new organic molecules. Heterotrophs are considered as consumers in the food web and are placed at a secondary or tertiary level.

All the non-green plants and animals, inclusive of human beings, are the best examples of heterotrophs.

The heterotrophs are benefited from photosynthesis in many ways.

- Directly by consuming plants as herbivores
- Indirectly by attacking, killing and consuming other herbivores animals (carnivores) or both animals and plants (omnivores)
- By using oxygen for the cellular respiration process

Lithotroph:

A lithotroph is a microorganism that uses inorganic substrates as a source of electron donors to drive energy acquisition, using either organic carbon or carbon dioxide as a source of carbon for constructing cellular materials (Ehrlich and Newman 2008). Microorganisms oxidize the electron donors to generate electrons that are channeled into electron respiratory chains to produce the energy-storing molecule, ATP. These organisms can use a variety of electron acceptors to complete the respiratory process, including oxygen, sulfate, and other compounds. Lithotroph means rock (lithos) eater (troph) and representatives are found in both the Bacterial and Archaeal domains.

(c) Habitat:

A place where organisms make their home is called habitat. It has all the important environmental conditions which are must for survival. In everything it comes gathering of food, selection of mate, reproducing successfully, etc. In the case of plants, a good habitat means a place where there is a good combination of light, air, water, and soil. For example: plants like prickly pear cactus need sandy soil, dry climate and bright sunlight for proper growth as they mainly grow in areas like the Sonoran Desert in northwest Mexico. This type of plants cannot grow in wet, cold areas.

Few major components of a good host are shelter, water, food and space. And when all kinds of arrangements are there in a proper way then it is called to be a good habitat.

Types of Habitat

A. Terrestrial Habitat: When plants and animals survive on the earth, then such habitats are called terrestrial habitats. There are three kinds of terrestrial habitats, they are:

Desert: In desert habitat, at night animals stay out and in day they stay inside the deep holes in the sand. And in desert plant photosynthesis takes place through stems, to prevent loss of water.

Mountain: In mountainous habitat plants are cone shaped and leaves have needle like structure, to prevent snow from shed on plants. And animals of such habitat have thick fur to protect them from cold.

Grassland: Such habitats are present in grassy areas.

B. Aquatic Habitats: Plants and animals which live under water are called to live in aquatic habitats. Further, aquatic habitat are of two types:

Ponds: In ponds plants have their root stick to soil and their roots are totally submerged in water.

Oceans: Organisms who live in the ocean have gills which help them in the utilization of dissolved oxygen in the water. While some animals also use nostrils for breathing like whales and dolphins.

Environmental Factor

There are so many factors which affect the distribution of an organism, they are temperature, humidity, climate, soil and light intensity, and the presence or absence of all the requirements that the organism needs to sustain it. In the case of some plants and animal species their requirements are fulfilled in a wide range of locations. Like Pieris rapae butterfly is found all over the continent except Antarctica continent as its larvae have capability to feed on a wide range of Brassicas and various other plant species, and it thrives in any open location with diverse plant associations.

Habitat Ecology

A fascinating area of natural science which helps to broaden our understanding of the interactions that determine the distribution and abundance of organisms is called habitat ecology.

It can also be defined as the type of natural environment in which few species of an organism survive, characterised by both physical and biological features.

(d) Ammonia excretion:- ammonotelic, 17ricotelic and ureotelic:

Ammonotelic animals:

1. An ammonotelic organism generally excretes nitrogenous waste as soluble ammonia.
2. Ammonia, the product or waste formed is highly toxic and requires a large amount of water for its excretion.
3. Most aquatic animals including protozoans, crustaceans, Platyhelminthes, cnidarians, poriferans, echinoderms, fishes, larvae/tadpoles of amphibians are ammonotelic.

Ureotelic animals:

1. A ureotelic organism generally excretes excess nitrogen as urea. Urea is less toxic and needs less water for excretion. The uricotelic organism excretes either uric acid or its salts.
2. Uric acid is the least toxic and requires less water in comparison to urea and ammonia. It can be stored in the cells and body tissues without causing any toxic effects.
3. Ureotelic organisms include cartilaginous fish, a few bony fishes, adult amphibians, and also mammals including humans.

Uricotelic animals:

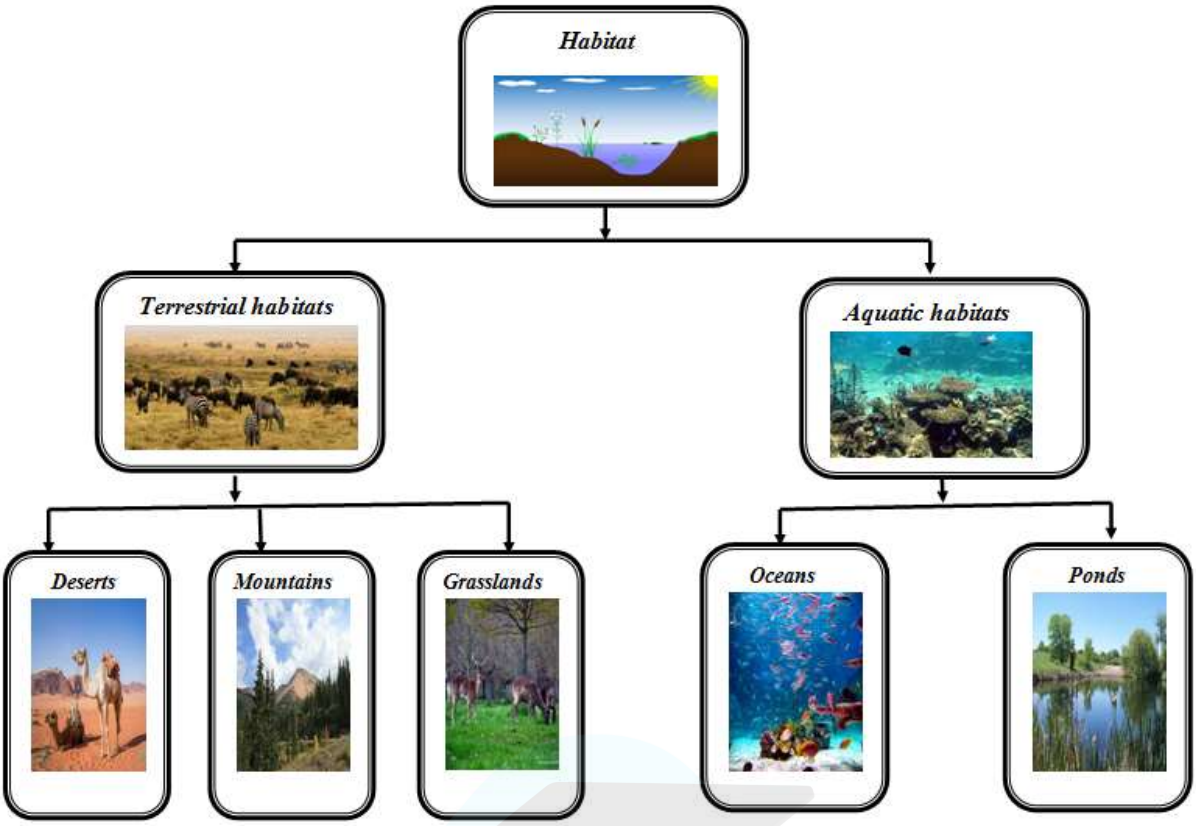
1. The species which excrete uric acid waste are called uricotelic organisms.
2. The excreta of the uricotelic organisms are insoluble solids or semi-solid and requires less water.
3. For example: Terrestrial arthropods (including insects), lizards, snakes, birds, etc.

(e) Habitat- acquatic or terrestrial:

Different types of living organism are found in different regions of the world. In this article, we will be studying about different kinds of living creatures and how they survive in different types of climate. How is the habitat different for different living organisms?

Certain characteristic of living organisms which enables them to survive in their surrounding are known as an **adaptation** in living organism.

The surrounding where living organisms survive is known as **habitat**.



Types of habitat:

Different types of habitats are:

1) Terrestrial habitat:

- Plants and animals that survive on land.
- Three types:
- **Desert:** At night, small animals stay out, while in the day they stay inside the deep holes in the sand.

Plants do not have leaves. Photosynthesis takes place through stems.

- **Mountain:** Plants are cone shaped, and leaves have needle-like structure.

Animals have thick fur to protect them from cold.

- **Grassland:** Brown in color, found in the grassy area.

2) Aquatic habitat:

- Plants and animals that live under water.
- Types:
- **Ponds:**

Plants with their roots fixed in the soil.

Plants whose roots are totally submerged in water.

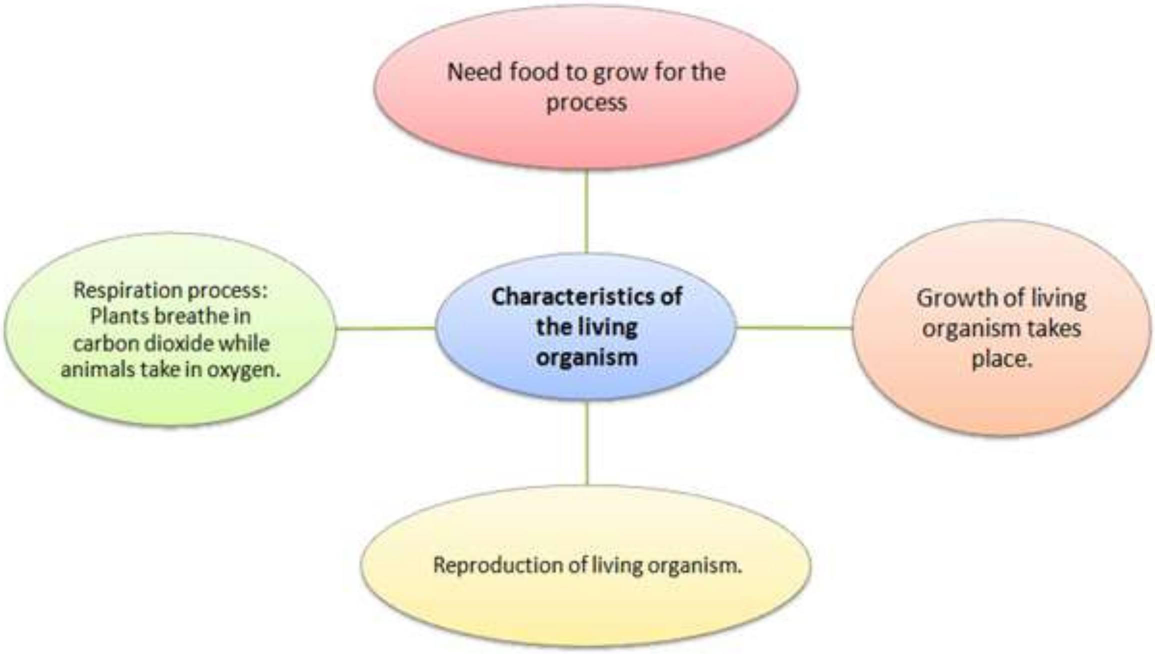
- **Oceans:**

Animals have gills which help them in the utilization of dissolved oxygen in the water.

Some animals like whales and dolphins have nostrils to breathe.

Characteristics of living organism:

Humans are living organism. So is the dog living outside our house and plants providing us shade are living organisms. All of them have some special characteristics. But some of the characteristics are in general common to all the living organisms.



From the above diagram, we got to know about the various characteristics of living organisms. Some of them are respiration, growth, reproduction of living organism and the need for food to stay alive.

(e) Molecular taxonomy- three major kingdoms of life

Five Kingdom Classification

The five-kingdom classification that we see today was not the initial result of the classification of living organisms. Carolus Linnaeus first came up with a two-kingdom classification, which included only kingdom Plantae and kingdom Animalia.

The two-kingdom classification lasted for a very long time but did not last forever because it did not take into account many major parameters while classifying. There was no differentiation of the eukaryotes and prokaryotes; neither unicellular and multicellular; nor photosynthetic and the non-photosynthetic.

Putting all the organisms in either plant or animal kingdom was insufficient because there were a lot of organisms which could not be classified as either plants or animals.

All this confusion led to a new mode of classification which had to take into account cell structure, the presence of cell wall, mode of reproduction and mode of nutrition. As a result, R H Whittaker came up with the concept of the five-kingdom classification.

The five-kingdom classification of living organisms included the following kingdoms:

Kingdom Monera

Bacteria are categorized underneath the Kingdom Monera.

Features of Monerans

They possess the following important features:

- Bacteria occur everywhere and they are microscopic in nature.

- They possess a cell wall and are prokaryotic.
- The cell wall is formed of amino acids and polysaccharides.
- Bacteria can be heterotrophic and autotrophic.
- The heterotrophic bacteria can be parasitic or saprophytic. The autotrophic bacteria can be chemosynthetic or photosynthetic.

Types of Monerans

Bacteria can be classified into four types based on their shape:

- **Coccus (pl.: cocci) –** These bacteria are spherical in shape
- **Bacillus (pl.: bacilli)** – These bacteria are rod-shaped
- **Vibrium (pl.: vibrio) –** These bacteria are comma-shaped bacteria
- **Spirillum (pl.: spirilla) –** These bacteria are spiral-shaped bacteria

Monera has since been divided into Archaebacteria and Eubacteria.

Kingdom Protista

Features of Protista

Protista has the following important features:

- They are unicellular and eukaryotic organisms.
- Some of them have cilia or flagella for mobility.
- Sexual reproduction is by a process of cell fusion and zygote formation.

Sub-groups of Protista

Kingdom Protista is categorized into subsequent groups:

- **Chrysophytes**: The golden algae (desmids) and diatoms fall under this group. They are found in marine and freshwater habitats.
- **Dinoflagellates**: They are usually photosynthetic and marine. The colour they appear is dependent on the key pigments in their cells; they appear red, blue, brown, green or yellow.
- **Euglenoids**: Most of them live in freshwater habitation in motionless water. The cell wall is absent in them, instead, there is a protein-rich layer called a pellicle.
- **Slime Moulds**: These are saprophytic. The body moves along putrefying leaves and twigs and nourishes itself on organic material. Under favourable surroundings, they form an accumulation and were called Plasmodial slime moulds.
- **Protozoans**: They are heterotrophs and survive either as parasites or predators.

Kingdom Fungi

The kingdom fungi include moulds, mushroom, yeast etc. They show a variety of applications in domestic as well as commercial purposes.

Features of Kingdom Fungi

- The fungi are filamentous, excluding yeast (single-celled).
- Their figure comprises slender, long thread-like constructions called hyphae. The web of hyphae is called mycelium.

- Some of the hyphae are unbroken tubes which are jam-packed with multinucleated cytoplasm. Such hyphae are labelled Coenocytic hyphae.
- The other type of hyphae has cross-walls or septae.
- The cell wall of fungi is composed of polysaccharides and chitin.
- Most of the fungi are saprophytes and are heterotrophic.
- Some of the fungi also survive as symbionts. Some are parasites. Some of the symbiont fungi live in association with algae, like lichens. Some symbiont fungi live in association with roots of higher plants, as mycorrhiza.

Kingdom Plantae

Features of Kingdom Plantae

- The kingdom Plantae is filled with all eukaryotes which have chloroplast.
- Most of them are autotrophic in nature, but some are heterotrophic as well.
- The Cell wall mainly comprises cellulose.
- Plants have two distinct phases in their lifecycle. These phases alternate with each other. The diploid saprophytic and the haploid gametophytic phase. The lengths of the diploid and haploid phases vary among dissimilar groups of plants. Alternation of Generation is what this phenomenon is called.

Kingdom Animalia

Features of Kingdom Animalia

- All multicellular eukaryotes which are heterotrophs and lack cell wall are set aside under this kingdom.
- The animals are directly or indirectly dependent on plants for food. Their mode of nutrition is holozoic. Holozoic nutrition encompasses ingestion of food and then the use of an internal cavity for digestion of food.
- Many of the animals are adept for locomotion.
- They reproduce by sexual mode of reproduction.

The five-kingdom classification of living organisms took a lot into consideration and is till now the most efficient system.

The older system of classification was based only on one single characteristic according to which two highly varied organisms were grouped together. For example, the fungi and plants were placed in the same group based on the presence of the cell wall. In the same way, unicellular and multicellular organisms were also grouped together.

Therefore, all the organisms were classified again into the five kingdoms known as the five-kingdom classification, starting with Monera, where all the prokaryotic unicellular organisms were placed together.

Following that, all the eukaryotic unicellular organisms were placed under the kingdom Protista.

The organisms were then classified based on the presence and absence of a cell wall. The ones without the cell wall were classified under kingdom Animalia and the ones with cell wall were classified under kingdom Plantae.

The organisms under kingdom Plantae were further classified into photosynthetic and non-photosynthetic, which included Plantae and fungi respectively.

This system of classification of living organisms is better than following the older classification of plants and animals because it eradicated the confusion of putting one species in two different kingdoms.

Unit-II

Introduction to Biomolecules

What is Carbohydrates ?

Carbohydrates are a group of naturally occurring carbonyl compounds (aldehydes or ketones) that also contain several hydroxyl groups. It may also include their derivatives which produce such compounds on hydrolysis. They are the most abundant organic molecules in nature and are also referred to as “saccharides”. The carbohydrates which are soluble in water and sweet in taste are called “sugars”.

Our body utilizes this sugar as a source of energy for the cells, organs and tissues. The extra amount of energy or sugar is stored in our muscles and liver for further requirement. The term ‘carbohydrate’ is derived from a French term ‘***hydrate de carbone***‘ meaning ‘*hydrate of carbon*‘. The general formula of this class of organic compounds is $\mathbf{C_n(H_2O)_n}$.

Classification of Carbohydrates

The carbohydrates are further classified into simple and complex which is mainly based on their chemical structure and degree of polymerization.

Simple Carbohydrates (Monosaccharides, Disaccharides and Oligosaccharides)

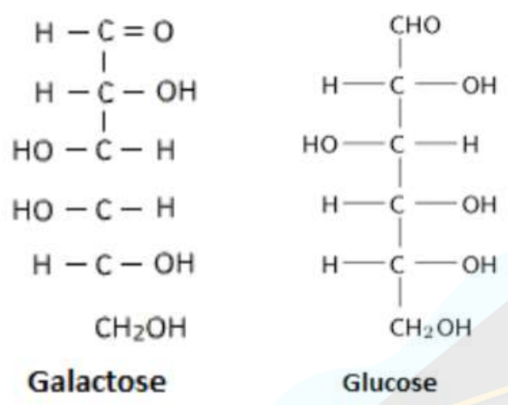
Simple carbohydrates have one or two sugar molecules. In simple carbohydrates, molecules are digested and converted quickly resulting in a rise in the blood sugar levels. They are abundantly found in milk products, beer, fruits, refined sugars, candies, etc. These carbohydrates are called empty calories, as they do not possess fiber, vitamins and minerals.

Plants, being producers, synthesize glucose ($C_6H_{12}O_6$) using raw materials like carbon dioxide and water in the presence of sunlight. This process of photosynthesis converts solar energy to chemical energy. Consumers feed on plants and harvest energy stored in the bonds of the compounds synthesized by plants.

Also, read more about Photosynthesis

1. Monosaccharides

Glucose is an example of a carbohydrate monomer or monosaccharide. Other examples of monosaccharides include mannose, galactose, fructose, etc. The structural organization of monosaccharides is as follows:



Monosaccharides may be further classified depending on the number of carbon atoms:

(i)Trioses ($C_3H_6O_3$): These have three carbon atoms per molecule. Example: Glyceraldehyde

(ii)Tetroses ($C_4H_6O_4$): These monosaccharides have four carbon atoms per molecule. Example: Erythrose.

Similarly, we have-

(iii) Pentoses,

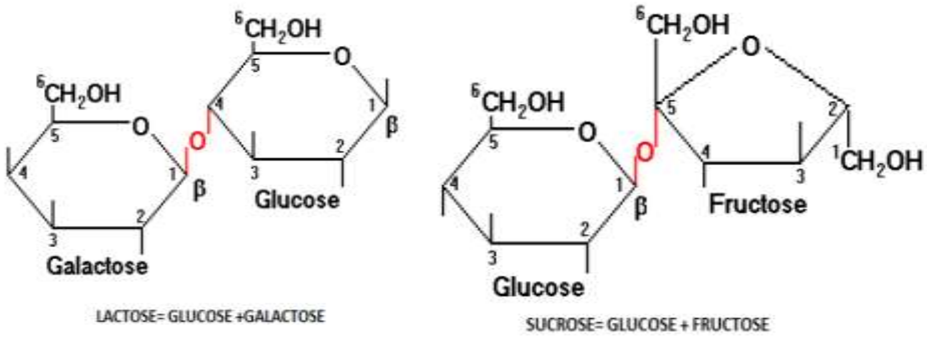
(iv) Hexoses, and

(v) Heptoses

2. Disaccharides

Two monosaccharides combine to form a disaccharide. Examples of carbohydrates having two monomers include- Sucrose, Lactose, Maltose, etc.

3.



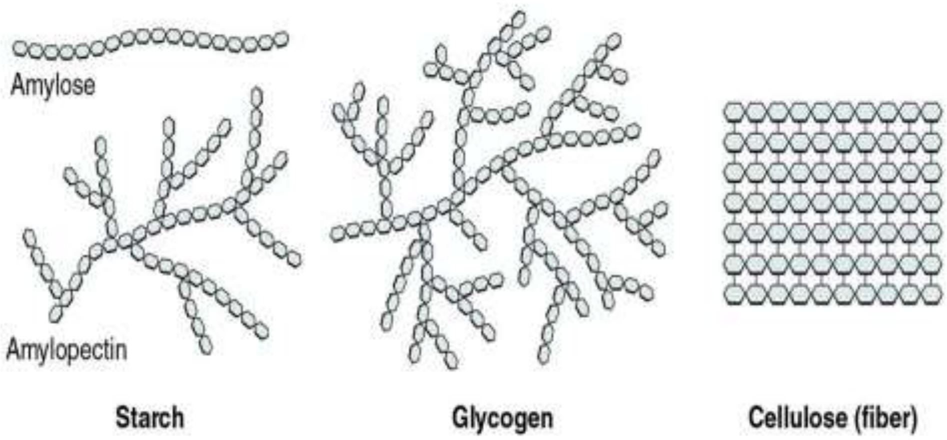
Oligosaccharides

Carbohydrates formed by the condensation of 2-9 monomers are called oligosaccharides. By this convention, trioses, pentoses, hexoses are all oligosaccharides.

Complex Carbohydrates (Polysaccharides)

Complex carbohydrates have two or more sugar molecules, hence they are referred to as starchy foods. In complex carbohydrates, molecules are digested and converted slowly compared to simple carbohydrates. They are abundantly found in lentils, beans, peanuts, potatoes, peas, corn, whole-grain bread, cereals, etc.

Polysaccharides are complex carbohydrates formed by the polymerization of a large number of monomers. Examples of polysaccharides include starch, glycogen, cellulose, etc. which exhibit extensive branching and are homopolymers – made up of only glucose units.



1. Starch is composed of two components- amylose and amylopectin. Amylose forms the linear chain and amylopectin is a much-branched chain.
2. Glycogen is called animal starch. It has a structure similar to starch, but has more extensive branching.
3. Cellulose is a structural carbohydrate and is the main structural component of the plant cell wall. It is a fibrous polysaccharide with high tensile strength. In contrast to starch and glycogen, cellulose forms a linear polymer.

Examples of Carbohydrates

Following are the important examples of carbohydrates:

- Glucose
- Galactose
- Maltose
- Fructose
- Sucrose
- Lactose
- Starch
- Cellulose
- Chitin

Name some bad carbohydrates that are harmful to the body.

The bad carbs include:

- White bread
- Sugary drinks
- Pastries
- Candies and chocolates

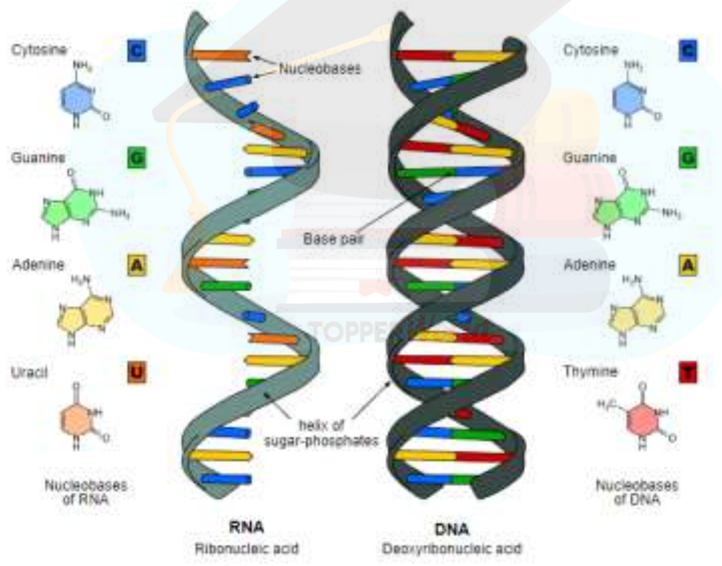
Functions of carbohydrates:

- Carbohydrates are helpful in performing many functions such as breakdown of protein molecules, dehydration as well as eliminating ketosis.
- They serve as primary energy sources.
- They provide energy.
- They help in the regulation of blood glucose.

- They provide the carbon skeleton for the synthesis of some non-essential amino acids.

lipids, proteins, nucleic acids (DNA& RNA: Structure and forms):

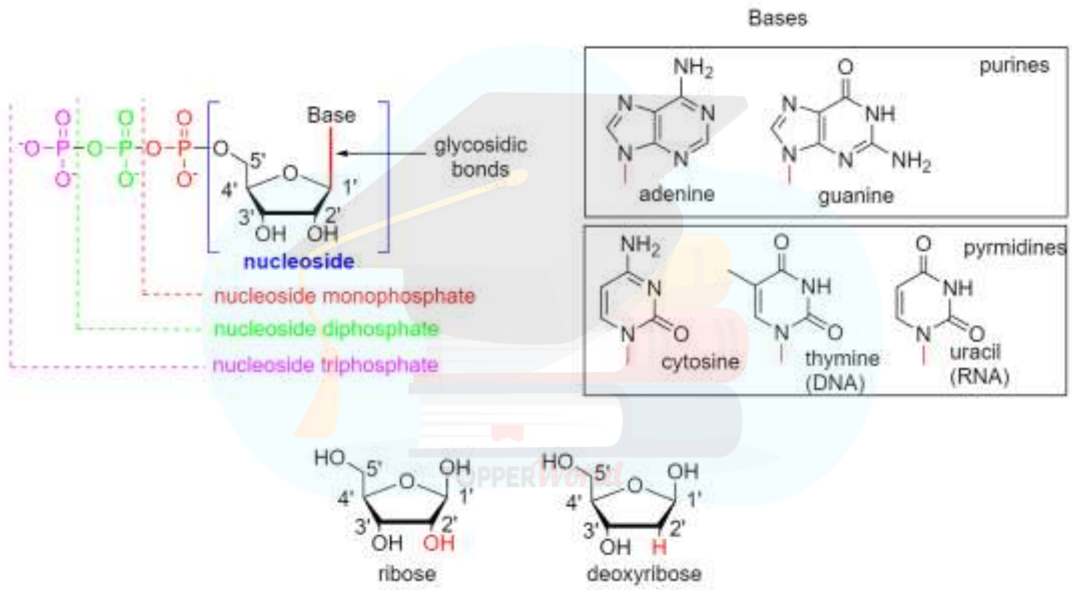
Alongside proteins, lipids and complex carbohydrates (polysaccharides), *nucleic acids* are one of the four major types of macromolecules that are essential for all known forms of life. The nucleic acids consists of two major macromolecules, *Deoxyribonucleic acid (DNA)* and *ribonucleic acid (RNA)* that carry the genetic instructions for the development, functioning, growth and reproduction of all known organisms and viruses. Both consist of polymers of a sugar-phosphate-sugar backbone with organic heterocyclic bases attached to the sugars. The sugar in DNA is deoxyribose while in RNA it is ribose. DNA contain four bases, cytosine and thymine (pyrimidine bases) and guanine and adenine (purine bases). DNA in vivo consist of two antiparallel strands intertwined to form the iconic DNA double-stranded helix. RNA is single stranded but may adopt many secondary and tertiary conformations not unlike that of a protein. Below shows a low resolution comparison of the structure of DNA and RNA.



The biological function of DNA is quite simple, to carry and protect the genetic code. Its structure serves that purpose well. In the next section, we will study the functions of RNA, which are much more numerous and complicated. The structure of RNA has evolved to serve those added functions.

The core structure of a nucleic acid monomer is the *nucleoside*, which consists of a sugar residue + a nitrogenous base that is attached to the sugar residue at the 1′ position as shown in. The sugar utilized for RNA monomers is ribose, whereas DNA monomers utilize deoxyribose that has lost the hydroxyl functional group at the 2′ position of ribose. For the DNA molecule, there are four nitrogenous bases that are incorporated into the standard DNA structure. These include the *Purines:* Adenine (A) and Guanine (G), and the *Pyrimidines:* Cytosine (C) and Thymine (T). RNA uses the same nitrogenous bases as DNA, except for Thymine. Thymine is replaced with Uracil (U) in the RNA structure.

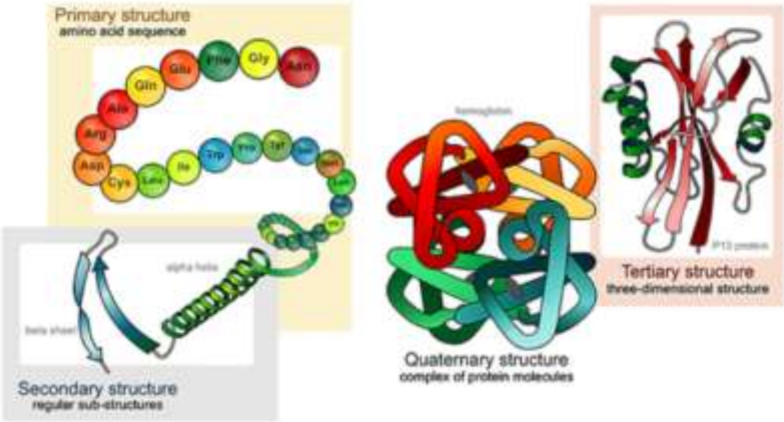
When one or more phosphate groups are attached to a nucleoside at the 5′ position of the sugar residue, it is called a *nucleotide. Nucleotides* come in three flavors depending how many phosphates are included: the incorporation of one phosphate forms a *nucleoside monophosphate*, the incorporation of two phosphates forms a *nucleoside diphosphate*, and the incorporation of three phosphates forms a nucleoside triphosphate as shown in.



The Monomer Building Blocks of Nucleic Acids. The site of the nitrogenous base attachment to the sugar residue (glycosidic bond) is shown in red.

Hierarch in protein structure:

Protein structures are made by condensation of amino acids forming peptide bonds. The sequence of amino acids in a protein is called its primary structure. The secondary structure is determined by the dihedral angles of the peptide bonds, the tertiary structure by the folding of protein chains in space. Association of folded polypeptide molecules to complex functional proteins results in quaternary structure.

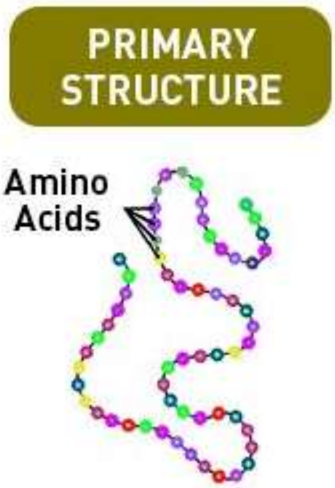


Primary, Secondary, Tertiary and Quaternary Structure of Proteins

1. Primary Structure of Protein

- The Primary structure of proteins is the exact ordering of amino acids forming their chains.
- The exact sequence of the proteins is very important as it determines the final fold and therefore the function of the protein.
- The number of polypeptide chains together form proteins. These chains have amino acids arranged in a particular sequence which is characteristic of the specific protein. Any change in the sequence changes the entire protein.

The following picture represents the primary protein structure (an amino acid chain). As you might expect, the amino acid sequence within the polypeptide chain is crucial for the protein's proper functioning. This sequence is encrypted in the DNA genetic code. If mutation is present in the DNA and the amino acid sequence is changed, the protein function may be affected.



Primary Structure of Protein

The protein ‘s primary structure is the amino acid sequence in its polypeptide chain. If proteins were popcorn stringers designed to decorate a Christmas tree, a protein ‘s primary structure is the sequence in which various shapes and varieties of popped maize are strung together.

Covalent, peptide bonds which connect the amino acids together maintain the primary structure of a protein.

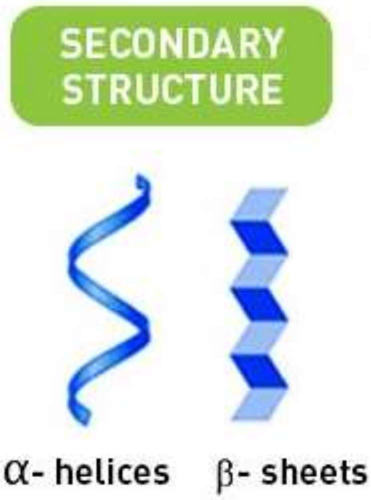
All documented genetic disorders, such as cystic fibrosis, sickle cell anemia, albinism, etc., are caused by mutations resulting in alterations in the primary protein structures, which in turn lead to alterations in the secondary , tertiary and probably quarterly structure.

Amino acids are small organic molecules consisting of a chiral carbon with four substituents. Of those only the fourth the side chain is different among amino acids.

2. Secondary Structure of Protein

Secondary structure of protein refers to local folded structures that form within a polypeptide due to interactions between atoms of the backbone.

- The proteins do not exist in just simple chains of polypeptides.
- These polypeptide chains usually fold due to the interaction between the amine and carboxyl group of the peptide link.
- The structure refers to the shape in which a long polypeptide chain can exist.
- They are found to exist in two different types of structures α – helix and β – pleated sheet structures.
- This structure arises due to the regular folding of the backbone of the polypeptide chain due to hydrogen bonding between -CO group and -NH groups of the peptide bond.
- However, segments of the protein chain may acquire their own local fold, which is much simpler and usually takes the shape of a spiral an extended shape or a loop. These local folds are termed secondary elements and form the proteins secondary structure.



Secondary Structure of Protein

(a) α – Helix:

α – Helix is one of the most common ways in which a polypeptide chain forms all possible hydrogen bonds by twisting into a right-handed screw with the -NH group of each amino acid residue hydrogen-bonded to the -CO of the adjacent turn of the helix. The polypeptide chains twisted into a right-handed screw.

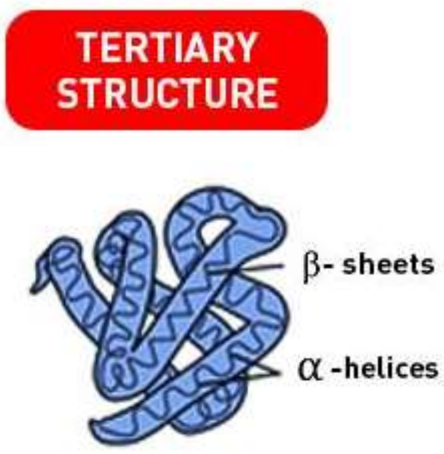
(b) β – pleated sheet:

In this arrangement, the polypeptide chains are stretched out beside one another and then bonded by intermolecular H-bonds. In this structure, all peptide chains are stretched out to nearly maximum extension and then laid side by side which is held together by intermolecular hydrogen bonds. The structure resembles the pleated folds of drapery and therefore is known as β – pleated sheet

3. Tertiary Structure of Protein

- This structure arises from further folding of the secondary structure of the protein.
- H-bonds, electrostatic forces, disulphide linkages, and Vander Waals forces stabilize this structure.
- The tertiary structure of proteins represents overall folding of the polypeptide chains, further folding of the secondary structure.
- It gives rise to two major molecular shapes called fibrous and globular.

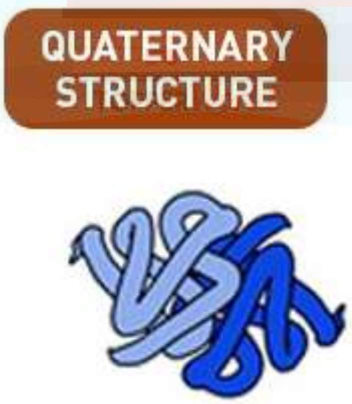
- The main forces which stabilize the secondary and tertiary structures of proteins are hydrogen bonds, disulphide linkages, van der Waals and electrostatic forces of attraction.



Tertiary Structure of Protein

4. Quaternary Structure of Protein

The spatial arrangement of various tertiary structures gives rise to the quaternary structure. Some of the proteins are composed of two or more polypeptide chains referred to as sub-units. The spatial arrangement of these subunits with respect to each other is known as quaternary structure.



Quaternary Structure of Protein

The exact amino acid sequence of each protein drives it to fold into its own unique and biologically active three-dimensional fold also known as the tertiary structure. Proteins consist of different combinations of secondary elements some of which are simple whereas others are more complex. Parts of the protein chain, which have their own three-dimensional fold and can be attributed to some function are called ***"domains"***. These are considered today as the evolutionary and functional building blocks of proteins.

Many proteins, most of which are enzymes contain organic or elemental components needed for their activity and stability. Thus the study of protein evolution not only gives structural insight but also connects proteins of quite different parts of the metabolism.

Proteins as enzymes:

Enzymes are proteins that help speed up chemical reactions in our bodies. Enzymes are essential for digestion, liver function and much more. Too much or too little of a certain enzyme can cause health problems. Enzymes in our blood can also help healthcare providers check for injuries and diseases.

Enzymes also help with:

- Breathing.
- Building muscle.
- Nerve function.
- Ridding our bodies of toxins

What are the different types of enzymes?

There are thousands of individual enzymes in the body. Each type of enzyme only has one job. For example, the enzyme sucrase breaks down a sugar called sucrose. Lactase breaks down lactose, a kind of sugar found in milk products.

Some of the most common digestive enzymes are:

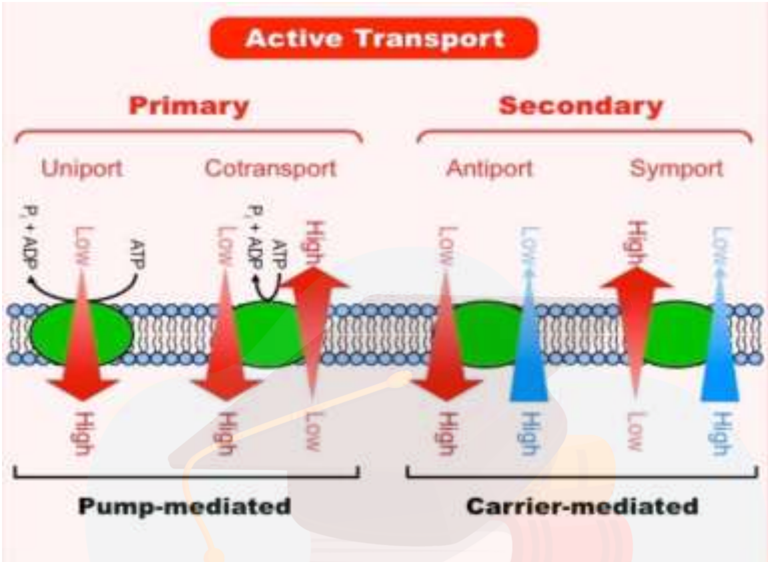
- **Carbohydrase** breaks down carbohydrates into sugars.
- **Lipase** breaks down fats into fatty acids.
- **Protease** breaks down protein into amino acids

Transport :

In biology, **transport** is the act or the means by which molecules, ions, or substrates are moved across a biological membrane, such as the plasma membrane. It may also pertain to electrons being transported along the electron transport chain .

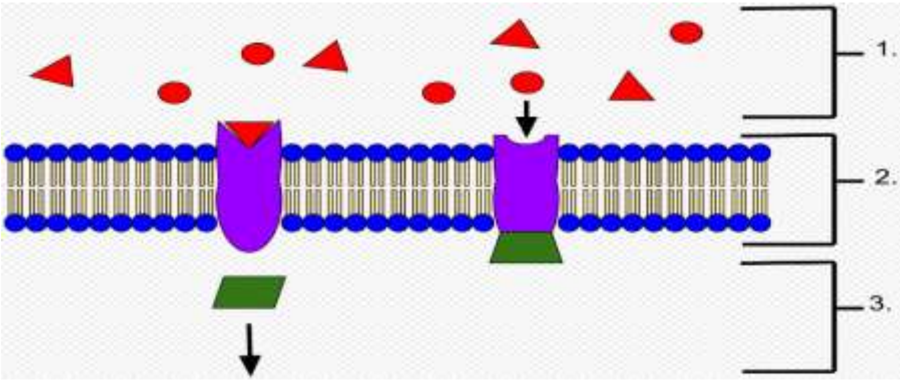
At the cellular level, a concenration gradient is necessary for cellular transport to occur. A concentration gradient occurs when there is a concentration difference, for example, between the cell cytoplasm and extracellular fluid. Transport may then be *along* or *against* their respective concentration gradient.

Transport may also be used to pertain to the transport activity of blood and other bodily fluids in the circulatory system. Thus, the transport of biological substances may occur in intracellular and extracellular fluids.

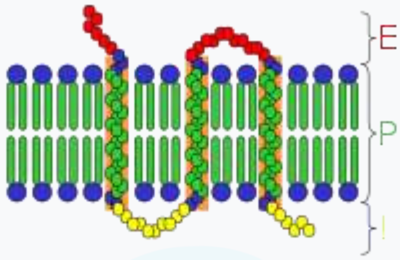


Receptors and structural elements:

Receptors are chemical structures, composed of protein that receive and transduce signals that may be integrated into biological systems. These signals are typically chemical messengers which bind to a receptor and cause some form of cellular/tissue response, e.g. a change in the electrical activity of a cell. There are three main ways the action of the receptor can be classified: relay of signal, amplification, or integration. Relaying sends the signal onward, amplification increases the effect of a single ligand , and integration allows the signal to be incorporated into another biochemical pathway.



Structure:



Transmembrane receptor: E=extracellular space; I=intracellular space; P=plasma membrane

The structures of receptors are very diverse and include the following major categories, among others:

- Type 1: Ligand -gated ion channels (ionotropic receptors) – These receptors are typically the targets of fast neurotransmitters such as acetylcholine (nicotinic) and GABA ; activation of these receptors results in changes in ion movement across a membrane. They have a heteromeric structure in that each subunit consists of the extracellular ligand-binding domain and a transmembrane domain which includes four transmembrane alpha helices . The ligand-binding cavities are located at the interface between the subunits.

Type 2: G protein -coupled receptors (metabotropic receptors) – This is the largest family of receptors and includes the receptors for several hormones and slow transmitters e.g. dopamine, metabotropic glutamate. They are composed of seven transmembrane alpha helices. The loops connecting the alpha helices form extracellular and intracellular domains. The binding-site for larger peptide ligands is usually located in the extracellular domain whereas the binding site for smaller non-peptide ligands is often located between the seven alpha helices and one extracellular loop.

- Type 3: Kinase-linked and related receptors (see "Receptor tyrosine kisnase " and "Enzyme -linked receptor") – They are composed of an extracellular domain containing the ligand binding site and an intracellular domain, often with enzymatic-function, linked by a single transmembrane alpha helix. The insulin receptor is an example.

- Type 4: Nuclear receptor – While they are called nuclear receptors, they are actually located in the cytoplasm and migrate to the nucleus after binding with their ligands. They are composed of a C-terminal ligand-binding region, a core DNA binding domain (DBD) and an N- terminal domain that contains the *AF1*(activation function 1) region

Enzymes as biocatalysts:

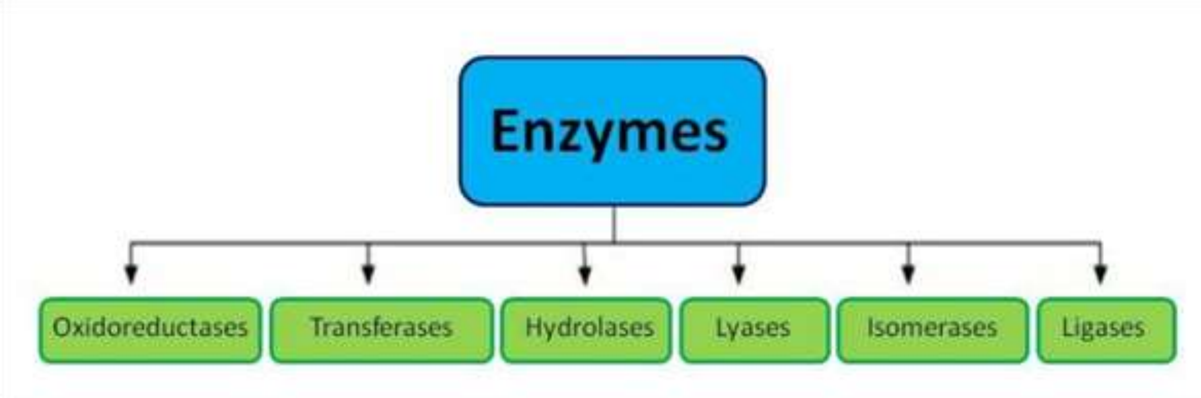
What is Enzymes:

The majority of enzymes are proteins with catalytic capabilities crucial to perform different processes. Metabolic processes and other chemical reactions in the cell are carried out by a set of enzymes that are necessary to sustain life.

The initial stage of metabolic process depends upon the enzymes, which react with a molecule and is called the substrate. Enzymes convert the substrates into other distinct molecules, which are known as products.

The regulation of enzymes has been a key element in clinical diagnosis because of their role in maintaining life processes. The macromolecular components of all enzymes consist of protein, except in the class of RNA catalysts called ribozymes. The word ribozyme is derived from the ribonucleic acid enzyme. Many ribozymes are molecules of ribonucleic acid, which catalyze reactions in one of their own bonds or among other RNAs.

Enzymes Classification



Earlier, enzymes were assigned names based on the one who discovered them. With further research, classification became more comprehensive.

According to the International Union of Biochemists (I U B), enzymes are divided into six functional classes and are classified based on the type of reaction in which they are used to catalyze. The six kinds of enzymes are hydrolases, oxidoreductases, lyases, transferases, ligases and isomerases.

Listed below is the classification of enzymes discussed in detail:

Types	Biochemical Property
Oxidoreductases	The enzyme Oxidoreductase catalyzes the oxidation reaction where the electrons tend to travel from one form of a molecule to the other.
Transferases	The Transferases enzymes help in the transportation of the functional group among acceptors and donor molecules.
Hydrolases	Hydrolases are hydrolytic enzymes, which catalyze the hydrolysis reaction by adding water to cleave the bond and hydrolyze it.
Lyases	Adds water, carbon dioxide or ammonia across double bonds or eliminate these to create double bonds.
Isomerases	The Isomerases enzymes catalyze the structural shifts present in a molecule, thus causing the change in the shape of the molecule.
Ligases	The Ligases enzymes are known to charge the catalysis of a ligation process.

Oxidoreductases

These catalyze oxidation and reduction reactions, e.g. pyruvate dehydrogenase, catalysing the oxidation of pyruvate to acetyl coenzyme A.

Transferases

These catalyze transferring of the chemical group from one to another compound. An example is a transaminase, which transfers an amino group from one molecule to another.

Hydrolases

They catalyze the hydrolysis of a bond. For example, the enzyme pepsin hydrolyzes peptide bonds in protiens.

Lyases

These catalyze the breakage of bonds without catalysis, e.g. aldolase (an enzyme in glycolysis) catalyzes the splitting of fructose-1, 6-bisphosphate to glyceraldehyde-3-phosphate and dihydroxyacetone phosphate.

Isomerases

They catalyze the formation of an isomer of a compound. Example: phosphoglucomutase catalyzes the conversion of glucose-1-phosphate to glucose-6-phosphate (phosphate group is transferred from one to another position in the same compound) in glycogenolysis (glycogen is converted to glucose for energy to be released quickly).

Ligases

Ligases catalyze the association of two molecules. For example, DNA ligase catalyzes the joining of two fragments of DNA by forming a phosphodiester bond.

Enzyme class	Reaction type	Description
EC 1 Oxidoreductases	$A_{red} + B_{ox} \rightleftharpoons A_{ox} + B_{red}$	Catalyze redox reaction and can be categorized into oxidase and reductase.
EC 2 Transferases	$A\text{-}B + C \longrightarrow A + B\text{-}C$	Catalyze the transfer or exchange of certain groups among some substrates
EC 3 Hydrolases	$A\text{-}B + H_2O \longrightarrow A\text{-}H + B\text{-}OH$	Accelerate the hydrolysis of substrates
EC 4 Lyases	$A\text{-}B \rightleftharpoons A + B$ (reverse reaction: synthase)	Promote the removal of a group from the substrate to leave a double bond reaction or catalyze its reverse reaction
EC 5 Isomerases	$A\text{-}B\text{-}C \rightleftharpoons A\text{-}C\text{-}B$	Facilitate the conversion of isoisomers, geometric isomers or optical isomers.
EC 6 Ligases	$A + B + ATP \longrightarrow A\text{-}B + ADP + P_i$	Catalyze the synthesis of two molecular substrates into one molecular compound with the release energy
EC 7 Translocases		Catalyze the movement of ions or molecules across membranes or their separation within membranes

Main characteristics of an enzyme:

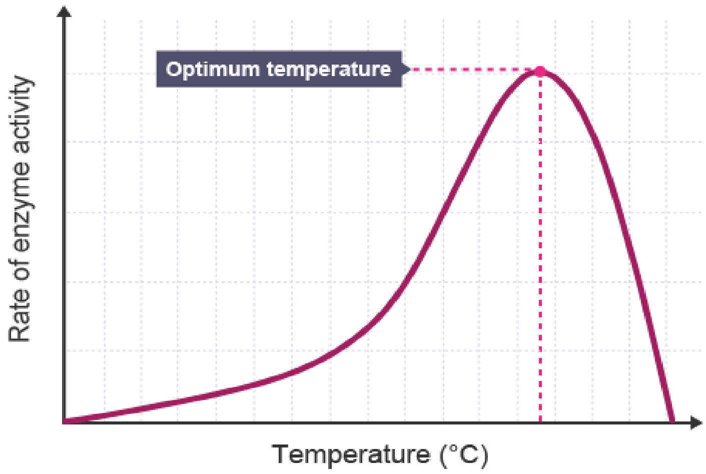
1. It is a protein and therefore, gets destroyed by heating.
2. It acts only on one kind of substance called the substrate. So, it is very specific.
3. It acts as a catalyst, so it can be used again and again.
4. It only affects the rate of a chemical reaction.
5. It always forms the same end products from the fixed substrate.
6. It acts best only at a particular pH.
7. It acts best within a narrow temperature range, usually between 35°C-40°C.

Nomenclature

The nomenclature of enzymes is derived from their substrates or the catalyzed chemical reactions, and "ase" is usually added as a suffix. Enzymes can be indexed with letters and numbers according to International Union of Biochemistry and Molecular Biology: the letter EC plus four numbers representing four elements. The first number represents enzymes that are classified according to the mechanism of enzymatic reaction.

Effect of temperature:

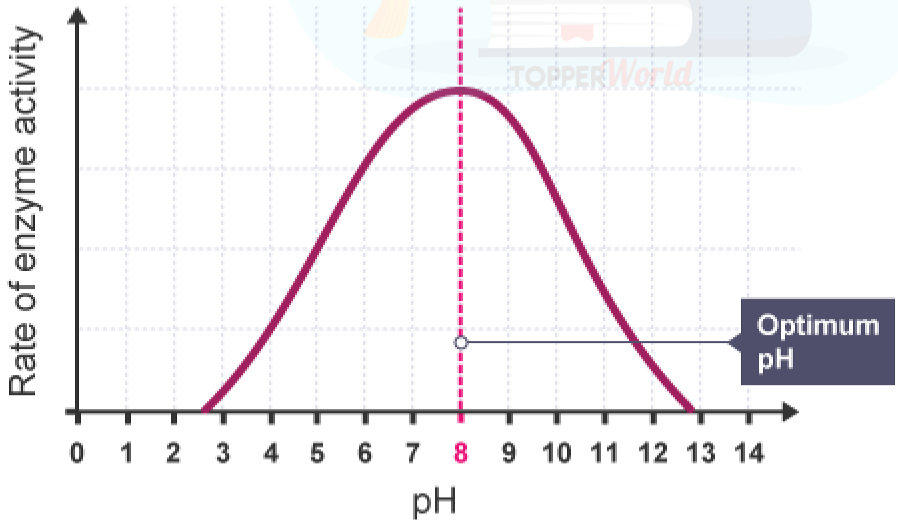
As with many chemical reactions, the rate of an enzyme-catalysed reaction increases as the temperature increases. However, at high temperatures the rate decreases again because the enzyme becomes denatured and can no longer function. This is shown in the graph below.



As the temperature increases so does the rate of enzyme activity.
An optimum activity is reached at the enzyme's optimum temperature. A continued increase in temperature results in a sharp decrease in activity as the enzyme's active site changes shape. It is now denatured.

Effects of pH

Changes in pH also alter the shape of an enzyme's active site. Each enzyme work bests at a specific pH value. The optimum pH for an enzyme depends on where it normally works. For example, enzymes in the small intestine have an optimum pH of about 7.5, but stomach enzymes have an optimum pH of about 2.

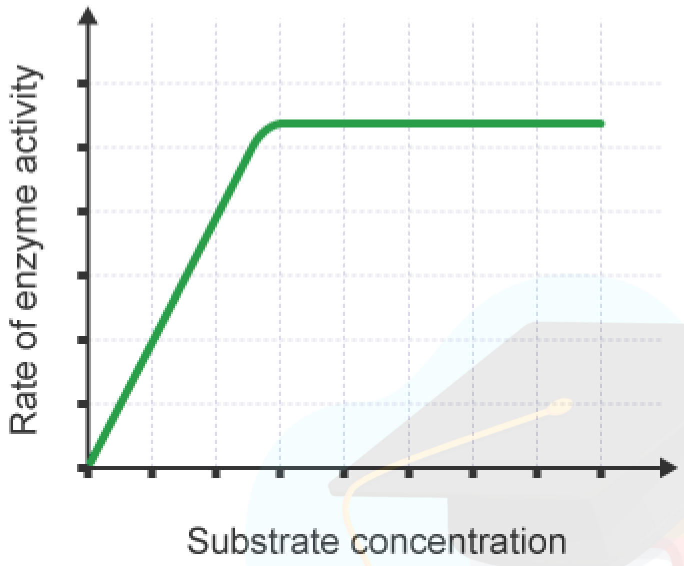


In the graph above, as the pH increases so does the rate of enzyme activity. An optimum activity is reached at the enzyme's optimum pH, pH 8 in this example.

A continued increase in pH results in a sharp decrease in activity as the enzyme's active site changes shape. It is now denatured.

Substrate concentration

Enzymes will work best if there is plenty of substrate. As the concentration of the substrate increases, so does the rate of enzyme activity. However, the rate of enzyme activity does not increase forever. This is because a point will be reached when the enzymes become saturated and no more substrates can fit at any one time even though there is plenty of substrate available.



As the substrate concentration increases so does the rate of enzyme activity. An optimum rate is reached at the enzyme's optimum substrate concentration. A continued increase in substrate concentration results in the same activity as there are not enough enzyme molecules available to break down the excess substrate molecules.

Elementary concept of and coenzymes:

A coenzyme is defined as an organic molecule that binds to the active sites of certain enzymes to assist in the catalysis of a reaction. More specifically, coenzymes can function as intermediate carriers of electrons during these reactions or be transferred between enzymes as functional groups.

For example, during the conversion of pyruvate to acetyl coenzyme A (CoA), several coenzymes including free CoA, thiamine pyrophosphate (TPP), lipoic acid (LA), flavin adenine dinucleotide (FAD), two cellular redox enzymes including oxidized nicotinamide adenine dinucleotide (NAD) and reduced nicotinamide adenine dinucleotide (NADH) are required.

Coenzymes and citric acid cycle

Within the body, glucose is required for the synthesis of ATP, which functions to store and transfer energy to cells throughout the body. Glucose can be metabolized through an anaerobic process known as glycolysis or an aerobic process known as the citric acid cycle.

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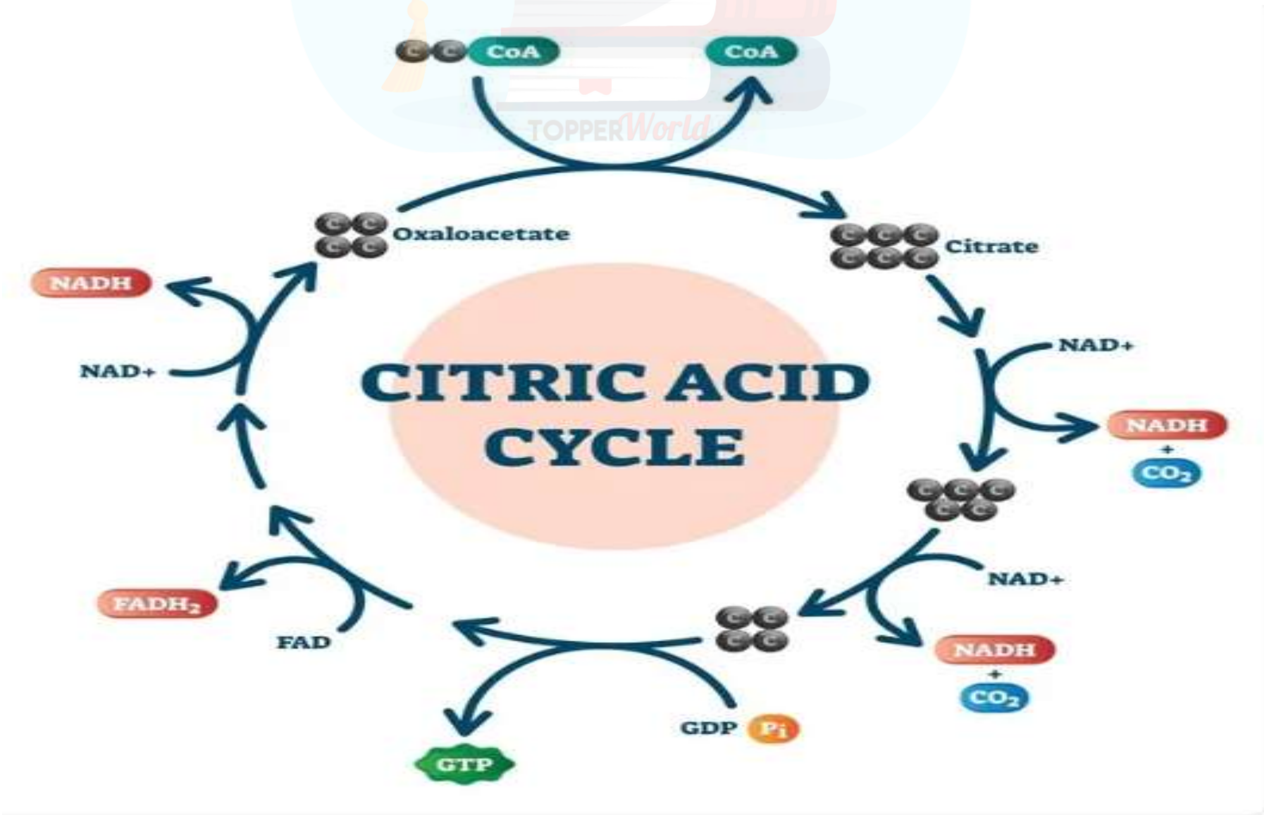
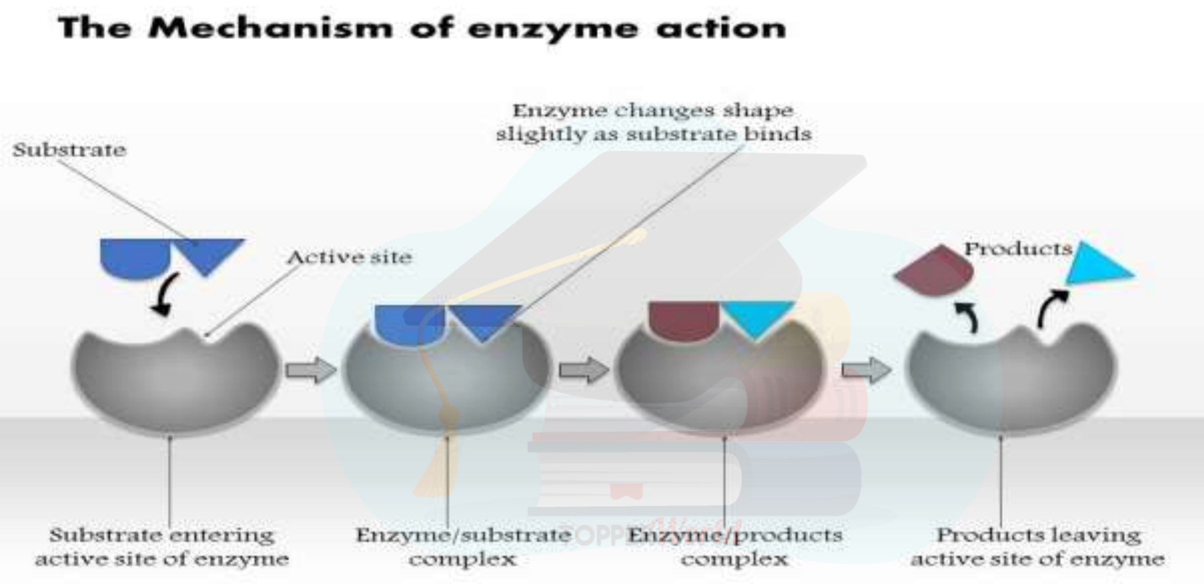


Mechanism of enzyme action:

An enzymes attracts substrates to its active site, catalyzes the chemical reaction by which products are formed, and then allows the products to dissociate (separate from the enzyme surface). The combination formed by an enzyme and its substrates is called the enzyme–substrate complex. When two substrates and one enzyme are involved, the complex is called a ternary complex; one substrate and one enzyme are called a binary complex. The substrates are attracted to the active site by electrostatic and hydrophobic forces, which are called noncovalent bonds because they are physical attractions and not chemical bonds



Enzymes are very specific and it was suggested by **Fischer in 1890** that this was because the enzyme had a particular shape into which the substrate or substrates fit exactly.

Enzyme kinetics and kinetic parameters (Km and Vmax):

Michaelis-Menten kinetics is a model of enzyme kinetics which explains how the rate of an enzyme-catalysed reaction depends on the concentration of the enzyme and its substrate. Let's consider a reaction in which a substrate (S) binds **reversibly** to an enzyme (E) to form an enzyme-substrate complex (ES), which then reacts **irreversibly** to form a product (P) and release the enzyme again.

$S + E \rightleftharpoons ES \rightarrow P + E$

Two important terms within Michaelis-Menten kinetics are:

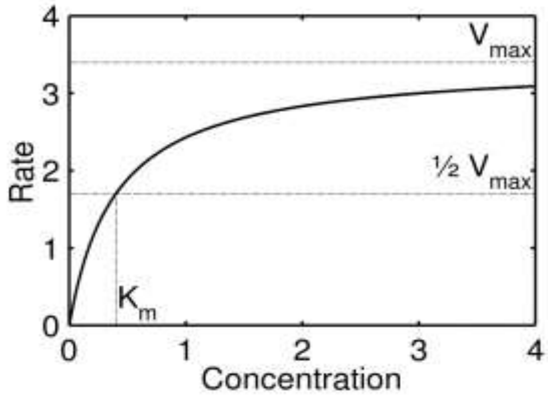
- **Vmax** – the maximum rate of the reaction, when all the enzyme's active sites are saturated with substrate.
- **Km** (also known as the Michaelis constant) – the substrate concentration at which the reaction rate is **50% of the Vmax**. Km is a measure of the affinity an enzyme has for its substrate, as the lower the value of Km, the more efficient the enzyme is at carrying out its function at a lower substrate concentration.

The Michaelis-Menten equation for the reaction above is:

$$v = \frac{V_{max}[S]}{K_M + [S]}$$

This equation describes how the **initial rate** of reaction (V) is affected by the initial substrate concentration ([S]). It assumes that the reaction is in the **steady state**, where the ES concentration remains constant.

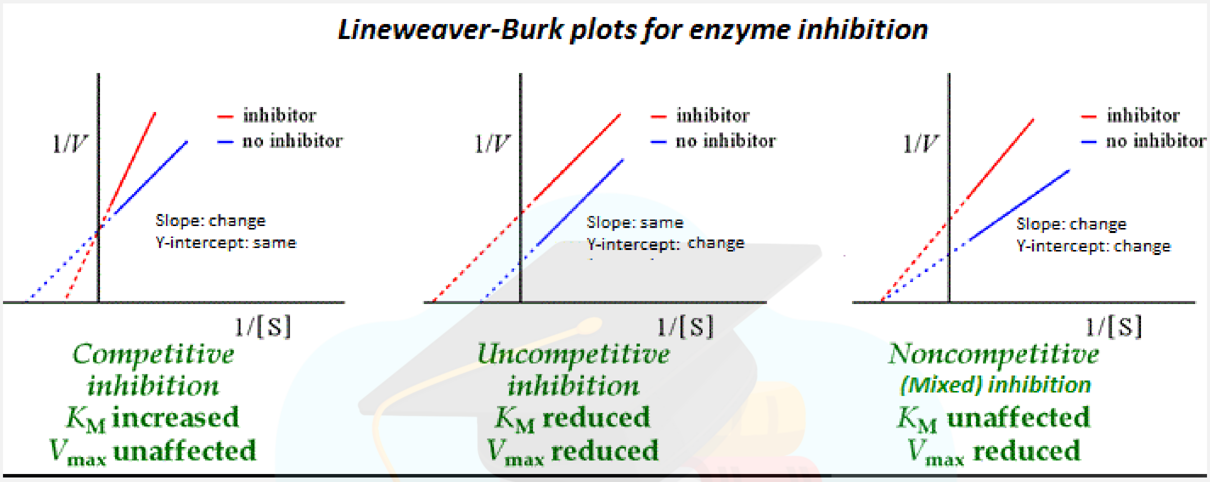
When a graph of substrate concentration against the rate of the reaction is plotted, we can see how the rate of reaction initially increases rapidly in a linear fashion as substrate concentration increases (**1st order kinetics**). The rate then plateaus, and increasing the substrate concentration has no effect on the reaction velocity, as all enzyme active sites are already saturated with the substrate **(0 order kinetics**).



This plot of rate of reaction against substrate concentration has the shape of a rectangular hyperbola. However, a more useful representation of Michaelis–Menten kinetics is a graph called a **Lineweaver–Burk plot**, which plots the inverse of the reaction rate (1/r) against the inverse of the substrate concentration (1/[S]). The equation used to generate this plot is given by:

$$\frac{1}{V} = \frac{K_m}{V_{max}}\frac{1}{S} + \frac{1}{V_{max}}$$

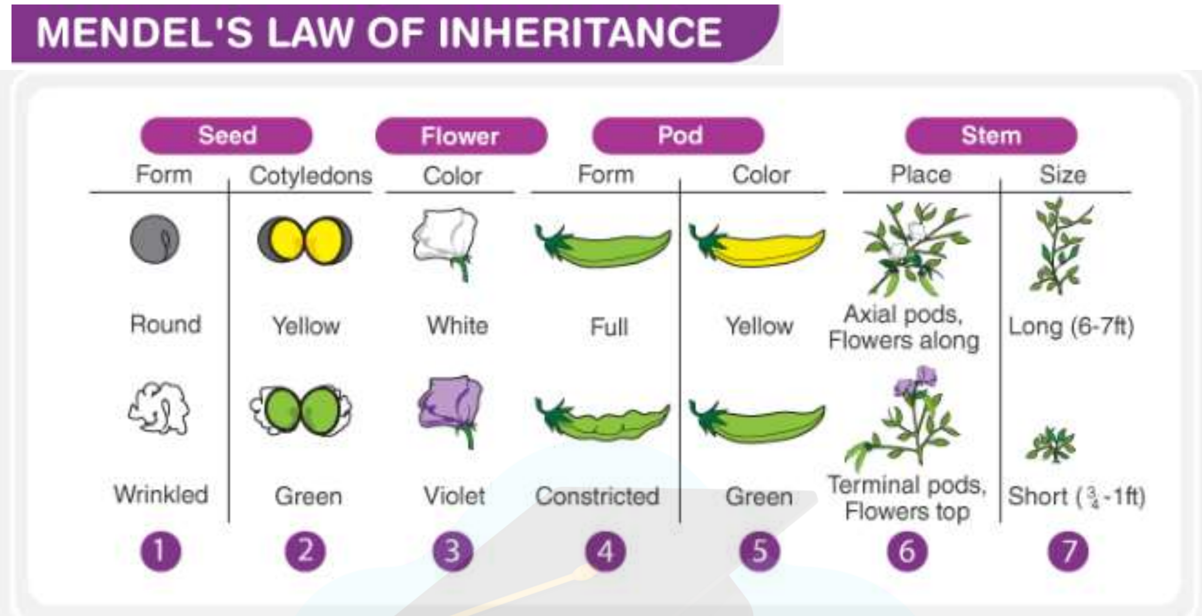
This produces a straight line, allowing for the easier interpretation of various quantities and values from the graph. For example, the y-intercept of the graph is equivalent to the Vmax. The Lineweaver-Burk plot is also useful when determining the type of enzyme inhibitition present by, comparing its effect on Km and Vmax.



Unit-III

Genetics

Mendel's laws of inheritance:



Between 1856-1863, Mendel conducted the hybridization experiments on the garden peas. During that period, he chose some distinct characteristics of the peas and conducted some cross-pollination/ artificial pollination on the pea lines that showed stable trait inheritance and underwent continuous self-pollination. Such pea lines are called true-breeding pea lines.

The two experiments lead to the formulation of Mendel's laws known as laws of inheritance which are:

1. Law of Dominance
2. Law of Segregation
3. Law of Independent Assortment

Law of Dominance

This is also called Mendel's first law of inheritance. According to the law of dominance, hybrid offspring will only inherit the dominant trait in the phenotype. The alleles that are suppressed are called the recessive traits while the alleles that determine the trait are known as the dominant traits.

Law of Segregation

The law of segregation states that during the production of gametes, two copies of each hereditary factor segregate so that offspring acquire one factor from each parent. In other words, allele (alternative form of the gene) pairs segregate during the formation of gamete and re-unite randomly during fertilization. This is also known as Mendel's third law of inheritance.

Law of Independent Assortment

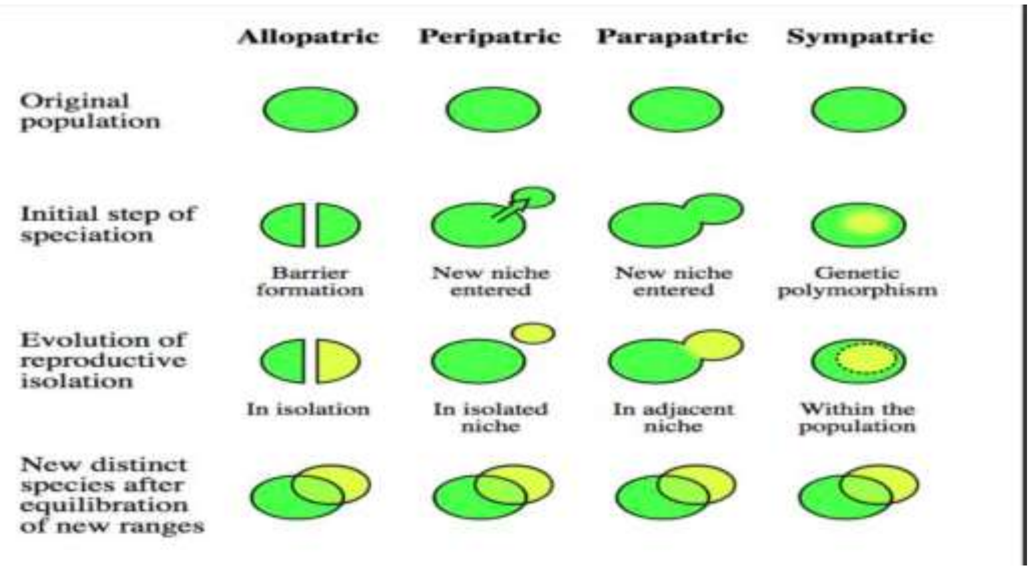
Also known as Mendel's second law of inheritance, the law of independent assortment states that a pair of traits segregates independently of another pair during gamete formation. As the individual **heredity** factors assort independently, different traits get equal opportunity to occur together.

Key Points on Mendel's Laws

- The law of inheritance was proposed by Gregor Mendel after conducting experiments on pea plants for seven years.
- Mendel's laws of inheritance include law of dominance, law of segregation and law of independent assortment.
- The law of segregation states that every individual possesses two alleles and only one allele is passed on to the offspring.
- The law of independent assortment states that the inheritance of one pair of genes is independent of inheritance of another pair.

Variation and speciation of Genetic:

There are four major variants of speciation: allopatric, peripatric, parapatric, and sympatric-

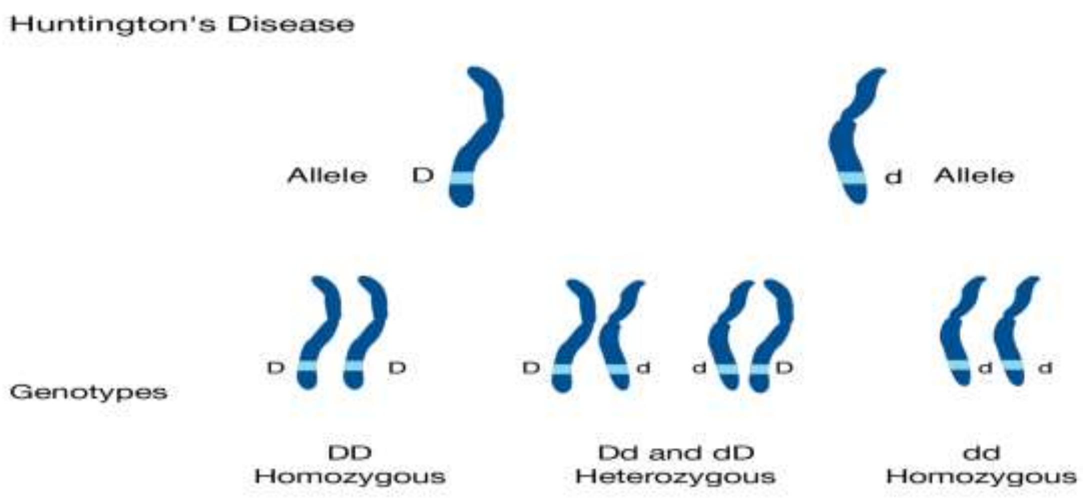


Speciation is how a new kind of plant or animal species is created. Speciation occurs when a group within a species separates from other members of its species and develops its own unique characteristics. The demands of a different environment or the characteristics of the members of the new group will differentiate the new species from their ancestors.

An example of speciation is the Galápagos finch. Different species of these birds live on different islands in the Galápagos archipelago, located in the Pacific Ocean off South America. The finches are isolated from one another by the ocean. Over millions of years, each species of finch developed a unique beak that is especially adapted to the kinds of food it eats. Some finches have large, blunt beaks that can crack the hard shells of nuts and seeds. Other finches have long, thin beaks that can probe into cactus flowers without the bird being poked by the cactus spines. Still other finches have medium-size beaks that can catch and grasp insects. Because they are isolated, the birds don't breed with one another and have therefore developed into unique species with unique characteristics. This is called allopatric speciation.

Concepts of recessiveness and dominance:

Dominance: Dominant refers to the relationship between two versions of a gene. Individuals receive two versions of each gene, known as alleles, from each parent. If the alleles of a gene are different, one allele will be expressed; it is the dominant gene. The effect of the other allele, called recessive, is masked.



Dominant refers to a relationship between two versions of a gene. If one is dominant, the other one must be not dominant. In that case, we call it recessive. A dominant gene, or a dominant version of a gene, is a particular variant of a gene, which for a variety of reasons, expresses itself more strongly all by itself than any other version of the gene which the person is carrying, and, in this case, the recessive. Now, it usually refers to inheritance patterns frequently used in conjunction with a Punnett square where, if an individual has two versions of a gene, and one is observed to frequently be transferred from one generation to another, then it is called dominant. Biochemically, what is going on in this case is that the genetic variation, for a variety of reasons, can either induce a function in a cell, which is either very advantageous or very detrimental, which the other version of the gene can't cover up or compensate for. In that case, you're going to have a dominant mutation, and that dominant mutation can be benign. It can refer to eye color of one sort or another; that can be can a dominant mutation.

Recessiveness

In genetics, Recessiveness can be defined as the failure experienced by one of the pairs of alleles or genes to express itself that are present in a human being. This happens because of the presence of a more dominant gene that tends to have a greater influence in the first place.

Both of the genes or the alleles have an effect on the inherited trait or characteristic. However, the presence of a recessive gene would mean that is not observed. In other words, the recessive characteristic would not be observable in the person in the first place. In this article, students will get to know more about the recessive meaning and much more

Genetic Disorders: Single gene disorders in human

What are genetic disorders?

Genetic disorders occur when a mutation (a harmful change to a gene, also known as a pathogenic variant) affects your genes or when you have the wrong amount of genetic material. Genes are made of DNA (deoxyribonucleic acid), which contain instructions for cell functioning and the characteristics that make you unique.

You receive half your genes from each biological parent and may inherit a gene mutation from one parent or both. Sometimes genes change due to issues within the DNA (mutations). This can raise your risk of having a genetic disorder. Some cause symptoms at birth, while others develop over time.

Genetic disorders can be:

- **Chromosomal:** This type affects the structures that hold your genes/DNA within each cell (chromosomes). With these conditions, people are missing or have duplicated chromosome material.
- **Complex (multifactorial):** These disorders stem from a combination of gene mutations and other factors. They include chemical exposure, diet, certain medications and tobacco or alcohol use.
- **Single-gene (monogenic):** This group of conditions occurs from a single gene mutation.

What are the causes of genetic disorders?

To understand genetic disorder causes, it's helpful to learn more about how your genes and DNA work. Most of the DNA in your genes instructs the body to make proteins. These proteins start complex cell interactions that help you stay healthy.

When a mutation occurs, it affects the genes' protein-making instructions. There could be missing proteins. Or the ones you have do not function properly. Environmental factors (also called mutagens) that could lead to a genetic mutation include:

- Chemical exposure.
- Radiation exposure.
- Smoking.
- UV exposure from the sun.

single gene disorders?

Single gene disorders are caused by DNA changes in one particular gene, and often have predictable inheritance patterns.

- Over 10,000 human disorders are caused by a change, known as a mutation, in a single gene.
- These are known as single gene disorders.
- The mutated version of the gene responsible for the disorder is known as a mutant, or disease, allele.
- Individually, single gene disorders are each very rare, but as a whole, they affect about one per cent of the population.
- Since only a single gene is involved, these disorders can be easily tracked through families and the risk of them occurring in later generations can be predicted.

- Single gene disorders can be divided into different categories: domianat, recessive and X-linked.

Human traits:

Genetics of blood groups:

Blood is a complex, living tissue that contains many cell types and proteins. A transporter, regulator, and defender, blood courses through the body carrying out many important functions.

Blood Types

Distinct molecules called agglutinogens (a type of antigen) are attached to the surface of red blood cells. There are two different types of agglutinogens, type "A" and type "B". Each type has different properties. The ABO blood type classification system uses the presence or absence of these molecules to categorize blood into four types.

Another level of specificity is added to blood type by examining the presence or absence of the Rh protein. Each blood type is either positive "+" (has the Rh protein) or negative "-" (no Rh protein). For example, a person whose blood type is "A positive" (A +), has both type A and Rh proteins on the surface of their red blood cells.

Blood Type Is Determined Genetically

The A and B antigen molecules on the surface of red blood cells are made by two different enzymes. These two enzymes are encoded by different versions, or alleles, of the same gene.

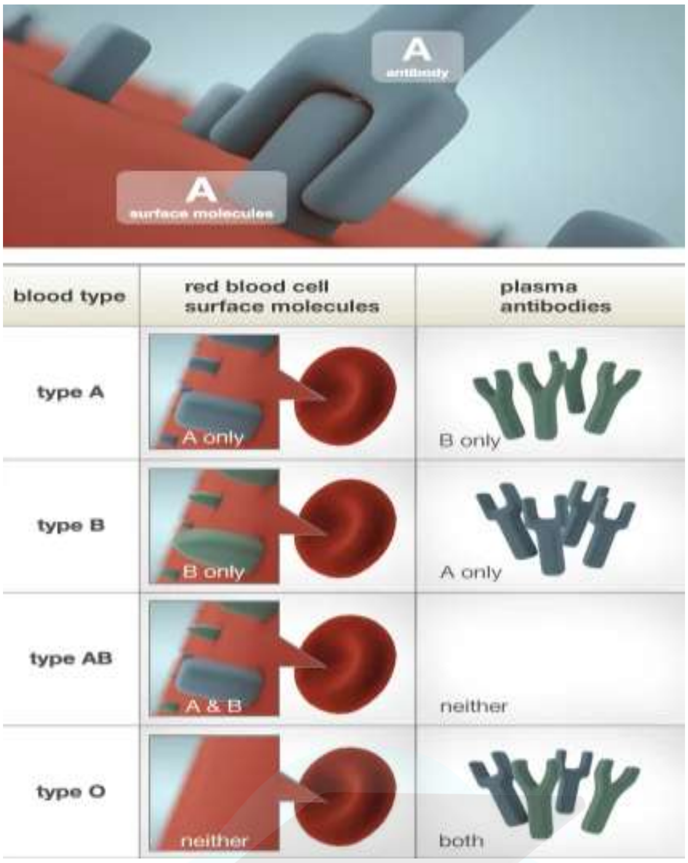
The A allele codes for an enzyme that makes the A antigen, and the B allele codes for an enzyme that makes the B antigen. A third version of this gene, the O allele, codes for a protein that is not functional; it makes no surface molecules at all.

Everyone inherits two alleles of the gene, one from each parent. The combination of your two alleles determines your blood type.

	mother		
father	A	B	O
A	AA	AB	AO
B	BA	BB	BO
O	OA	OB	OO

alleles		blood type
A+A	=	A
A+O	=	A
A+B	=	AB
B+B	=	B
B+O	=	B
O+O	=	O

The table on the left shows all of the possible combinations of blood type alleles. The blood type for each allele combination is shown on the right. For example, if you inherit a B allele from your father and an A allele from your mother, your blood type will be AB.



Blood plasma is packed with proteins called antibodies. The body produces a wide variety of antibodies that will recognize and attack foreign molecules that may enter from the outside world. A person's plasma does not contain any antibodies that will bind to molecules that are part of his or her own body.

When conducting a blood transfusion, it is important to carefully match the donor and recipient blood types. If the donor blood cells have surface molecules that are different from those of the recipient, antibodies in the recipient's blood recognize the donor blood as foreign. This triggers an immune response resulting in blood clotting. If the donor blood cells have surface molecules that are the same as those of the recipient, the recipient's body will not see them as foreign and will not mount an immune response.

There are two special blood types when it comes to blood transfusions. People with type O blood are universal donors because there are no molecules on the surface of the red blood cells that can trigger an immune response. People with type AB blood are universal recipients because they do not have any antibodies that will recognize type A or B surface molecules.

Note: Blood cells are covered with a variety of surface molecules. For simplicity, only type A and B surface molecules are shown here.

Diabetes type I & II.

Type 1 Diabetes

The main difference between the two types of diabetes is that type 1 diabetes is a genetic disorder that often shows up early in life, and type 2 is largely diet-related and develops over time. If you have type 1 diabetes, your immune system is attacking and destroying the insulin-producing cells in your pancreas. (The pancreas is the flat organ that looks kind of like an elongated, sideways comma and hangs out behind your stomach.)

Type 2 Diabetes

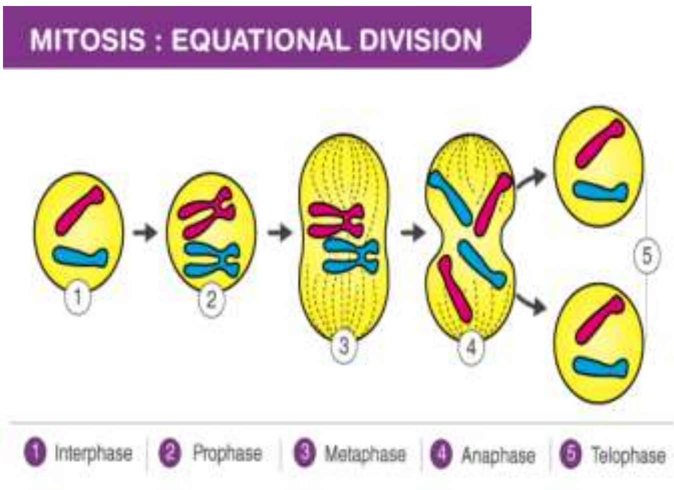
Type 2 Diabetes is more common in the U.S. than type 1, and it is typically caused by lifestyle. With type 2 diabetes, your body still produces a small amount of insulin, but it isn't effective enough. The pancreas can't keep up with the high blood sugar levels resulting from poor diet and lack of exercise. Some people with type 2 diabetes actually have "insulin resistance," which means the pancreas produces insulin but the body does not recognize it (this is different than type 1, in which the insulin-producing cells are being attacked by the immune system).

Cell Division:-

Mitosis and its utility to living systems

What is Mitosis?

Cell division is the driving process of reproduction at the cellular level. Most eukaryotic cells divide in a manner where the ploidy or the number of chromosomes remains the same, except in the case of germ cells where the number of chromosomes is halved.



Mitosis Diagram showing the different stages of mitosis

Mitosis is the phase of the cell cycle where the nucleus of a cell is divided into two nuclei with an equal amount of genetic material in both the daughter nuclei. It succeeds the G2 phase and is succeeded by cytoplasmic division after the separation of the nucleus.

Mitosis is essential for the growth of the cells and the replacement of worn-out cells. Abnormalities during mitosis may alter the DNA, resulting in genetic disorders.

Features of Mitosis

1. In each cycle of cell division, two daughter cells are formed from the parent cell.
2. The cell is also known as equational cell division because the chromosome number in the parent cell and daughter cell is the same.
3. In plants, mitosis leads to the growth of vegetative parts of the plant like root tip, stem tip, etc.
4. Segregation and combination do not occur in this process.

The processes occurring during mitosis have been divided into different stages.

Genetic significance

- Meiosis is a type of cell division that reduces the number of chromosomes in the parent cell by half and produces four gamete cells.
- The significance of meiosis is in-

Formation of gametes − Meiosis form gametes that are essential for sexual reproduction.

Genetic information − Meiosis switches on the genetic information for the development of gametes.

Crossing over − It introduces new combination of traits or variations.

Mutation − Mutations take place due to irregularities of meiotic division

Evidence of nucleic acids as a genetic material

For the first time, an English Health officer, Frederick Griffith (1928) gave an experimental evidence that the DNA was the genetic material. He took two types of a bacterial strain, pneumococci (Streptococcus pneumonia) that causes pneumonia in humans and other animals.

There were two types of pneumococci, type II and type III. Each type exists in two forms RII, SII, and RIII, SIII forms where ‘R’ represents the rough, non-capsulated and non- virulent form and ‘S’ represent the smooth, encapsulated and virulent form.

ADVERTISEMENTS:

After injection of smooth (virulent) strain, mice were killed . When boiled smooth strain was injected, the mice were not affected and no pneumococci could be recovered from the mice.

Upon injection of a mixture of heat killed smooth strain and live rough (non-virulent) strain, the mice were killed and live virulent bacteria could be recovered from blood of dead mice.

Griffith called this change of non-virulent strain into virulent strain as transformation, because the virulent strain transformed the non-virulent strain into the virulent strain. This is called Griffith's transformation experiment . The phenomenon of bacterial transformation is called "Griffith effect".

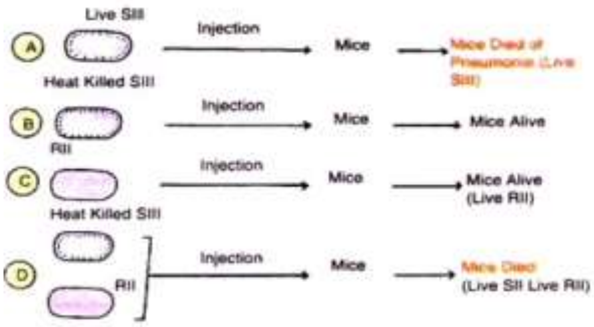
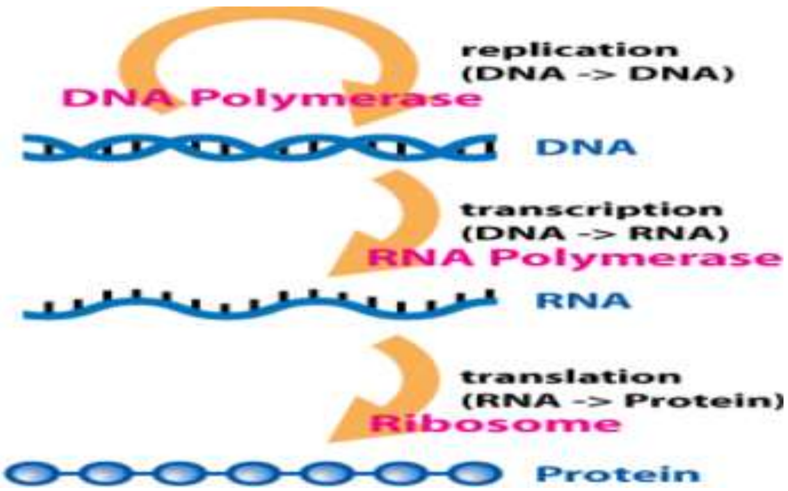


Fig. 5.24 : Griffith's transformation experiment

Central Dogma of molecular biology

The **central dogma of molecular biology** is an explanation of the flow of genetic information within a biological system. It is often stated as "DNA makes RNA, and RNA makes protein", although this is not its original meaning. It was first stated by Francis Crick in 1957, then published in 1958:

The Central Dogma. This states that once "information" has passed into protien it cannot get out again. In more detail, the transfer of information from nuclic acid to nucleic acid, or from nucleic acid to protein may be possible, but transfer from protein to protein, or from protein to nucleic acid is impossible. Information means here the precise determination of sequence, either of bases in the nucleic acid or of amino acid residues in the protein.

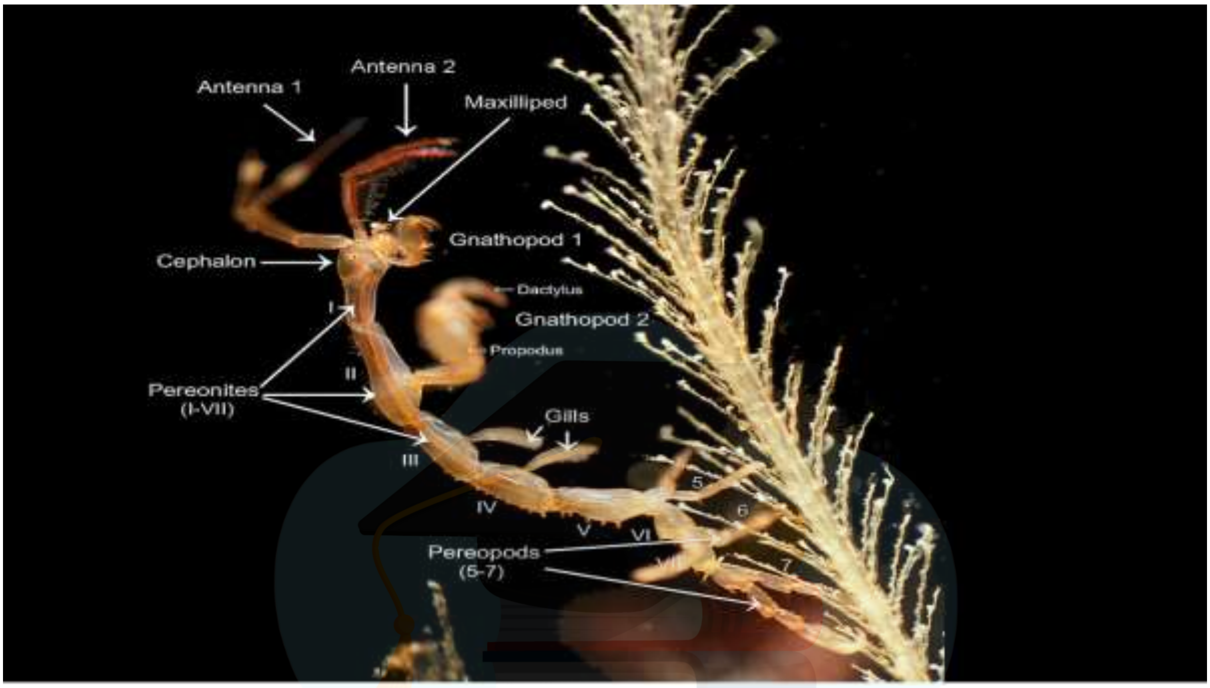


Role of immune system in health and disease:

Brief introduction to morphology

Morphology is a branch of biology dealing with the study of the form and structure of organism and their specific structural features.

This includes aspects of the outward appearance (shape, structure, color, pattern, size), i.e. **external morphology** (or eidionoy), as well as the form and structure of the internal parts like bones and organs, i.e. **internal morphology** (or anatony). This is in contrast to physilogy, which deals primarily with function. Morphology is a branch of life science dealing with the study of gross structure of an organsim or taxon and its component parts.

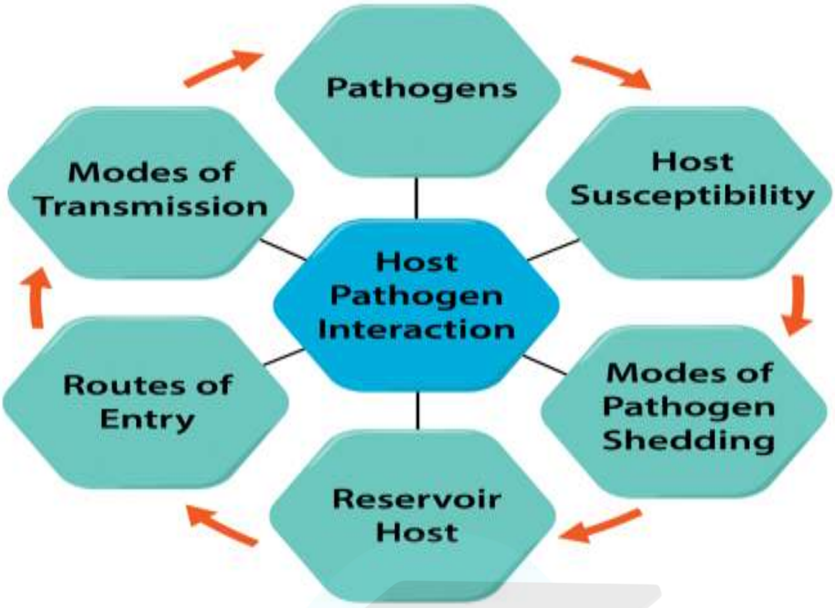


Morphology of a male shrimp

Pathogenicity of bacteria

A microbe that is capable of causing disease is referred to as a **pathogen,** while the organism being infected is called a **host**. The ability to cause disease is referred to as **pathogenicity**, with pathogens varying in their ability. An **opportunistic pathogen** is a microbe that typically infects a host that is compromised in some way, either by a weakened immune system or breach to the body's natural defenses, such as a wound. The measurement of pathogenicity is called **virulence**, with highly virulent pathogens being more likely to cause disease in a host.

It is important to remember that there are many variables to take into account in a host-pathogen interaction, which is a dynamic relationship that is constantly changing. The virulence of the pathogen is important, but so is the number of microbes that gained entry to the host, the location of entry, the overall health of the host, and the state of the host's defenses. Exposure to a pathogen does not ensure that disease will occur, since a host might be able to fight off the infection before disease signs/symptoms develop.



Host-Pathogen Interactions.

What Are Germs?

The term "germs" refers to the microscopic bacteria, viruses, fungi, and protozoa that can cause disease.

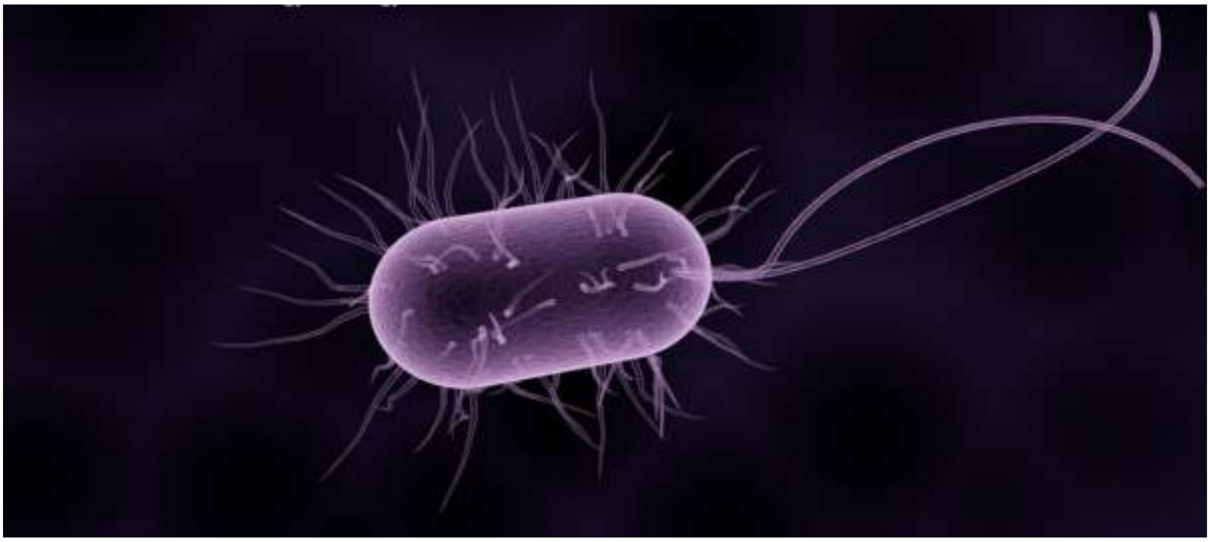
Washing hand well and often is the best way to prevent germs from leading to infections and sickness.

Bacteria

Bacteria are tiny, single-celled organisms that get nutrients from their environments.

Some bacteria are good for our bodies — they help keep the digestive system in working order and keep harmful bacteria from moving in. Some bacteria are used to make medicines and vaccines.

But bacteria can cause trouble too, as with cavities, urinary tract infection , ear infection or strep throat . Antibiotics are used to treat bacterial infections.



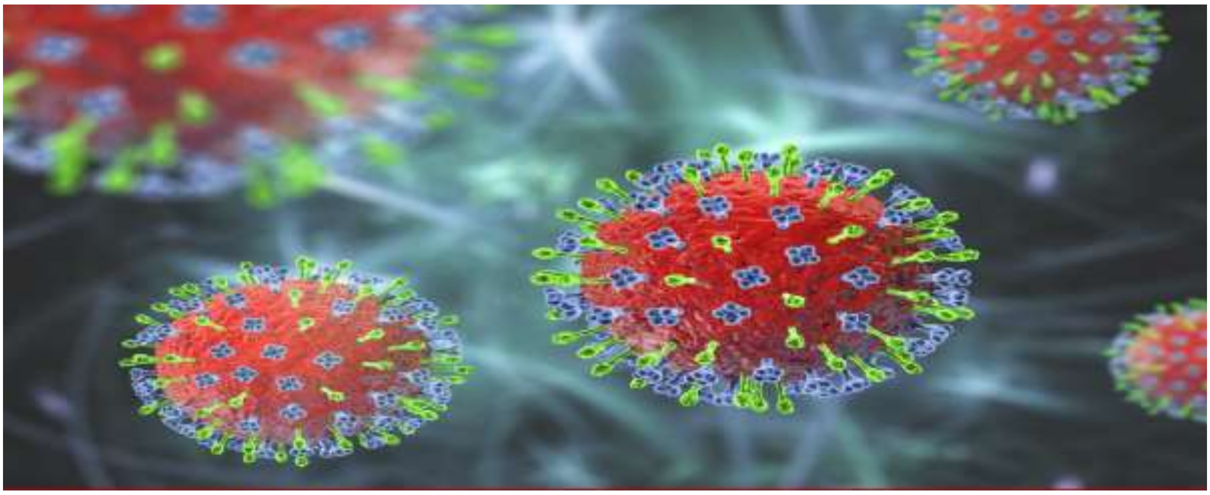
Viruses

Viruses are even smaller than bacteria. They aren't even a full cell. They are simply genetic material (DNA or RNA) packaged inside of a protein coating. They need to use another cell's structures to reproduce, which means they can't survive unless they're living inside something else (such as a person, animal, or plant).

Viruses can only live for a very short time outside other living cells. For example, viruses in infected body fluids left on surfaces like a countertop or toilet seat can live there for a short time, but quickly die unless a live host comes along.

Once they've moved into someone's body, though, viruses spread easily and can make a person sick. Viruses are responsible for some minor sicknesses like colds, common illnesses like the flu, and very serious diseases like smallpox or HIV/ AIDS.

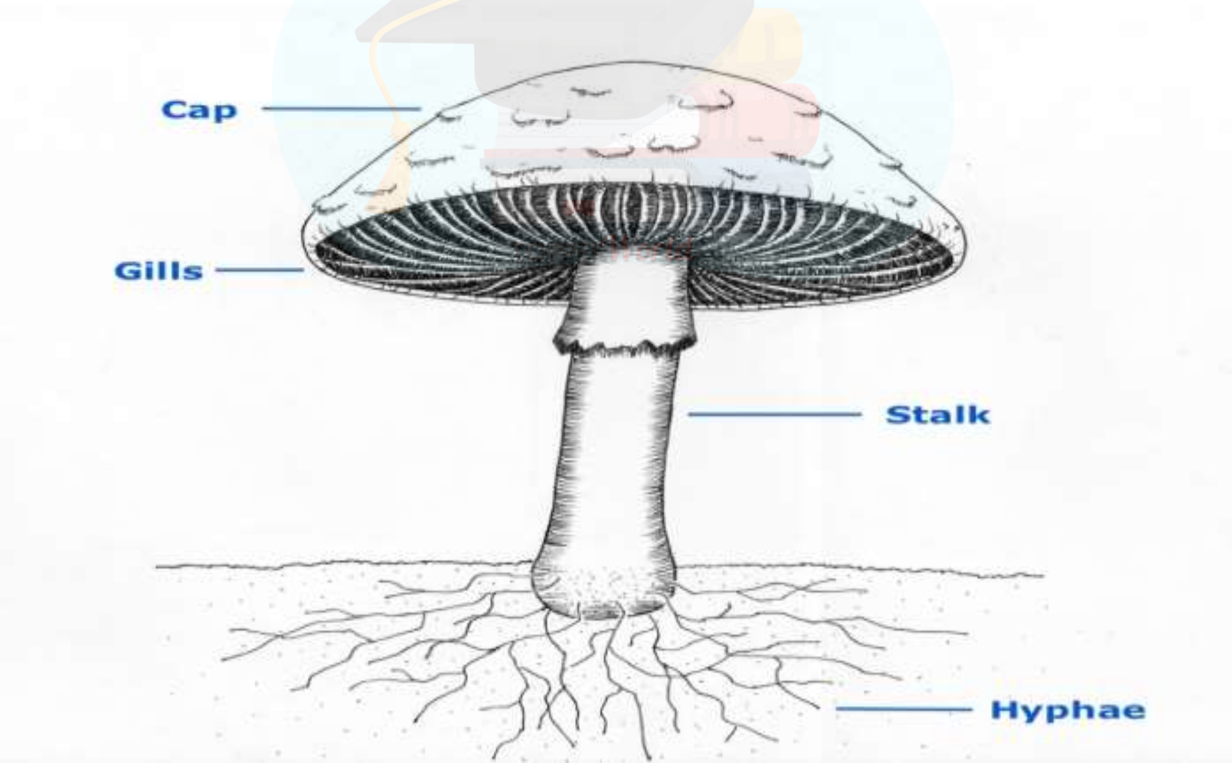
Antibiotics are not effective against viruses. Antiviral medicines have been developed against a small, select group of viruses.



Fungi

Fungi (pronounced: FUN-guy) are multicelled, plant-like organisms. A fungus gets nutrition from plants, food, and animals in damp, warm environments.

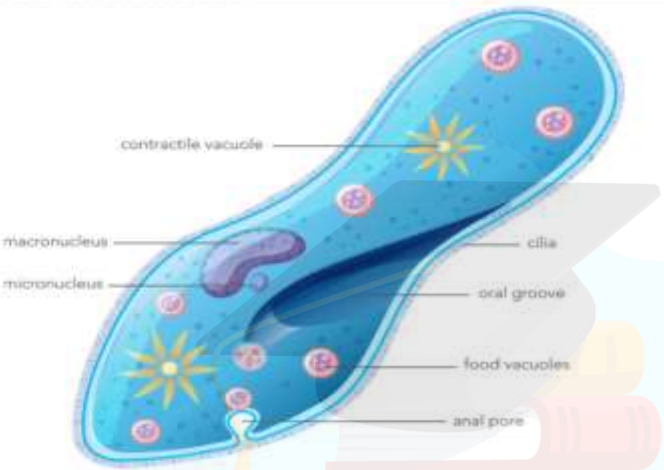
Many fungal infections, such as athlete's foot and yeast infections, are not dangerous in a healthy person. People who have weakened immune system (from diseases like HIV or cancer), though, may develop more serious fungal infections.



Protozoa

Protozoa (pronounced: pro-toe-ZO-uh) are one-celled organisms, like bacteria. But they are bigger than bacteria and contain a nucleus and other cell structures, making them more similar to plant and animal cells.

Protozoa love moisture, so intestinal infections and other diseases they cause, such as amebiasis and giardiasis, often spread through contaminated water. Some protozoa are parasites, which means that they need to live on or in another organism (like an animal or plant) to survive. For example, the protozoa that causes malaria grows inside red blood cells, eventually destroying them. Some protozoa are encapsulated in cysts, which help them live outside the human body and in harsh environments for long periods of time.



Unit-IV

Metabolism

Concept of Exothermic and endothermic reactions:

Endothermic Reactions

The endothermic process is a term that describes a reaction where the system absorbs the energy from its surrounding in the form of heat. A few examples of the endothermic process are photosynthesis, evaporating liquids, melting ice, dry ice, alkane cracking, thermal decomposition, ammonium chloride in water and much more.

As the name implies, 'endo' means 'to absorb,' and 'thermic' means 'heat.'

This energy is produced as a result of the reaction of reactants into the product. It occurs as a result of the dissociation of the bonds between the molecules. The energy is then released through the formation of new bonds.

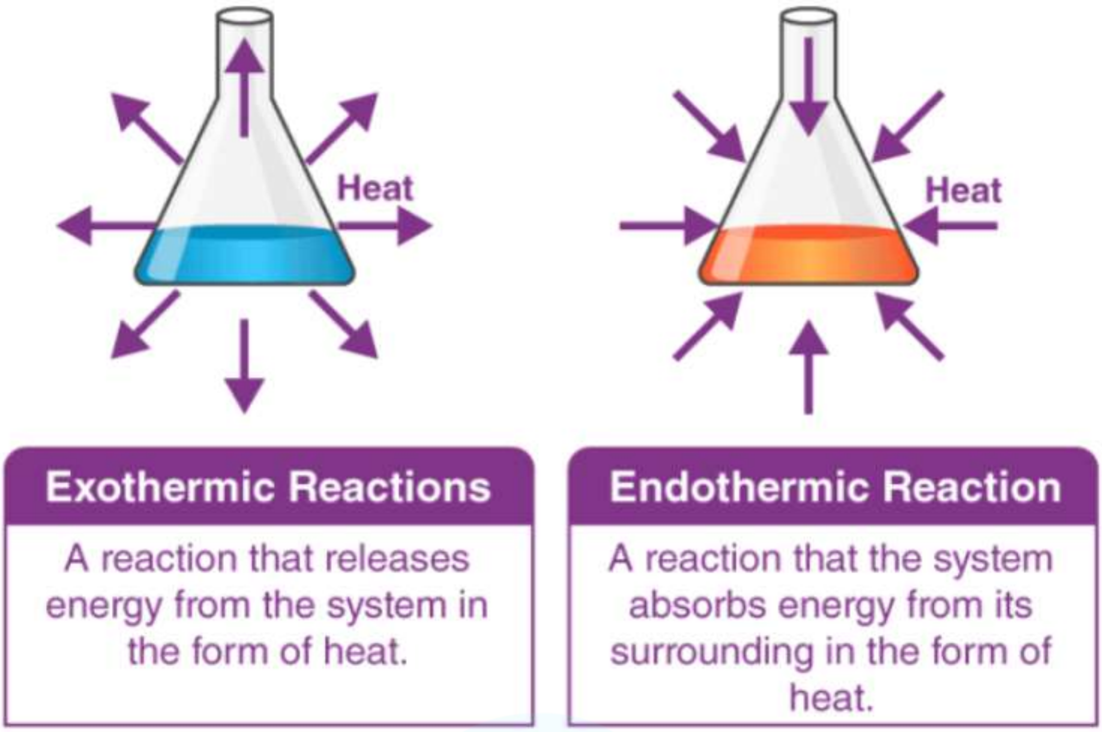
Heat is taken up from the surroundings in such reactions, so the temperature of the system where the reaction is taking place remains cooler. Also, at the end of the reaction, the enthalpy, which is the change in heat energy during the conversion of reactants to products, increases.

Exothermic Reactions

The exothermic reaction is the opposite of an endothermic reaction. It releases energy by light or heat to its surrounding. A few examples are neutralisation, burning a substance, reactions of fuels, deposition of dry ice, respiration, solution of sulphuric acid into water and much more.

The term 'Exo' refers to 'to release,' and 'thermic' refers to 'heat.'

The energy released is caused by the formation of new bonds (products) at a higher level. While the energy required to break up the bonds (reactants) is lower. At the end of the reaction, the enthalpy change decreases as well. During chemical reactions, a great deal of energy is required. This energy was used to maintain the bond that held the molecules together. As a result of the reactions between molecules and compounds, as well as the breaking of bonds, a tremendous amount of energy is released.



Difference between Endothermic and Exothermic Reactions

Endothermic Reaction	Exothermic Reaction
Endothermic reactions are chemical reactions in which the reactants absorb heat energy from the surroundings to form products.	An exothermic reaction is a reaction in which energy is released in the form of light or heat.
The energy is absorbed from the surrounding into the reaction.	The energy is released from the system to its environment.
Energy in the form of heat.	Energy is released as heat, electricity, light or sound.
Melting ice, evaporation, cooking, gas molecules, and photosynthesis are a few examples.	Rusting iron, settling, chemical bonds, explosions, and nuclear fission are a few examples.

Concept of standard free energy and Spontaneity in biological reactions:

Spontaneous Reactions

A **spontaneous reaction** *is a reaction that favors the formation of products at the conditions under which the reaction is occurring*. A roaring bonfire (see figure below) is an example of a spontaneous reaction. A fire is exothermic, which means a decrease in the energy of the system as energy is released to the surroundings as heat. The products of a fire are composed mostly of gases such as carbon dioxide and water vapor, so the entropy of the system increases during most combustion reactions. This combination of a decrease in energy and an increase in entropy means that combustion reactions occur spontaneously.

A **nonspontaneous reaction** *is a reaction that does not favor the formation of products at the given set of conditions*. In order for a reaction to be nonspontaneous, one or both of the driving forces must favor the reactants over the products. In other words, the reaction is endothermic, is accompanied by a decrease in entropy, or both. Out atmosphere is composed primarily of a mixture of nitrogen and oxygen gases. One could write an equation showing these gases undergoing a chemical reaction to form nitrogen monoxide.

$$N_2\,(g) + O_2\,(g) \rightarrow 2NO\,(g)$$

$$H_2CO_3\,(aq) \rightleftharpoons CO_2\,(g) + H_2O\,(l)$$

A home soda making machine is shown with a bottle of water and a CO2CO2 cartridge. When the water is carbonated, only a small amount of carbonic acid is formed because the reaction is nonspontaneous.

Gibbs Free Energy

Many chemical reactions and physical processes release energy that can be used to do other things. When the fuel in a car is burned, some of the released energy is used to power the vehicle. **Free energy** *is energy that is available to do work*. Spontaneous reactions release free energy as they proceed. Recall that the determining factors for spontaneity of a reaction are the enthalpy and entropy changes that occur for the system. The free energy change of a reaction is a mathematical combination of the enthalpy change and the entropy change.

$$\Delta G^o = \Delta H^o - T\Delta S^o$$

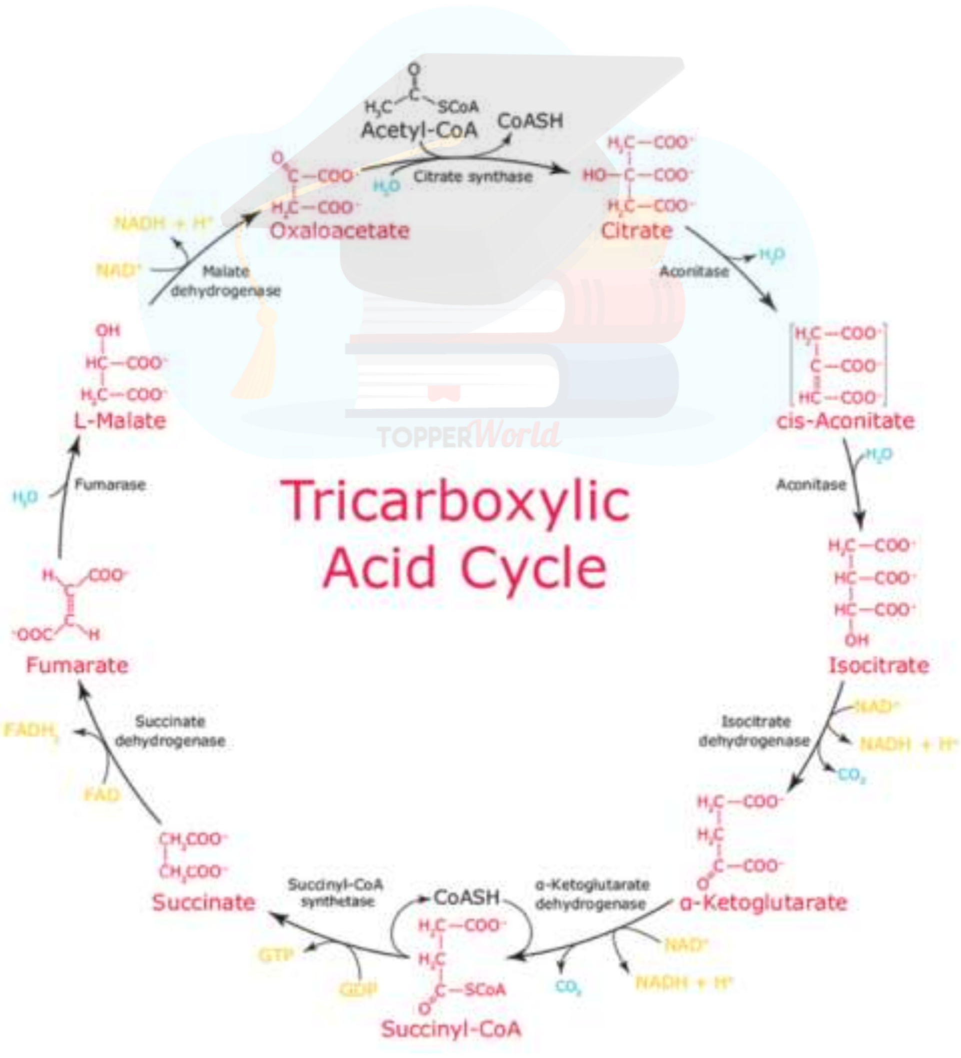
The symbol for free energy is GG, in honor of American scientist Josiah Gibbs (1839 - 1903), who made many contributions to thermodynamics. The change in Gibbs free energy is equal to the change in enthalpy minus the mathematical product of the change in entropy multiplied by the Kelvin temperature. Each thermodynamic quantity in the equation is for substances in their standard states, as indicated by the oo superscripts.

A spontaneous reaction is one that releases free energy, and so the sign of ΔGΔG must be negative. Since both ΔHΔH and ΔSΔS can be either positive or negative, depending on the characteristics of the particular reaction, there are four different possible combinations. The outcomes for ΔGΔG based on the signs of ΔHΔH and ΔSΔS are outlined in the table below. Recall that −ΔH−ΔH indicates that the reaction is exothermic and a +ΔH+ΔH means the reaction is endothermic. For entropy, +ΔS+ΔS means the entropy is increasing and the system is becoming more disordered. A −ΔS−ΔS means that entropy is decreasing and the system is becoming less disordered (more ordered).

Catabolism (Glycolysis and Krebs cycle):

The tricarboxylic acid (TCA) cycle, also known as the Krebs or citric acid cycle, is the main source of energy for cells and an important part of aerobic respiration. The cycle harnesses the available chemical energy of acetyl coenzyme A (acetyl CoA) into the reducing power of nicotinamide adenine dinucleotide (NADH).

The TCA cycle is part of the larger glucose metabolism whereby glucose is oxidized to form pyruvate, which is then oxidized and enters the TCA cycle as acetyl-CoA.



Krebs cycle diagram

KREBS CYCLE INTERMEDIATES

These intermediates are numbered on the diagram below

1. Citrate
2. Isocitrate
3. Oxoglutarate
4. Succinyl-CoA
5. Succinate
6. Fumarate
7. Malate
8. Oxaloacetate (oxaloacetic acid)

KREBS CYCLE STEPS

1. The TCA cycle begins with an enzymatic aldol addition reaction of acetyl CoA to oxaloacetate, forming citrate.

2. The citrate is isomerized by a dehydration-hydration sequence to yield (2R,3S)-isocitrate.

3. Further enzymatic oxidation and decarboxylation gives 2-ketoglutarate.

4. After another enzymatic decarboxylation and oxidation, 2-ketoglutarate is transformed into succinyl-CoA.

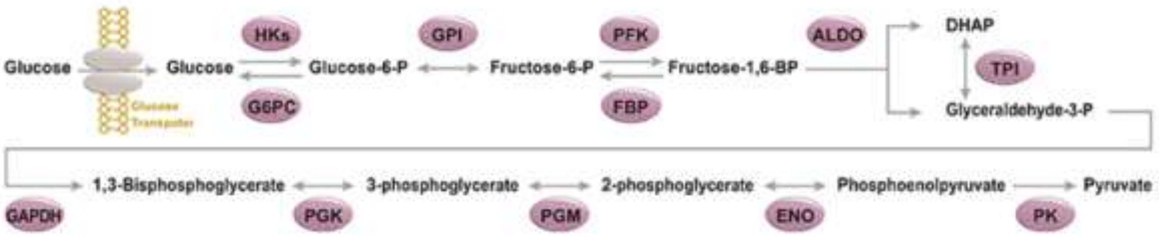
5. The hydrolysis of this metabolite to succinate is coupled to the phosphorylation of guanosine diphosphate (GDP) to guanosine triphosphate (GTP).

6. Enzymatic desaturation by flavin adenine dinucleotide (FAD)-dependent succinate dehydrogenase yields fumarate.

7. After stereospecific hydration, fumarate catalyzed by fumarase is transformed to L-malate.

8. The last step of NAD-coupled oxidation of L-malate to oxaloacetate is catalyzed by malate dehydrogenase and closes the cycle.

Glycolysis:



Glycolysis is a universal catabolic pathway that converts glucose into pyruvate through a sequence of ten enzyme-catalyzed reactions, and generates the high-energy molecules ATP (adenosine triphosphate) and NADH (reduced nicotinamide adenine dinucleotide). Its primary function is to provide energy and intermediates for other metabolic pathways. The glycolysis pathway can be separated into two phases: the preparatory/investment phase (first five reactions in the figure above) where ATP is consumed, and the pay-off phase (final five reactions in the figure above) where ATP is produced.

Glycolysis is an oxygen-independent metabolic pathway. Therefore, it not only plays important roles in generating energy to support normal cell homeostasis, but also is the major energy production pathway in hypoxic cancer cells.

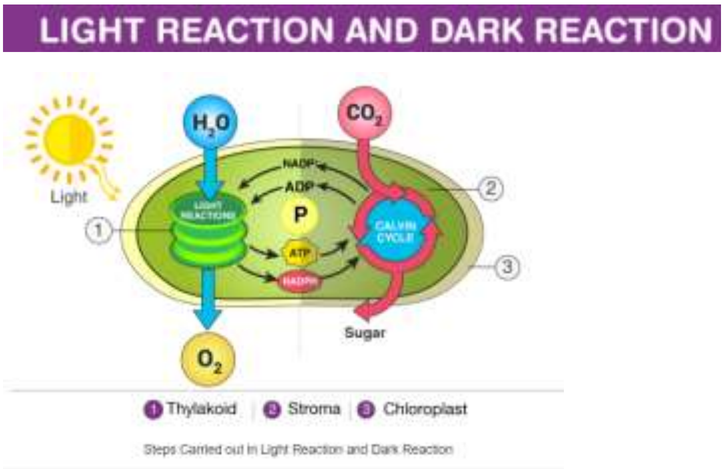
Synthesis of glucose of glucose:

Photosynthesis is the process of conversion of light energy into chemical energy which can then be utilized by living organisms. It is a rather complex process which is carried out through various stages.

Photosynthesis comprises two phases:

- The first phase is the photochemical phase or **light-dependent process**. This phase is commonly known as the light reaction.
- The second phase is the biosynthetic phase of the dark reaction of photosynthesis. This phase is the **light-independent process.**

The whole process of photosynthesis takes place within the chloroplast.



Steps Carried out in Light Reaction and Dark Reaction

Light reaction And Dark reaction

As stated above, photosynthesis occurs in two phases – light reaction and dark reaction.

Light Reaction

The light reaction is a light-dependent process which includes a series of events such as light absorption, hydrolysis, the release of oxygen, formation of ATP and NADPH.

The light reaction of photosynthesis initiates only when it is supplied with light energy.

The photosystem is the arrangement of pigments, including chlorophyll within thylakoids.

There are two photosystems in plants:

- Photosystem I (PS-I)
- Photosystem II (PS-II)

Photosystem I absorbs light at a wavelength of 700 nm, whereas Photosystem II absorbs light at a wavelength of 680 nm.

The light reaction occurs in the thylakoids of the chloroplast. When the light hits, chlorophyll-*a* gets excited to a higher energy state followed by a series of reactions. This energy is converted into energy molecules ATP and NADPH by using PS I and PS II. Also, hydrolysis occurs and releases oxygen.

Dark Reaction

Dark reaction is also called carbon-fixing reaction. It is a light-independent process in which sugar molecules are formed from the carbon dioxide and water molecules.

The dark reaction occurs in the stroma of the chloroplast, where they utilize the products of the light reaction.

Plants capture the carbon dioxide from the atmosphere through stomata and proceed to the Calvi cycle.

In the Calvin cycle, the ATP and NADPH formed during light reaction drives the reaction and convert six molecules of carbon dioxide into one sugar molecule, i.e. glucose.

Difference between Light and Dark Reaction

Following are the important differences between light and dark reaction:

Light Reaction	Dark Reaction
It takes place only in the presence of light.	It can take place in the *presence* or *absence* of sunlight.
It is a photochemical phase.	It is a biochemical phase.
It takes place in the grana of the chloroplast.	It takes place in the stroma of the chloroplast.
NADP utilizes H+ ions to form NADPH.	The hydrogen of NADPH combines with CO2.
The end products are ATP and NADPH.	Glucose is the end product. ATP and NADPH help in the formation of glucose.
The water molecules split into hydrogen and oxygen.	Glucose is produced. Co2 is utilized in the dark reaction.
Photolysis occurs in PS-II.	Photolysis does not occur.

ATP as Energy Currency of the cell:

What is ATP-Adenosine Triphosphate?

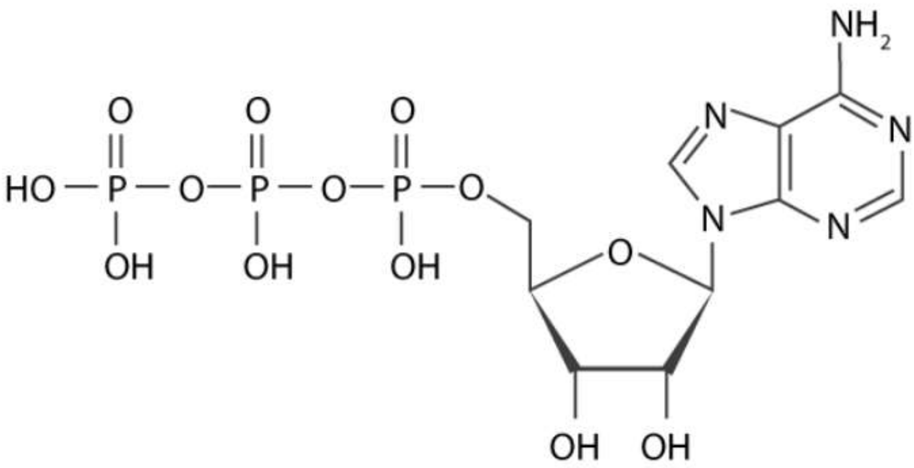
ATP – Adenosine triphosphate is called the energy currency of the cell.

It is the organic compound composed of the phosphate groups, adenine, and the sugar ribose. These molecules provide energy for various biochemical processes in the body. Therefore, it is called "Energy Currency of the Cell". These ATP molecules are synthesized by Mitochondria, therefore it is called powerhouse of the cell.

The ATP molecule was discovered in the year 1929 by German chemist Karl Lohmann. Later in the year 1948, Scottish biochemist Alexander Todd was the first person to synthesized the ATP molecule.

ATP – the energy-carrying molecules are found in the cells of all living things. These organic molecules function by capturing the chemical energy obtained from the digested food molecules and are later released for different cellular processes.

Structure of ATP Molecule



ATP – Adenosine triphosphate is a nucleotide, which is mainly composed of the molecule adenosine and three phosphate groups. It is soluble in water and has a high energy content, which is primarily due to the presence of two phosphoanhydride bonds connected to the three phosphate groups.

The triphosphate tail of ATP is the actual power source which the cell taps. The available energy is contained in the bonds between the phosphates and is released when they are broken or split into molecules. This occurs through the addition of a water molecule (hydrolysis). Usually, only the outer phosphate group is removed from ATP to yield energy; when this occurs, ATP – Adenosine triphosphate is converted into ADP – adenosine diphosphate, it is the form of the nucleotide having only two phosphates.

ATP molecules are largely composed of three essential components.

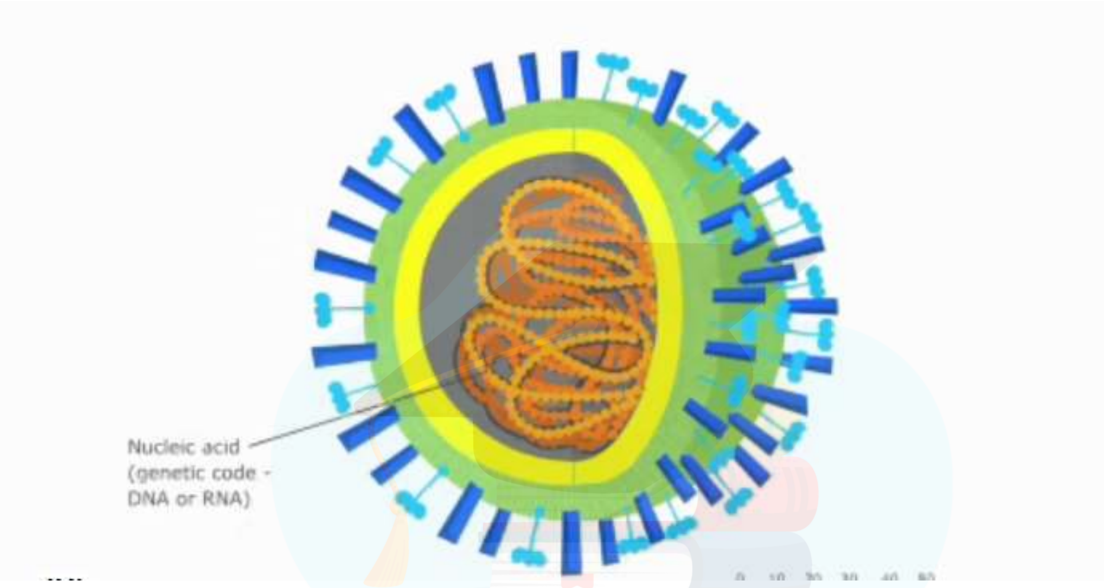
- The pentose sugar molecule i.e. ribose sugar.
- Nitrogen base- Adenine, attached to the first carbon of this sugar molecule.
- The three phosphate groups which are attached in a chain to the 5th carbon of the pentose sugar. The phosphoryl groups, starting with the group closest to the ribose sugar, are referred to as the alpha, beta, and gamma phosphates. These phosphates play an important role in the activity of ATP.

Microbiology:

Concept of species and strains

What is a Strain

A strain is a genetic variant, subtype or culture of a biological species. They are more popularly used in microbiology. Furthermore, a strain originates from a single cell colony, and microorganisms, such as viruses, bacteria, and fungi, have several strains within a species. As an example, a "flu strain" is a certain biological form of influenza or "flu" virus characterized by their differing isoforms of surface proteins. Thereby, a strain significantly carries a particular genetic characteristic, which does not occur within the other members of the species.



Virus Strain

Besides, genetic variation is the variation of genomes between individuals in the same species due to the genetic mutations, which occur during sexual reproduction. Usually, genetic variation can be caused by mutations of genes, gene flow, random mating, random fertilization, and crossing over between homologous chromosomes. In addition to that, genetic variation is an important mechanism, which forces evolution through natural selection. Also, it is important in maintaining biodiversity among species, as well.

What is a Species

A species is a closely related group of organisms with similar characteristics and interbreed to produce a fertile offspring. Also, it is the fundamental unit of the classification of organisms. In order to define a particular species, the similarities in the DNA sequences, morphological, and ecological features can be considered. In the historical means, the origination of species by natural selection is described by Charles Darwin in 1859. Sometimes, a particular species may consist of different breeds with great variations. More often, similar species live in similar habitats since they originate from a common ancestor. However, defining a species may become difficult due to variation within the species.

The Butterfly Genus Heliconius Contains Many Similar Species.

Furthermore, species is a taxonomic level of organisms, ranking below a genus. Although it consists of similar individuals who can interbreed with each other, a species comprises the biggest possible gene pool. Also, genes can be transferred between species by horizontal gene transfer. Moreover, particular species is scientifically named by a binomial name; the first part of it is the genus to which the organism belongs to and the second part is the specific name. For example, humans have scientifically named as *Homo sapiens*; 'Homo' is the genus to which humans belong, and 'sapiens' is the specific name of humans.

Sterilization and media compositions:

Sterilization

In microbiology, sterilization can be defined as the complete removal of all forms of microorganisms, both vegetative and spore forms, from a surface or an object. Sterilization is carried out by various physical and chemical methods such that it eliminates around 10^6 log colony-forming units.

Sterilization is done to avoid the growth of microorganisms which may grow on the surface of an object if left without killing the germs. It is, however, different from disinfection or sanitisation where only reduction of the microorganisms takes place, rather than total elimination. After sterilization, an object becomes sterile or aseptic

Classification of Sterilization

Sterilization is achieved by different physical and chemical methods in microbiology. Sterilization is classified into 2 types – physical sterilization and chemical sterilization. Let us discuss them in detail.

Physical Methods of Sterilization

Physical sterilization includes the following methods:

- **Heat Sterilization**

Heat sterilization is the most effective method of sterilization, where the elimination of microbes is achieved by the destruction of cell constituents and enzymes. It is done by two methods:

1.
    1.
        A. **Moist Heat Sterilization:** It is one of the best methods of sterilization. Moist heat sterilization is done with the help of an instrument called an autoclave. An autoclave works on the principle of producing steam under pressure. Thus moist heat sterilization is also known as steam sterilization. The water is boiled in an autoclave at 121-134°C at a pressure of 15psi. This leads to coagulation of proteins in the microorganism, and they are effectively killed.
        B. **Dry Heat Sterilization:** This method is used on objects that are sensitive to moisture. Moisture-free heat or dry heat is applied on the surface or objects such that there is denaturation and lysis of proteins which leads to oxidative damage, and ultimately the microbial cell dies out or may even burn. Some methods of dry heat sterilization include incinerators, hot air ovens and flaming techniques.

- **Filtration**

This is a mechanical method of sterilization in microbiology. This method uses membranous filters with small pores to filter out the liquid so that all the bigger particles and microbes cannot pass through. The three steps of filtration are sieving, adsorption and trapping.

- **Irradiation**

Irradiation is the process of exposing surfaces or objects to different kinds of radiation for sterilization. It is of two types:

1.
    1.
        A. **Non-ionising Radiation:** Ultraviolet radiation is exposed to the object, which is absorbed by nucleic acids of the microorganisms. This leads to the formation of pyrimidine dimers in the DNA strand, which causes the replicative error, and eventually, the microbe dies.
        B. **Ionising Radiation:** Upon exposure to ionising radiations such as gamma rays and X-rays, reactive oxygen species such as hydrogen peroxide and superoxide ions are formed that oxidise the cellular components of the microbe, and they die.

- **Sound Waves Vibration**

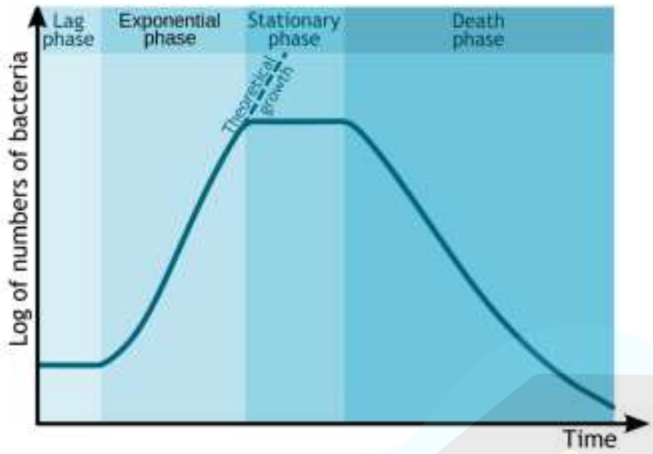
Sonix sound waves ranging from 20-40 kHz in frequency are applied across the fluid to be sterilized. These ultrasonic waves produce an alternation of compressive and tensile forces forming cavities in the solution. These cavities suddenly collapse, which creates submicroscopic voids and removes microorganisms from the container.

- **Fractional Sterilization**

Fractional sterilization or tyndallisation is a method used for media containing gelatin or sugar. Typically, exposure to 100°C for 20 minutes on 3 successive days is required. The principle is that the first exposure kills all spores and vegetative bacteria. If they germinate, they will be killed in the subsequent exposures. However, this method may fail to kill spores of certain thermophiles and anaerobes.

Growth kinetics

Since bacteria are easy to grow in the lab, their growth has been studied extensively. It has been determined that in a **closed system** or **batch culture** (no food added, no wastes removed) bacteria will grow in a predictable pattern, resulting in a **growth curve** composed of four distinct phases of growth: the lag phase, the exponential or log phase, the stationary phase, and the death or decline phase. Additionally, this growth curve can yield generation time for a particular organism – the amount of time it takes for the population to double.



Role of Biology :

Role of Biology in Agriculture

The large increase in the size of a population has led to an increasing demand for resources and basic requirements such as food, shelter, clothing, etc. Another impact of the increase in population is the exploitation of the land for crops production. Thus cultivation has been limited to a small area. In order to meet the demands with limited resources, we need to apply a great effort. Biotechnology in agriculture has changed the face of this condition.

Biotechnology is the use of technology to modify or manipulate any biological system or living system for the development or improvement of products for various purposes. It is widely employed in different fields and agriculture is one among them. Researchers have suggested different options for increasing food production . Genetically engineered crop-based agriculture is an option, others being agrochemical based agriculture and organic agriculture.

The green revolution was an initiation for increasing food production but it couldn't meet the growing demands. Later the idea of crop variety improvement program was put forward. However, the agrochemicals seem to be unfeasible for farmers. In addition, the environmental issues related to them also reduced their use.

Genetically Modified Crops

Genetically modified crops (GMO) are the latest advancement in the agricultural field. These crops result from the alteration in the genetic makeup of the crops. This modification leads to a number of advantages in the crops which include –

1. There is less loss after harvest.
2. The crops can be modified to have additional nutrients value for human welfare.
3. These crops are modified to be highly efficient, i.e, the high yield with less usage of minerals.
4. The decrease in the use of insecticides and pesticides which lead to pollution in the environment.
5. More tolerance to the natural stresses like natural calamities, extreme temperature and weather conditions, lack of water and minerals.

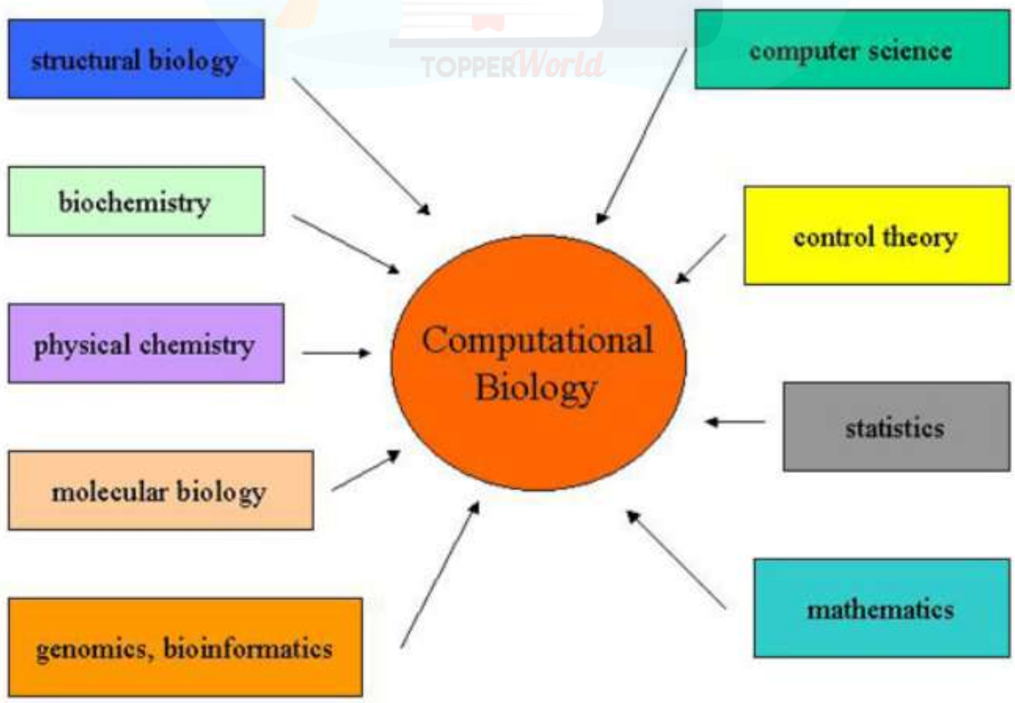
FORENSIC BIOLOGY

Forensic Biology is the application of concepts and procedures used in the biological sciences, typically in a medico-legal context. Forensic biologists analyze cellular and tissue samples, as well as physiological fluids that are relevant to a legal investigation. These techniques can also definitively identify paternity/kinship relationships and are used to determine the manner, mechanism, cause and time of death.

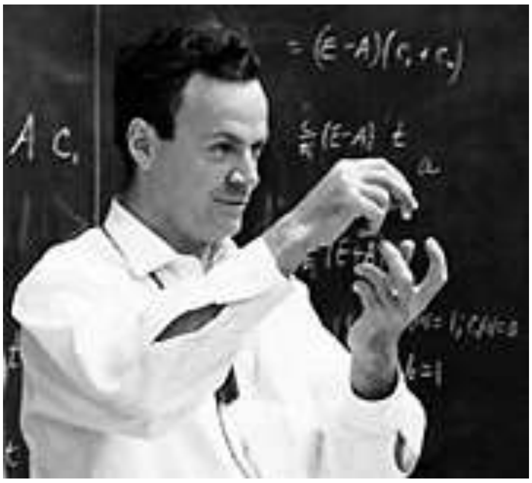
Bioinformatics

Bioinformatics, as related to genetics and genomics, is a scientific subdiscipline that involves using computer technology to collect, store, analyze and disseminate biological data and information, such as DNA and amino acid sequences or annotations about those sequences. Scientists and clinicians use databases that organize and index such biological information to increase our understanding of health and disease and, in certain cases, as part of medical care.

The role of bioinformatics in biological research can be compared with the role of data analysis in the age of information and the Internet. In earlier days, the primary challenge was getting to the information. Advances in reading DNA sequences have lowered that barrier substantially. Going forward, the challenge is how to understand and interpret the information that has been collected. Because the data sets are large, whether you're talking about information about website visits or the human genome, computer-based methods are the default approach. In the end, bioinformatics work with human genomes seeks to discover practical insights about human health and biology with all its complexity.



Nanotechnology



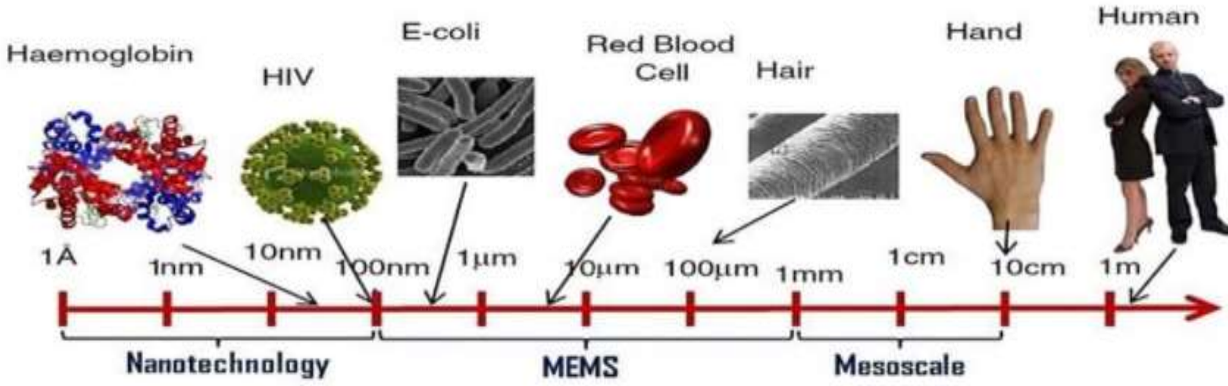
Physicist Richard Feynman, the father of nanotechnology.

Nanotechnology is science, engineering, and technology conducted at the nanoscale, which is about 1 to 100 nanometers. Nanoscience and nanotechnology are the study and application of extremely small things and can be used across all the other science fields, such as chemistry, biology, physics, materials science, and engineering.

Micro-electromechanical systems (Bio-MEMS) and Sensors (Biosensors):

What is MEMS?

MEMS stands for the micro-electro-mechanical system. It is also known by other affiliated names such as microsystems technology (MST) or micromachines. MEMS is an umbrella term for a wide range of microfabrication designs, methods and mechanisms that involve realising moving mechanical parts at the microscopic scale.

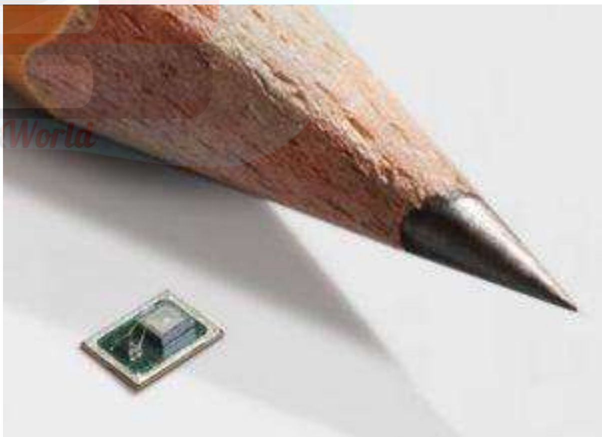


MEMS microscopic scale

What are the uses of MEMS?

Microelectromechanical systems (MEMS) are used in various sensors, actuators, generators, energy sources, biochemical and biomedical systems and oscillators. Some examples of MEMS applications in engineering product design include:

MEMS microphones (credit:vespermems.com)



- Actuators such as MEMS switches, micro-pumps, micro-levers and micro-grippers
- Generators and energy sources such as MEMS vibration energy harvesters, MEMS fuel cells and MEMS radioisotope power generators
- Biochemical and biomedical systems such as MEMS biosensors, lab-on-chips, and MEMS air microfluidic and particulate sensors
- MEMS oscillators for accurate timekeeping and frequency control applications

Advantages and disadvantages of MEMS

Advantages of MEMS

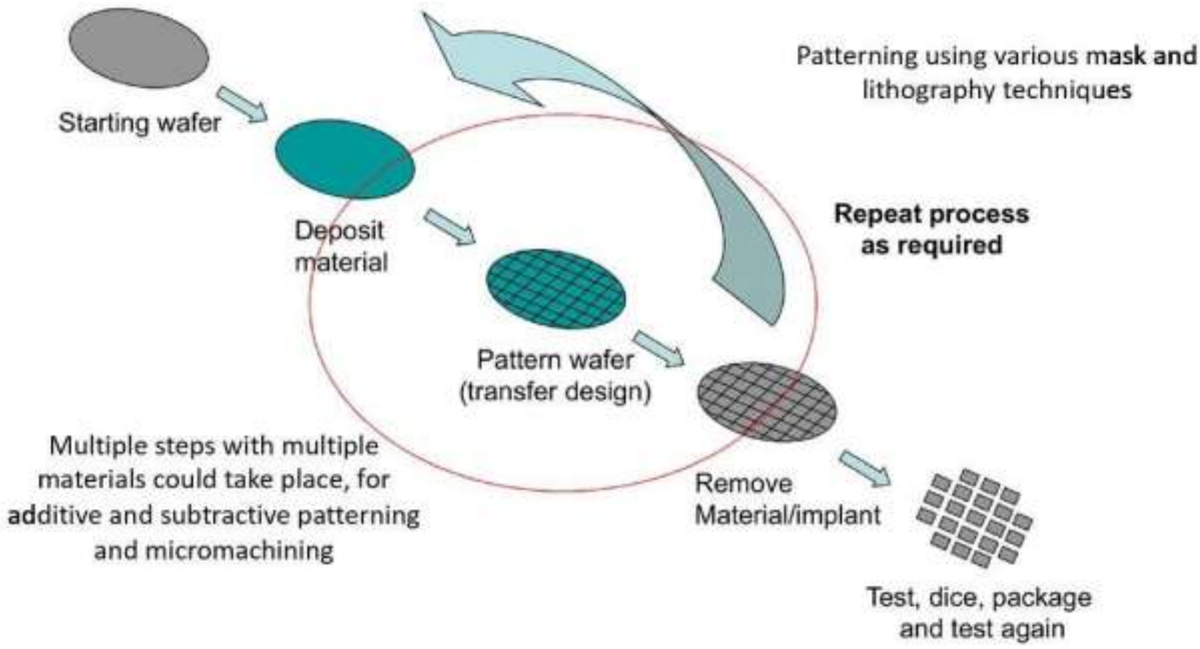
- Highly scalable in manufacturing, resulting in very low unit costs when mass-produced
- MEMS sensors possess extremely high sensitivity
- MEMS switches and actuators can attain very high frequencies
- MEMS devices require very low power consumption
- MEMS can be readily integrated with microelectronics to achieve embedded mechatronic systems – For example Microphones
- Scaling effects at microscopic levels can be leveraged to achieve designs and dynamic mechanisms otherwise not possible at macro-scales.

Disadvantages of MEMS

- Very expensive during the research and development stage for any new MEMS design or devices
- Very expensive upfront setup cost for fabrication cleanrooms and foundry facilities
- Fabrication and assembly unit costs can be very high for low quantities. Therefore, MEMS are not suitable for niche applications unless cost is not an issue.
- Testing equipment to characterise the quality and performance can also be expensive.

How are MEMS made?

MEMS are classically micromachined from silicon. Various types of silicon wafers exist, and silicon can be doped to varying conductivity levels. Additional functional materials can be added to provide various capabilities, such as electrode layers or piezoelectric layers. MEMS design and fabrication involves a series of steps and cycles, which can be summarised into:


Starting wafer
Patterning using various mask and lithography techniques
Deposit material
Repeat process as required
Pattern wafer (transfer design)
Multiple steps with multiple materials could take place, for additive and subtractive patterning and micromachining
Remove Material/implant
Test, dice, package and test again