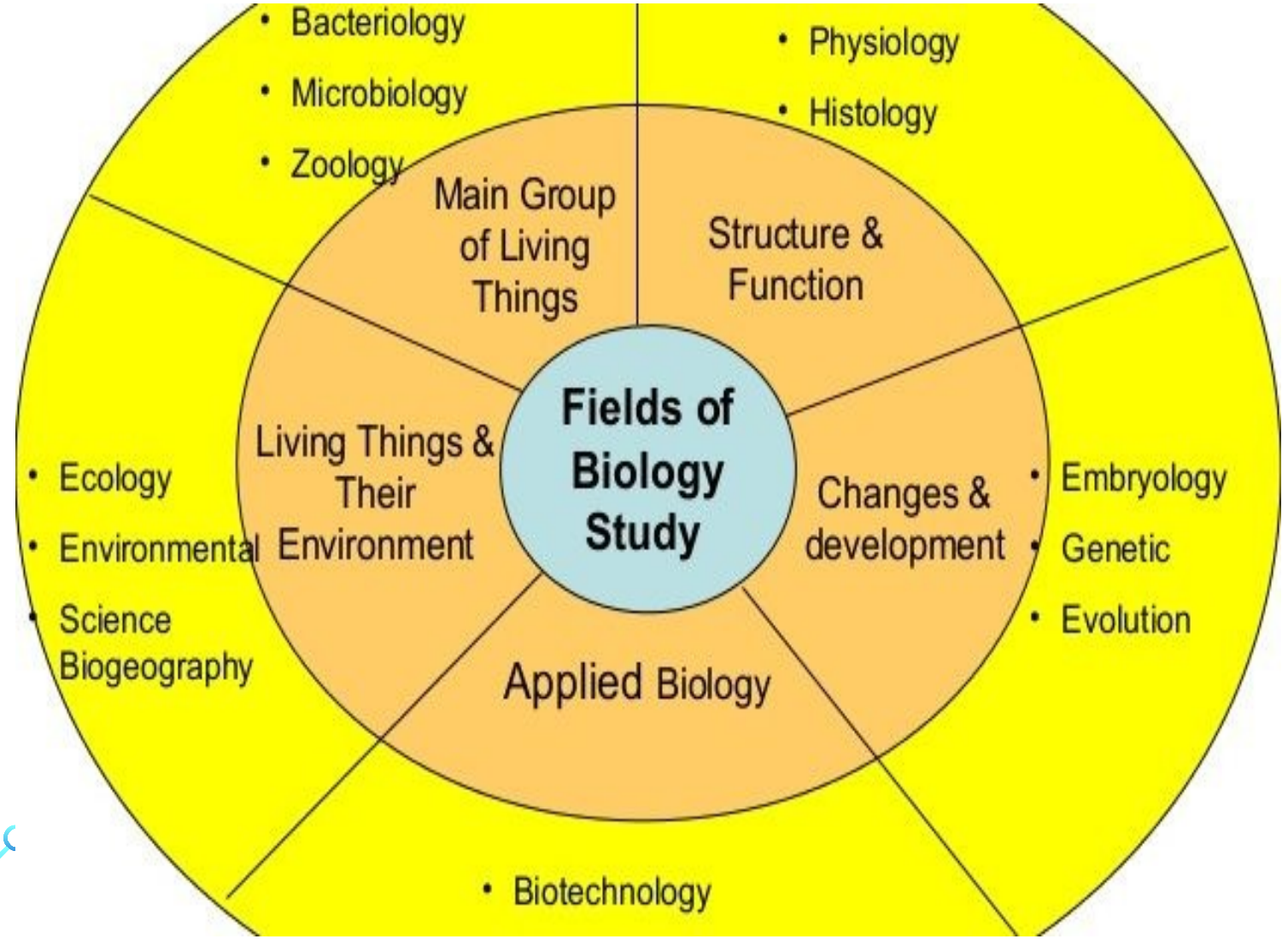
# UNIT ONE

# THE SCIENCE OF BIOLOGY

- **Biology** is a branch of science that deals with living things.
- The word **biology** is derived from two Greek words, **bios –** meaning ‘life’ and **logos –** meaning ‘study.
- So, Biology is the study of life and living organisms.
- That is why Biology is sometimes known as Life Science.
- Many Biologists are working on problems that critically affect our lives, such as the world’s

- Biological science is of great importance to mankind in a practical sense and has various scopes.



# The scientific Method

- **What is science?** The word Science comes from Latin word "***scientia***" which means knowledge'.
- It is a method of **discovery** and **understanding** by using a **problem solving** process called ***scientific method.***
- **Scientific Method** is a way of conducting research, based on theory construction, the generation of testable hypotheses, their empirical testing, and the revision of theory if the hypothesis is rejected.
- It is an empirical method of acquiring knowledge.

# The steps of the scientific method

Observation

Asking a question about something you observe

Doing background research and forming a hypothesis

Testing hypothesis / Experimentation

Analysis and interpretation of Data

Drawing conclusions

Theory

Evaluation

Reporting

## 1) Observation

- Observations can be made directly through the sensory systems, mainly vision, hearing, taste, smell and touch.
- They can also be made indirectly, through the use of special equipment such as the microscope. Most biological investigation starts with an observation of structure process or a behavioral pattern.

## 2. Asking the questions

- The scientific method starts when you ask a question about something that you observe: How, what, when, who, which, why, or where?

## 3. Do Background Research and forming a hypothesis

- The information gathered could be **qualitative** describing color, taste, etc. or **quantitative** involving the measurement of an amount of quantity.
- Hypothesis could be defined as a suggested explanation of certain observed phenomena/problem.
- Scientific hypothesis need to be tested since they are assumptions of tentative explanations.
- Hypothesis is a tentative theory characterized as:
  - ✓ An intelligent guess
  - ✓ Gradual accumulation of indirect evidence

## Inductive and deductive reasoning

- Induction and deduction are patterns of thought often recognized in the creation of a hypothesis.
- **Inductive** logic proceeds from the specific to the general whereas **deductive** logic proceeds from the general to the specific.
- Consider the following examples for better understanding of the difference b/n inductive and deductive reasoning.

## Deductive reasoning

- **Eg**: All animals are mortal (major premises).
Dogs are animals (minor premises).
- Therefore, Dogs are mortal

## Inductive reasoning

- **Eg**: Apple x – tastes sweet, Apple y – tastes sweet, Apple z – tastes sweet etc. **Conclusion**: All apples are sweet.

## 4) Testing hypothesis / Experimentation

- Hypothesis testing often involves experimentation
- A hypothesis that has with stood many such tests and has been shown to allow prediction to be made is known as **theory**.
- A theory may generate such confidence through its predictive ability to be known as a **law**.
- In most hypotheses there are a number of factors which may influence the observation.
- These are called **experimental variables.** These are:

## i. The independent variables

- Are the variable that the experimenter changes to see if this affects the performance of the dependent variables.
- They are the conditions or events under experimentation or testing.
- It can be changed systematically in an experiment.
- **Example**: In an experiment in which seedlings are grown at different temperatures.
- Temperature is the independent variable.

## ii. The dependent variables

- They are the factor in an experiment that the scientists measures to see if it changes when the independent variable is change.
- They variables that can possibly change because of the presence of or changes in the independent variables.

**Example**: The rate of growth (fast or slow) of seedlings at different temperatures.

**iii. The controlled variables –** are conditions that could affect the outcome of an experiment but that do not do so because they are held constant. e.g. in an investigation of the effect of light on plants

## iv. Confounding variables

- A factor that can not be controlled and which may influence the result of the experiment.
- The usual way of testing hypothesis is by performing a carefully planned experiment.
- Such a carefully planned experiment consists of two components
  - Experimental group (treated group)
  - Control group (un treated group)

## 5) Analysis and interpretation of Data

- Results are recorded carefully and systematically and usually organized in the form of data tables, charts or graphs in addition to verbal explanations.
- Analysis of data means studying the organized material in order to discover the essential facts.
- The 4 helpful modes that help you to analyze the data gathered:
  - Choose clear tables or figures for presenting the data
  - Examine carefully the statement of the problem
  - Further discuss with others about the problem

- Treat the data using various statistical calculations to check similarities and differences.
- The stage **of interpretation** after analysis is essential to state what the results show.
- Hence, interpretation needs a careful logical and critical examination of the results obtained after analysis.

## 6) Drawing conclusions

- Conclusions or generalizations require careful and objective analysis of the data gathered.

## 7) Theory, principles, fact and law

- When a given hypothesis has been tried (tested) many times by independent investigations and found to be acceptable it is no longer a hypothesis, but it becomes a **theory**.

- a theory is a hypothesis tested to be true
- a theory is open to tests, revision and tentative acceptance or rejection.
- e.g. A theory of evolution has changed over a period of time
- At times discoveries are made much earlier but take the form of a theory after subsequent findings only.
- E.g. Robert Hooke discovered cell in 1665 but cell theory was formulated by schleiden and schwann in 1838 - 1839.
- When a theory has proved invariable under all circumstances, or such variations are systematic

- A model is a mental map formed by deliberate analogy with a more familiar concept.
- Models are used in science to simplify ideas or certain aspects of a phenomenon.
- e.g. The key and lock model of enzyme action

  The crick and Watson model of DNA structure

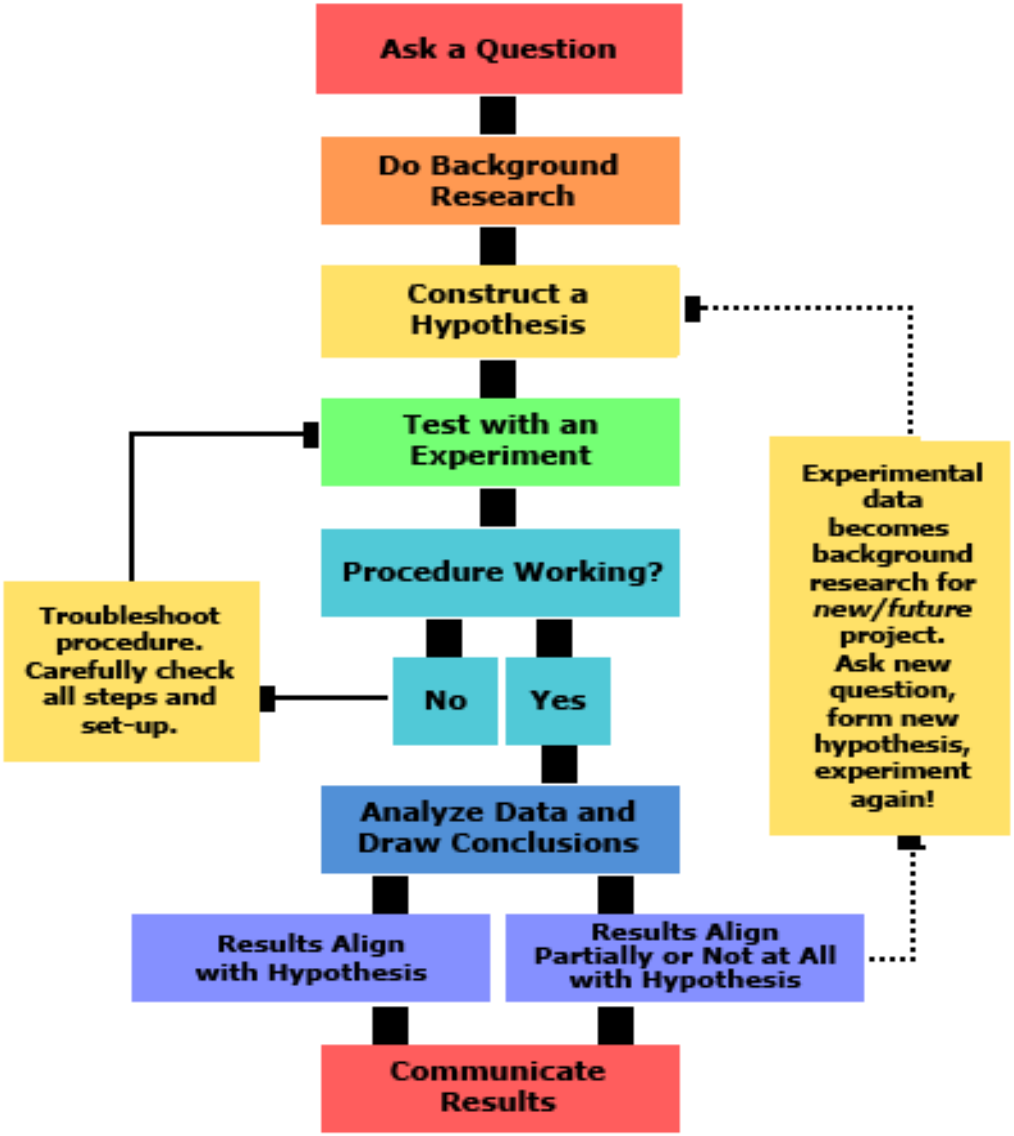
## 8. Evaluation

- For valid conclusions many rounds of the same experiment need to be undertaken. i.e. each experiment should be done again and again until consistent results are obtained.
- This phase of a scientific experimentation is known as **evaluation**.

9. **Reporting and publishing results**

- Communication is an important component of the scientific method.
- The knowledge generated in a field of science has to reach the scientific community.
- The proper channels of communication for scientists and researchers are scientific journals, conference proceedings, bulletins and other publication series.
- Communication through reporting also avoids repetition of the same work.

# Steps of the scientific method



## 1.2. The Basic tools of a Biologist

- Biological information is gathered through observations and experiments, conducted in the laboratory and in the field.
- Practical interactions with biological objects and processes are important in making the theoretical knowledge more concrete and meaningful.
- The tools or instruments used in Biology can be divided into the **laboratory** and **fields** tools.

| Laboratory tools/instrument | Field tools/instrument |
| --- | --- |
| 1. Dissecting kits (forceps, mounting needle, scissors, dropper, brush) | 1. Plant press, plastic bags, envelops |
| 2. Mortar and pestle | 2. Insect net |
| 3. Pipette | 3. Secateurs |
| 4. Microscope (Slides, cover slips) | 4. Auger |
| 5. Hand lens | 5. Meter |
| 6. Petri-dish | 6. Altimeter |
| 7. Rulers | 7. GIS*/GPS** |
| 8. Centrifuge, water-bath oven | 8. Traps, Cages |

# The Microscope

- A microscope is a precision device used to show objects that are too small to be seen at all with the naked human eye.
- The microscope is the most important tool used in biological sciences.
- After the invention of the first simple and crude type of microscope by Anton van Leeuwenhoek advancements were made in the field of microscopy.
- The best light microscope can magnify structures (increase in size of the image) up to 1500 times (x 1500) their original or normal size.

- At this high magnification, the image becomes less clear because the lenses cannot distinguish b/n small structures lying close together.
- The power of the microscope to scatter the image and show more details is known as the **resolving power** of the microscope.
- Microscopes could be categorized into the following major groups depending on **their complexity.**
- **These are simple, compound, Electron and others**

## A. Simple microscope

- The hand lens is an example of a simple microscope.
- It consists of a biconvex lens in a supporting frame.
- It is used to observe the external form of objects, and not the details of their internal structures.
- The magnification power of the common hand lens is usually between x10 and x20.
- The first microscopes were made of a single lens and hence were simple microscopes.

## B. Compound microscope

- This is a microscope with magnifying powers of two convex lenses, the eye piece (ocular lens) and the objective lens are used to produce a magnified image of small objects.
- The compound microscope uses light rays coming from a certain source (open light or an electric bulb), it is known as a light microscope.
- It uses to investigate internal structure of objects.
- Compound light microscopes are important to biologists because they allow them to observe many kinds of cells & single celled organisms while they are still alive.

- That is, an organism does not have to be filled to be observed under a compound microscope.
- There are limits to what we can see with the compound light microscope.
- As we increase the magnifying power of a light microscope, we see more and more detail - up to a certain point.
- Beyond that point, called the **limit of resolution**, objects get blurry & details are lost.
- For standard light microscopes, the limit of resolution is about 0.2 micrometers (A typical cell is about 10 micrometers across).

## C. Electron microscope

- Although light microscopes are very useful, their limits of resolution restrict their useful ness for studying very small objects such as viruses & individual molecule.
- In the 1920s, physicists in Germany realized that electromagnets could bend much the same way that glass lenses bend beams of light.
- This is a more powerful type of microscope. It uses a beam of electrons instead of light with a greater resolving power unlike the light microscope. The two types of electron microscopes are known as:

**1. Transmission electron microscope (TEM):** shine a beam of electrons at a specimen and then magnify the specimen onto a fluorescent scram. It reveals the inner most details of the cell interior.

**2. Scanning electron microscope (SEM):** beam of electrons that scans back & forth across the surface of specimen are picked up by detectors that provide the information to from an image on a TV screen.

- SEM allow us to study the surface of objects in their dimensional detail.
- The limitation of electron microscope is that living cells must be killed before they can be observed.

## D. Other Types of microscopes

### i. Dissecting microscope

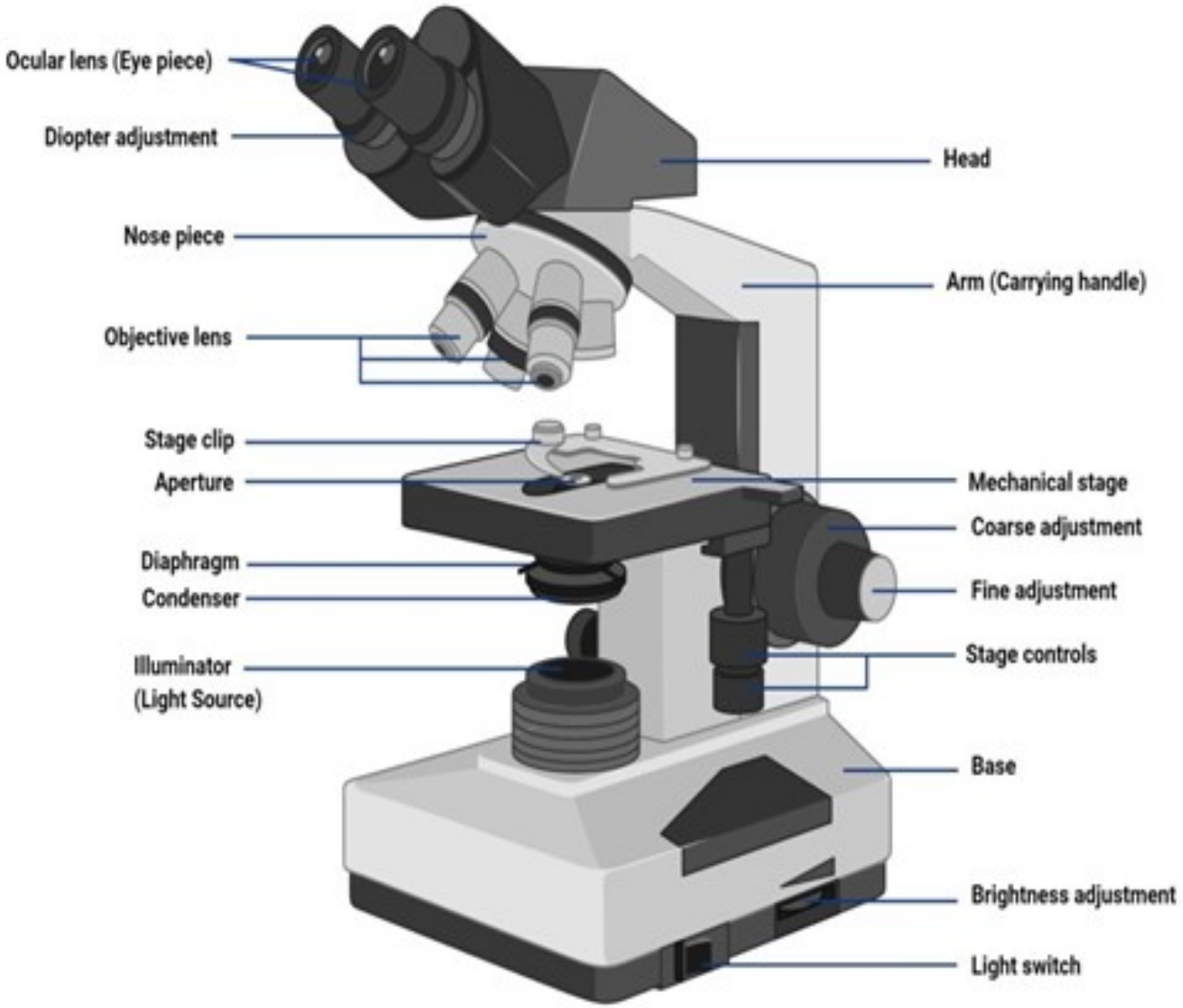
- This is designed to enable small objects to be dissected or manipulated while viewed under a moderate degree of magnification.
- In its simplest form, it consists of a stage above which is mounted a single lens magnifying about x10.
- A dissecting microscope is binocular, which has two oculars.
- It is made easier to make manipulation under the microscope easier.

- This type of microscope is intended for use in manipulative biological work, and for the examination of relatively large objects such as insects.
- **ii. Phase contrast microscope**
- This microscope is especially important in studying fine structures in living cells.

**iii. Interference microscope**

- It Works with the same principle as phase contrast microscope. But, increases in contrast as a result of interference between light waves.
- The interference microscope however, enables smaller differences in contrast to be detected and

# Microscope Parts



## Parts of microscope with their functions

- **Ocular (eye piece lens)-** A lenses system of the microscope with a magnification power x 10. This lens is often un attached to the other parts, hence can fall down if not properly kept.
- **Body tube-** This may be monocular or binocular, where the eyepiece and objective lenses are supported, at a known distance and angle. The lower and of the tube possess a revolving nosepiece on which the objective lenses are

- **Arm ( limb)-** Supports the body tube and is the part with which you can grip to carry the microscope.
- **Nose piece-** The revolving part to which the objective lenses are attached.
- **Stage clip-** This is located on the stage and hold the glass slide in position( place).
- **Objective Lens-** The lens, closed to the object placed on the stage, have several alternative lenses that are switched one at a time.
- These are x10, (40x), (x100). The oil immersion lens (x150), operates with the addition of oil, giving even larger magnification.

- **Stage-** This is a broad flat surface with a circular opening at its center that serve as a passage for light from the condenser to the objectives. The stage is also used to support the glass slide that holds the object.
- **Knobs-** These are used to move the stage up and down in order to bring the specimen into focus. The focusing knobs may be located near the base or the upper arm depending on the type of the microscope
- **Coarse adjustment-** Moves the body tube or

- **Iris diaphragm-** This is controlled by a lever than can be moved back and forth. It is used to regulate how much light and lamp heat goes through the specimen.
- **Condenser-** This is a lens located above the diaphragm, which concentrates the light before it passes thought the specimen.
- **Fine adjustment-** This is used to move the stage or body tube up and down to exactly the right position, so that the specimen is in focus. It uses to get fine focus with the low power objective and for all the high power and oil immersion objectives
- **Mirror-** Collects light and directs it to the condenser
- **Base (foot)-** Gives a firm and steady support to the microscope

# Unit 2

## BIOCHEMICAL MOLECULES

### 2.1. Organic Molecules

- All living organisms require several compounds to continue to live.
- We call these compounds biomolecules. The smallest unit that make up a cell are called elements.
- Scientists have identified 109 different elements & of the 103 different known elements only about, 13 kinds are involved in producing & maintaining life on our planet.
- Of these 13, 6 make up the common building block, which chemically join together to give a cell its unique structure & internal activity (chemical function).

- These 6 are the elements are carbon (C), hydrogen (H), Oxygen (O), nitrogen (N), phosphorus (P) & sulfur (S).
- All living things are composed these 6 elements.
- The 4 most common elements in living organism are, in order, H, C, O & N.
- The biological importance of H, O, N & C is largely due to their having valences of 1,2,3 & 4 respectively & their ability to form more stable covalent bonds than any other elements with these valences.
- C, H, and O & N chemically join or bond together to form 4 large units of organization called organic compounds, i.e. carbohydrates, lipids, proteins & nucleic acids.

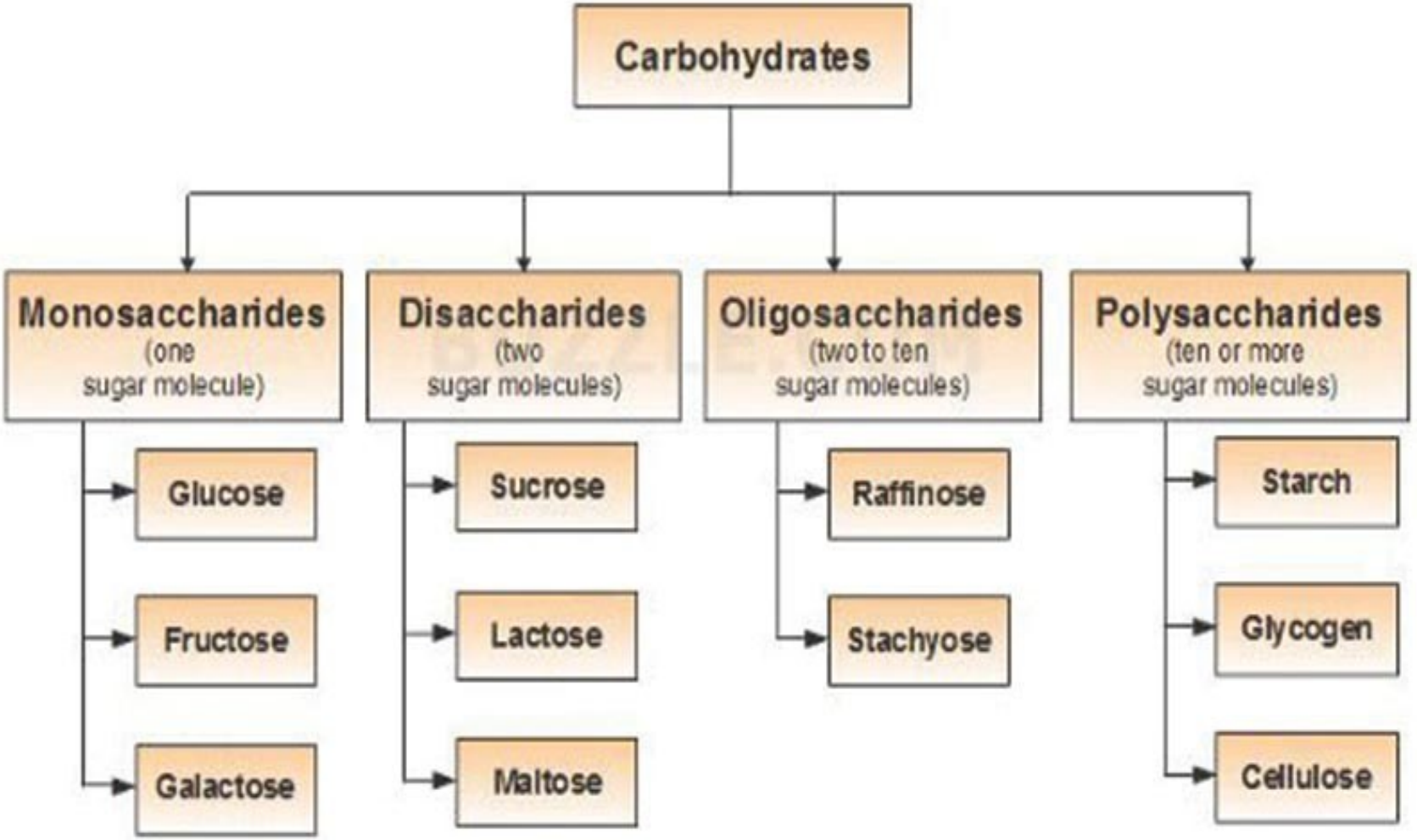
- Biomolecules are formed by joining many small units together to form a long chain.
- This process is called synthesis. Often, a water molecule is removed in the process. When this happens, we call it dehydration synthesis.

## A. Carbohydrates

- Carbohydrates are substances that contain the elements C, H & O, & have a general formula Cx(H2O)y, Where x & y are variable numbers.
- Carbohydrate means hydrated carbon & this name derived from the fact that H & O are present in the same ratio as in water, i.e. 2H atoms; 1O atom.

- Carbohydrates are good energy source for living organisms.
- Therefore, cells need large amount of carbohydrates.
- Carbohydrates are aldehydes and ketones, & all contain several hydroxyl groups.
- These groups determine their chemistry.
- Carbohydrates are divided into three main classes, monosaccharides, disaccharides & polysaccharides depending on their sugar units.

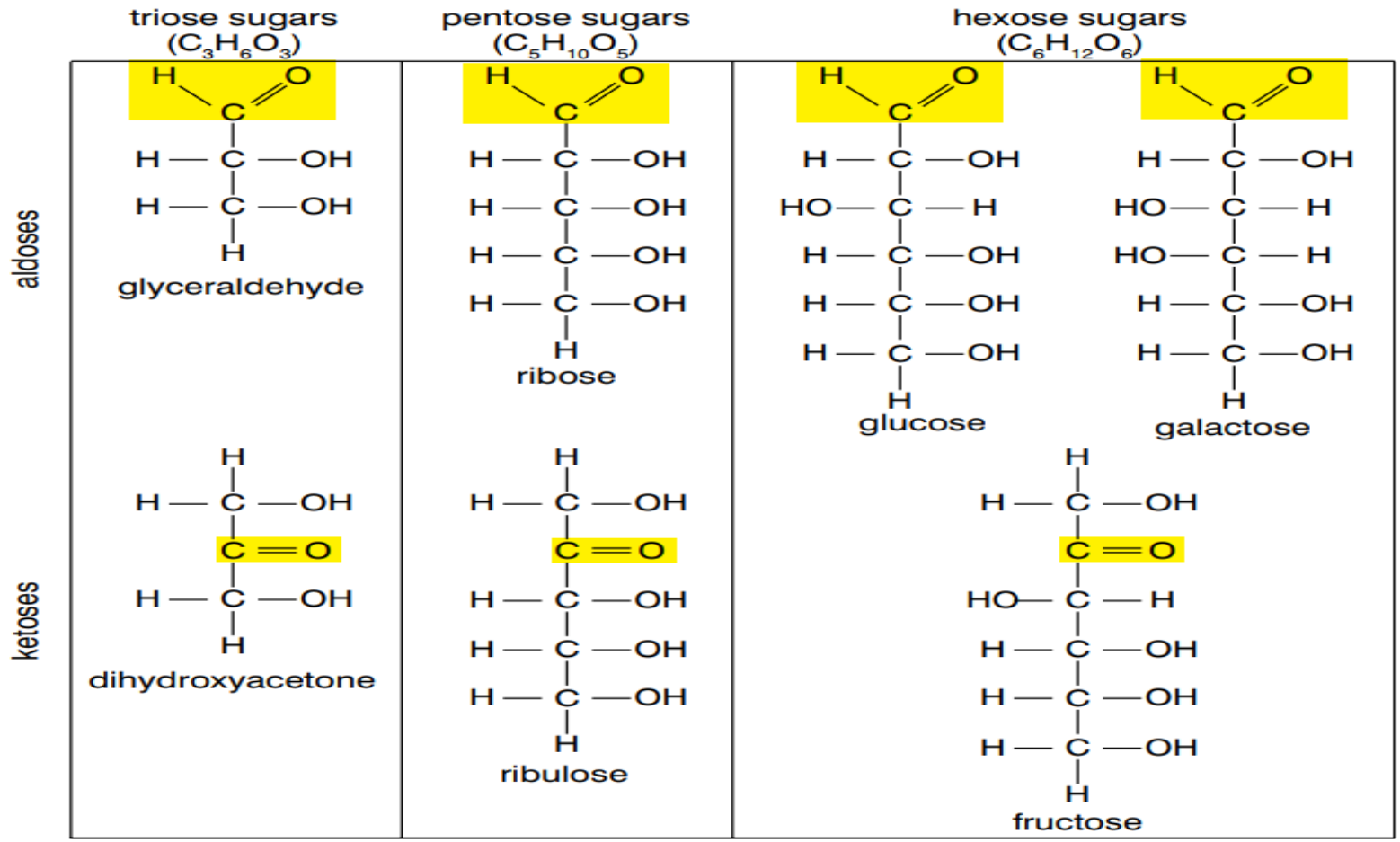
- **Based on the number sugar units they contain, they are categorized into four, as follows:**



## i) Monosaccharides

- Monosaccharides are single sugar units. The smallest functioning unit of a biomolecule is a monomer and the monomer for carbohydrates are monosaccharides.
- Their general formula is $(CH_2O)_n$. Monosaccharides are classified according to the number of carbon atoms as trioses (3C), tetroses (4C) pentoses (5C), hexoses (6C) & heptoses (7C).
- Of these, pentoses & hexoses are the most common monosaccharides. One of the most common monosaccharides is glucose, a six carbon sugar.

- There are **two** functional groups in monosaccharides: these are aldehyde (CHO) and ketone **(**C=O) groups.
- **Aldoses**- are reducing sugars; **ketoses** are non-reducing sugars.



## Why is glucose important?

Cells use glucose for many purposes. Here are mentioned some of its functions.

- ✓ It is important for brain cells
- ✓ Synthesized by green plants and used as a food by others
- ✓ A constant level of it should be maintained in the blood for normal functioning of the body
- ✓ It acts as a fuel & releases energy for cellular activity
- ✓ Stored in liver or muscles as a storage molecule in animals
- ✓ Stored as starch in plants
- ✓ Forms cellulose, building block of plant cells.

# *Chief functions of monosaccharides*

| **Monosaccharide class** | **Examples** | **Function** |
|---|---|---|
| Trioses ($C_3H_6O_3$) | Glyceraldehyde, dihydroxyacetone | Intermediate in cellular respiration (see glycolysis), Photosynthesis (see dark reaction) & other carbohydrate metabolism, |
| Pentoses ($C_5 H_{10}O_5$) | Ribose, deoxyribose, ribulose | - Synthesis of nucleic acids; ribose is a constituent of RNA & deoxyribose of DNA<br>- Synthesis of some coenzymes; ribose is used in NAD & NADP synthesis<br>- Synthesis of ATP requires ribose<br>- Ribulose bisphosphate is the $CO_2$ acceptor in photosynthesis |

## ii)Disaccharides

- Disaccharides are formed when two monosaccharides, usually hexoses, combine by means of a chemical reaction known as a **condensation**, i.e. removal of water.
- The bond formed between two monosaccharides as a result of condensation is called a **glyosidic bond**.
- The most common disaccharides are **maltose** (glucose + glucose), **lactose** (glucose + galactose) & **sucrose** (glucose + fructose).
- Maltose & lactose are reducing sugars while

**iii) Polysaccharides:** They are complex carbohydrate.

- They function chiefly as food & energy stores (e.g. **starch** in plants & **glycogen** in animals) & as structural material (e.g. cellulose).
- They are convenient storage molecules because their large size makes them more or less insoluble in water.

- **Starch-** is a polymer of **α-glucose.**
- It exists in two forms: amylose and amylopectin.
- Both are made from α-glucose.
- Amylose is an unbranched polymer of α-glucose

- **Chitin** is closely related to cellulose in structure & function as being a structural polysaccharide. It occurs in cell wall of fungi & exoskeleton of arthropods.
- **Murein** acts as the strengthening material of bacterial cell wall.
- **Pectin** are polysaccharides of galactose & galacturonic acid residues, & is an important component of the first layer of a cell wall.
- **Hemicelluloses** are made up of pentose sugar & sugar acid residues. **Inulin**, a polymer of fructose, is a reserve carbohydrate found in some groups of plants as an alternative to starch.

## B. Lipids

- **What are Lipids?**

- Lipids are organic molecules consists of C, H & O, as do carbohydrates, but in lipids the proportion of O is much less & H is more.
- Lipids usually contain Sulfur (S) & sometimes Phosphorous (P).
- Lipids are also insoluble in water & are said to be hydrophobic (water-hating).
- But they are soluble in organic solvents such as **ethanol & ether**.
- They are of two types: **fats & oils**.

- There is no basic difference between them but **fats** are simply solid at room temperature (10-20$^{o}$ C) whereas **oils** are liquids.
- They are made up of **fatty acids & glycerol** (an alcohol).
- Fatty acids contain the acid group -COOH (the carboxyl group).
- Fatty acids sometimes contain one or more double bonds (C=C) & called **unsaturated fatty acids**.
- Fatty acids & lipids that lacking double bond are said to be **saturated**. Unsaturated fatty acids melt at much lower temperature than saturated fatty acids.

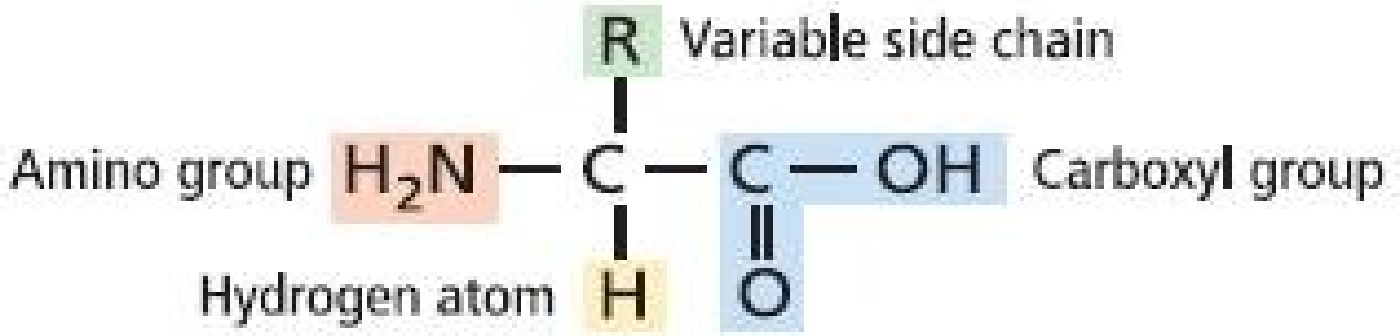
- The higher the proportion of unsaturated fatty acid the more likely the lipid to be liquid at a given temperature.
- Most lipids are triglycerides. Glycerol has three hydroxyl group (-OH) groups.
- Usually all three -OH groups undergo condensation reaction with fatty acid, & the lipid formed is therefore **triglycerol (triacylglycerol)**.
- Therefore, a triglyceride molecule consists of four molecules joined together: three fatty acid molecules attached to a glycerol molecule.

## Major functions

- Serve as the source of energy & heat.
- A given mass of lipid will yield more energy on oxidation than an equal mass of carbohydrate.
- This is because lipids have a higher proportion of hydrogen compared to carbohydrates.
- Structural constituent of cell membrane, e.g. phospholipids & glycolipids.
- Synthesis of hormones such as testosterone & estrogen, e.g. steroids (cholesterol in the tissue of mammals)
- Both bile acids that involve in digestion & vitamin D are manufactured from steroid such as cholesterol.
- Plant scents are derivatives of fatty acids. They are attractive to insects & thus aid pollination.

## C. Proteins

- Proteins are made up of a number of units called **amino acids**.
- More than 170 amino acids are currently known to occur in cells & tissues, but only 20 are commonly found in proteins.
- In the structure of amino acids there is a **central carbon (known as α-carbon)** to which are attached an acidic **carboxylic group** (-COOH), a basic **amino group** (-NH) & a **hydrogen atom**




- is

- Plants can synthesize all the amino acids they require from simpler substances, but animals unable to synthesize some of them.
- An **essential amino acid** is one, which must be included in the diet because either it cannot be made in the body at all, or it is made too slowly to meet needs.
- **Non-essential amino acid** is the one that can be synthesized in the cell or in the body.
- Amino acids can react with each other by condensation, i.e. the amino group of one amino acid reacts with the carboxylic group of the other with the removal of water.

- The bond formed between them is called **peptide bond**, & the resulting compound is a **dipeptide**. **Tripeptide** and **polypeptide for** 3 amino acid & many.
- Proteins differ from each other in the kind, number and sequence of amino acids along its chain.
- In the living cell the sequence of amino acids in polypeptide chain is determined by DNA.
- Each protein possesses a characteristic three-dimensional shape, its **conformation**.
- There are 4 separate level of structure & organization of proteins, i.e. primary, secondary, tertiary & quaternary.

**A. Primary structure:** It is the linear sequence of amino acids in a polypeptide chain.

**B. Secondary structure:** Polypeptide chains may be folded & twisted in various ways. The most common ways are the **coil to form a helix** (**α-helix**), e.g. keratin or to **fold into sheets** (**β-sheets**). These forms are referred to as secondary structure of proteins.

**C. Tertiary structure:** Usually the polypeptide chain bends & folds extensively, forming a precise, compact 'globular' shape. This is the protein's tertiary structure & the shape is maintained by ionic, hydrogen & disulphide bonds as well as hydrophobic interactions.

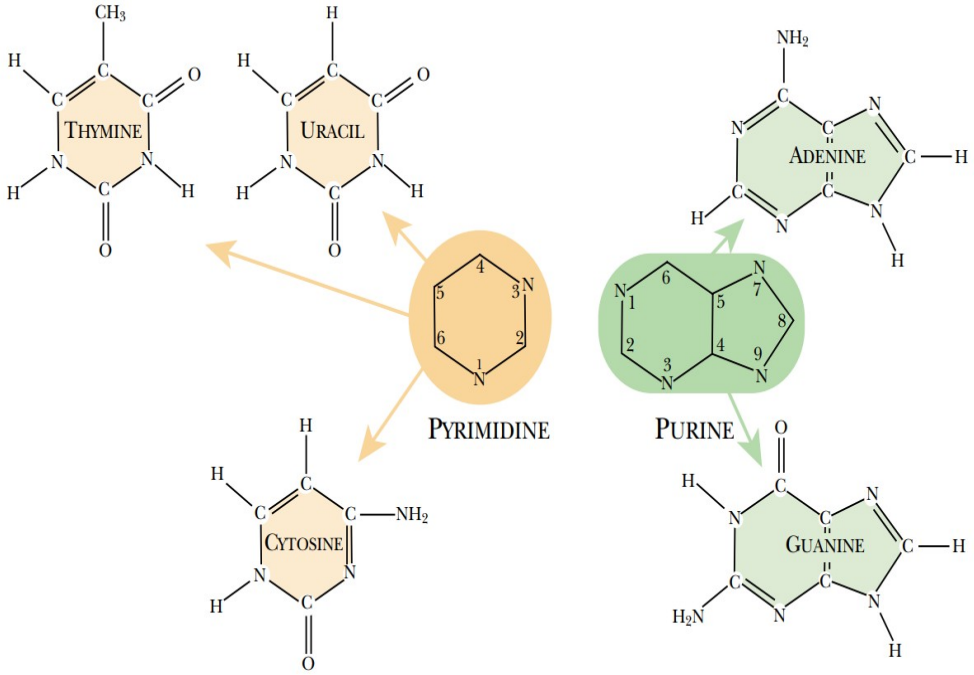
**D. Quaternary structure:** Many highly complex proteins consists of more than one polypeptide chain.

- The separate chains are held together by hydrophobic interactions & hydrogen & ionic bonds. Their precise arrangement is known as the quaternary structure.
- Because of the complexity of protein molecules & their diversity of function they classified in various ways & three of them are:
  - Their structure
  - Their composition and
  - According to functions

## D. Nucleic acids

- Nucleic acids are made of **polymers of nucleotides**. Individual nucleotides comprise three parts:
- **Phosphate group** (phosphate $H_3PO_4$): This has the same structure in all nucleotides.
- **Pentose sugar:** Two types occur, ribose ($C_5H_{10}O_5$) and deoxyribose($C_5H_{10}O_4$)
- **Organic (N-base):** There are five different bases which are divided into two groups as purine and pyrimidines.

- **Pyrimidines**: these are single rings each with six sides. Examples found in nucleic acids are Cytocine (C), Thymine(T) and Uracil(U).
- **Purines**: these are double rings comprising a six-sided and a five-sided ring. Two examples are found in nucleic acids: Adenine (A) and Guanir



- The three components of a nucleotide are combined by **condensation reactions** to give a nucleotide and linked with a **phosphodiester bonds**.
- By a similar condensation reaction between the sugar and phosphate groups of two nucleotides, a **dinucleotide** is formed.
- Continued condensation reaction lead to the formation of a **polynucleotide.**
- The function of nucleotides is the formation of the nucleic acids **RNA** and **DNA**, which play vital roles in protein synthesis and heredity.
- In addition, they form part of other metabolically important molecules.

# Biologically important molecules containing nucleotides, and their functions

| Molecules | Functions |
|---|---|
| **DNA** | Contains genetic information of cells |
| **RNA** | All three types play a vital role in protein synthesis |
| **AMP**<br>**ADP**<br>**ATP** | Coenzymes important in making energy available to cells for metabolic activities, osmotic work, muscular contraction, etc. |
| **NAD**<br>**FAD** | Electron (hydrogen) carries important in respiration in transferring hydrogen atoms from the Krebs cycle along the respiratory chain. |
| **NADP** | Electron (hydrogen) carrier important in photosynthesis for accepting electrons from the chlorophyll molecule and making them available for the photolysis of water. |
| **CoA** | Coenzyme important in respiration in combining with |

## A. Deoxyribonucleic acid (DNA)

- DNA is a double-stranded (chained) polymer of nucleotide where the pentose sugar is always deoxyribose and the organic bases are adenine, guanine, cytosine and thymine, but never uracil.
- Each of these polynucleotide chains is extremely long and may contain many million nucleotide units.
- The amount of guanine is usually equal to that of cytosine
- The amount of adenine is usually equal to that of thymine
- It is probably in the form of a helix whose shape

- Using the accumulated evidence, James Watson and Francis Crick in 1953 suggested a molecular structure.
- They postulated a **double helix** of two nucleotide strands, each strand being linked to the other pair of organic bases, which are themselves joined by hydrogen bonds.

## B. Ribonucleic acid (RNA)

- **RNA** is a single-stranded polymer of nucleotides where the pentose sugar is always ribose and the organic bases are adenine, guanine, cytosine and uracil. There are three types of RNA found in cells, all of which are involved in protein synthesis.

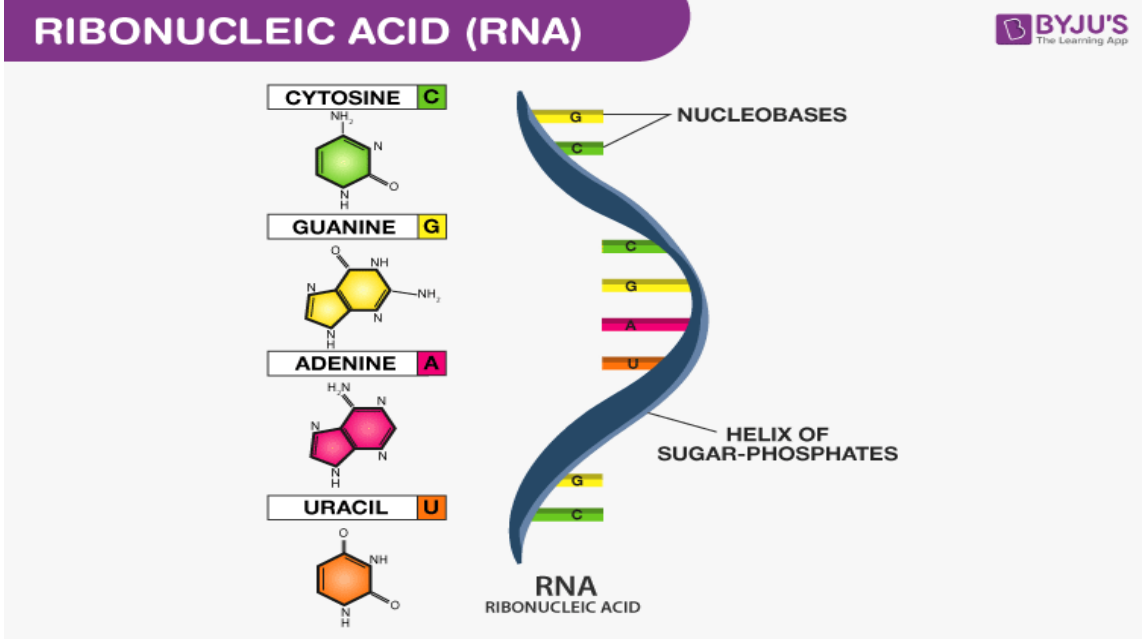
a) **Ribosomal RNA (rRNA) or" work bench"** is a large, complex molecule made up of both double and single helices.

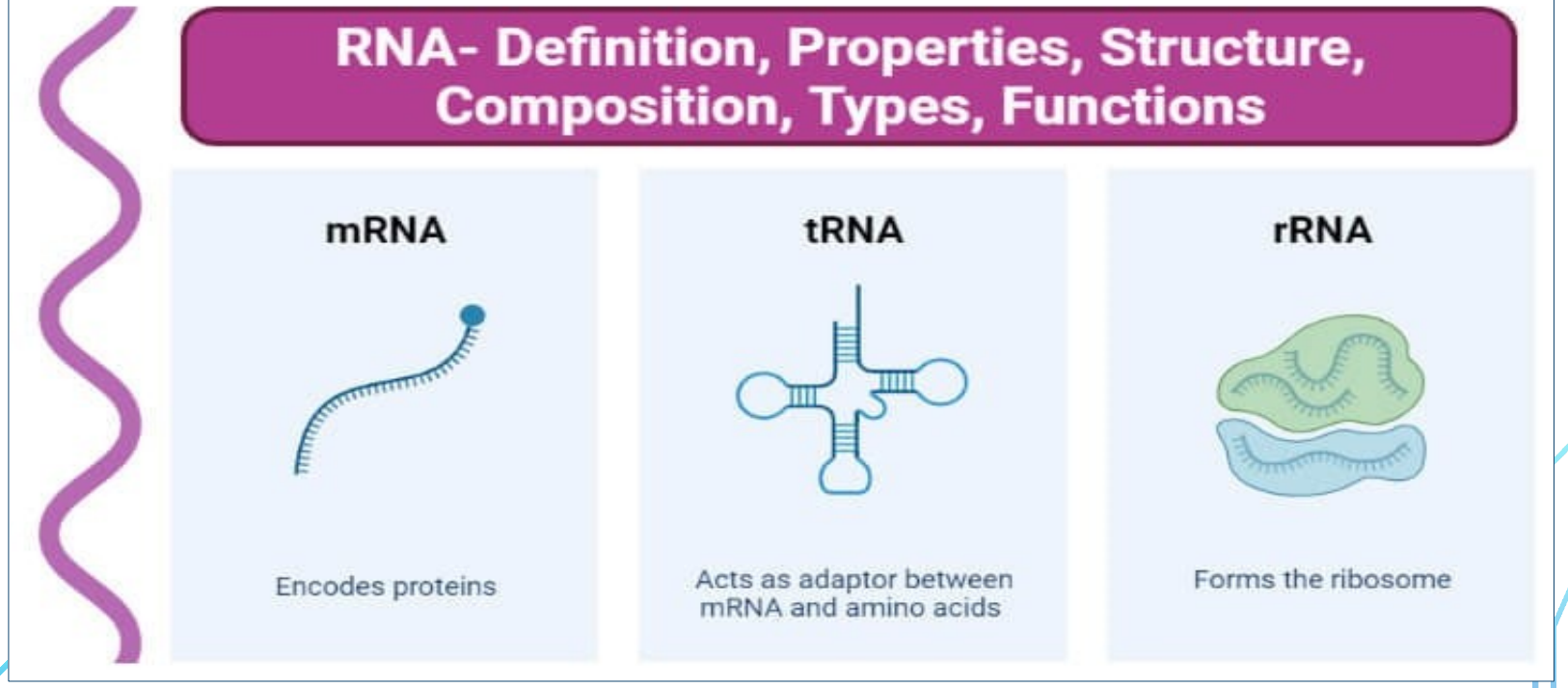
**b) Transfer RNA (tRNA) or "*Adapter*"** is a small molecule (about eight nucleotides) comprising a single strand.

- It makes up 10-15% of the cell's RNA and all types are fundamentally similar.
- It is at this point that an amino acid attaches itself. There are at least twenty types of tRNA, each one carrying a different amino acid. At an intermediate point along the chain is an important sequence of three bases, called the **anticodon**

**c) Messenger RNA (mRNA**)" or ***blue print***" is a long single-stranded molecule, of up to thousands of nucleotides, which is formed into a helix.

- Manufactured in the nucleus, it is a mirror copy of part of one strand of the DNA helix.
- There is hence an immense variety or types. It enters the cytoplasm where it associates with the ribosome and acts as a **template** for protein synthesis.
- It makes up less than 5% of the total cellular RNA. It is easily and quickly broken down, sometimes existing for only a matter of minutes.


RIBONUCLEIC ACID (RNA)
BYJU'S
The Learning App
CYTOSINE C
GUANINE G
ADENINE A
URACIL U
NUCLEOBASES
HELIX OF
SUGAR-PHOSPHATES
RNA
RIBONUCLEIC ACID


RNA- Definition, Properties, Structure, Composition, Types, Functions
mRNA
Encodes proteins
tRNA
Acts as adaptor between mRNA and amino acids
rRNA
Forms the ribosome

# Comparison between RNA and DNA

| RNA | DNA |
|---|---|
| Pentose sugar is ribose | Pentose sugar is deoxyribose |
| Single polynucleotide chain/strand | Double poynucleotide chain/strand |
| Smaller molecular mass | Large molecular mass |
| Organic bases present are adenine(A), guanine(G), cytosine(C) and uracil(U) | Organic base present are Adenine(A), guanine(G), cytocine(C) and thymine(T) |
| Ratio of **A** and **U** to **C** and **G** varies | Ratio of A and T to C and G is one |
| Manufactured in the nucleus but found throughout the cell | Found almost entirely in the nucleus |
| Amount varies from cell to cell (and within a cell according to metabolic activity) | Amount is constant for all cells of a species (except gametes and spores) |
| Chemically less stable | Chemically very stable |
| May be temporary-existing for short periods only | Permanent |
| Three basic forms: Messenger, transfer and | Only one basic form, but with an almost infinite variety within that form |

## E) Vitamins

- Vitamins are organic compounds necessary in small amounts for proper growth.
- They are usually complex organic substances that are nevertheless capable of being absorbed directly into your bloodstream from the gut.
- If any particular vitamin is lacking from your diet in the long term it will result in a **deficiency disease**.
- The major groups of vitamins are listed in the table below.

| Vitamins | Foods rich in vitamins | Deficiency diseases |
|---|---|---|
| **A (Retinol)** | Green pepper, carrots, leafy vegetables | Night blindness, poor growth, xeropthalmia (dryness of cornea of the eye) |
| **B1 (Thiamin)** | Whole cereals, sprouted beans, milk, liver | Loss of appetite, disease of muscles, nerve and heart called **beri-beri** |
| **B3 (Niacin)** | Milk, yeast, meat, fresh vegetables | Pellagra, which leads to mental disorder, memory loss and depression |
| **B2 (Riboflavin)** | Meat, milk, green vegetables, liver, peas | Slow growth, eye disease and sour mouth, inflammation of tongue |
| **C (Ascorbic acid)** | Vegetables, green peppers, lemons, oranges | **Scurvy-** pains in muscles and joints, bleeding gums, slow healing |
| **D (Calciferol)** | Fish liver oil, eggs, sun shine skin | **Rickets** – distorted legs in children, softening of bones in adults |
| **E (Tocopherol)** | Cereal oils, milk, | Sterility in animals such as |

## 2.2. Inorganic Bases of Life (Water and Minerals)

### 1. Water

- Of the smaller molecules, water is the most abundant, typically making up between 60-95% of the fresh mass of living organism. Without water, life could not exist on this planet. It is important for two reasons.

  i. it is a vital chemical constituent of living cells, &

  ii. it provides an environment for those organisms that live in water.

- The interesting chemical & physical properties of water are due to its **small size**, its **polarity** & to **hydrogen bonding** between its molecules.

# *The significance of the physical*

| Properties of water | Significance in living things |
|---|---|
| **1. Water is Liquid at room temperature** | Liquid medium for living things & for the chemistry of life |
| **2. It has very high latent heat (much heat energy is needed to raise the temperature of water)** | Aquatic environments are slow to change temperature<br>Large organisms have a stable temperature in the face of fluctuating temperatures. |
| **3. Very high latent heat of vaporization (evaporation of water needs great deal of heat)** | Evaporation of water in sweat or in transpiration causes marked cooling<br>Much heat is lost by evaporation of small quantity of water |
| **4. Very high latent heat of fusion (much heat must be removed before freezing** | Contents of cells & aquatic environments are slow to freeze in cold weather. |

| | |
|---|---|
| **5. Maximum density at 4°C (ice is less dense than water, even very cold water)** | Ice forms at the surface of water, insulating the water below<br>When surface water does freeze aquatic life can survive below the ice |
| **6. Very high surface tension (water molecules at surface with air orientate so that hydrogen bonds face inward)** | Water forms droplets on surfaces & run off<br>Certain small animals exploit surface tension to land on & move over the surface of water |
| **7. Very low viscosity (water molecules slide over each other very easily** | Water flows readily through narrow capillaries |
| **8. High surface cohesion** | With low viscosity, capillarity becomes |

| | |
|---|---|
| **9. High surface tension (water column does not break or pull apart under tension** | Water can be lifted by forces applied at the top, e.g. movement of water up the xylem of tall trees |
| **10. Universal solvent (water dissolves more substances than any other common liquid)** | Medium for chemical reactions of life<br>Acts as transport medium, as in blood, lymphatic & excretory systems, the alimentary canal & xylem & phloem. |
| **11. High transmission of visible light (water is colorless)** | Plants can photosynthesize at depth in water<br>Light may penetrate deeply into living tissue |
| **12. Water as reagent** | Water acts are as essential metabolite, i.e. |

# Some biologically important functions of water

## In plants

- Osmosis & turgidity
- Reagent in photosynthesis
- Transpiration
- Translocation of inorganic ions & organic molecules
- Germination of seeds
- Dispersal of seeds

## In animals:

- Transport in blood vascular, lymphatic, excretory systems
- Osmoregulation
- Cooling by evaporation
- Lubrication, as in joints
- Support: hydrostatic skeleton of e.g. annelid worms
- Protection, e.g. lachrymal fluid (tear), mucus

## Mineral and Salts

- Minerals form important components of organic and inorganic molecules.
- The minerals, which are essential for growth and development, form **essential elements** required in large quantity.
- Some are called **major essential elements** like calcium, phosphorus, nitrogen, sodium, chlorine, magnesium and sulfur; some are required in traces and form **trace elements**.
- These are iron, manganese, molybdenum, copper, cobalt, zinc, fluorine, iodine and selenium.

## Calcium(Ca)

- strength and rigidity to bones and teeth
- used as fertilizer in bone dust
- exoskeleton of invertebrates ($CaCO_3$)
- shells of mollusks
- formation of middle lamella in plant cell walls

## Phosphorus (P)

- synthesis of nucleic acids, ATP and proteins
- constituent of bones and teeth enamel
- as phospholipids in membranes
- rigidity to bones and teeth.

## Magnesium (Mg)

- structure of chlorophyll
- Co-factor of enzymes like ATPase

## Sulphur (S)

- synthesis of proteins e.g. Keratin
- synthesis of organic compounds e.g. Co-enzyme A.

## Nitrogen (N)

- synthesis of proteins, nucleic acids and organic compounds
- synthesis of chlorophyll

## Sodium (Na)

- maintenance of electric potential across the membrane
- conduction of nerve impulses
- balance of anion/cation and osmotic balance of cellular fluids
- Co-factor in photosynthesis and respiration

## Potasium (K)

- Similar function as sodium; generally, there is a Na+/K+ pump i.e. exchange of Na+

## 2. Trace elements

| | |
|---|---|
| **Iron** | - oxygen carrier as a haem group in hemoglobin and myoglobin (respiratory pigments), electron carriers in cytochromes (respiration, photosynthesis)<br>- synthesis of chlorophyll, its deficiency leads to anemia. |
| **Manganese** | - for oxidation of fatty acids, for enzymes in respiration and photosynthesis, (mitochondria are rich in manganese), for bone development |
| **Molybdenum** | - fixation of nitrogen catalyzed by nitrogenase |
| **Copper** | - electron carrier in cytochrome oxidase (respiratory system and photosynthesis), production of melanin |

# UNIT 3

## THE CELLULAR BASIS OF LIFE

- A cell is the basic **structural and functional** unit of organisms.
- Cell, though very small, is extremely complex.
- It acts as an autonomous unit i.e. Able to carry out its activities independently:
- It can carry out all biological processes
- It can oxidize the food molecules to produce energy & store this energy rich molecule by using nutrient molecules, it can build new structures & can replace worn out cells.
- It can respire and exchange gases with its surroundings
- It can replace its own self

# Cell Theory

**Schleiden & Schwann formulated the Cell Theory**




- In the mid-16th Leeuwenhoek was the first person to see micro-organisms by his microscope. He called the tiny organisms that he observed "animalcules," meaning little animals.
- In **1665 Robert hook** was the first to observe the tiny box-like structure in the tree cork & called it 'cells'.
- In **1838 a formal** hypothesis that cells make up the part of living thing was advanced by

**The cell theory, in its modern form, includes the following three principles:**

1. All organisms are composed of one or more cells within which the life processes of metabolism and heredity occur.
2. Cells are the smallest living things, the basic units of organizations of all organisms.
3. Cells arise from a previously existing cell.

In nature we have two categories of cells:

***Prokaryotic and Eukaryotic.***

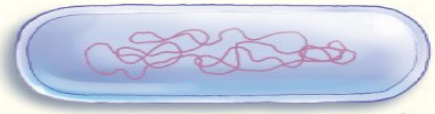
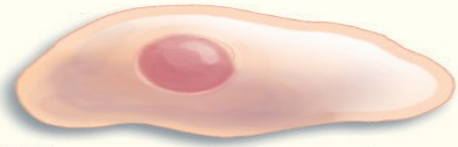
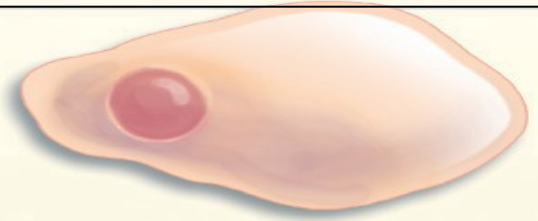
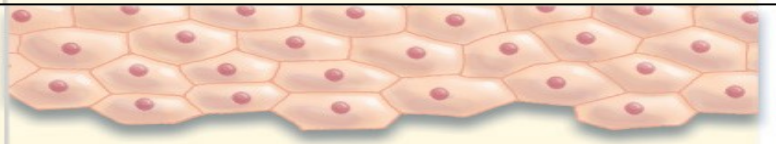
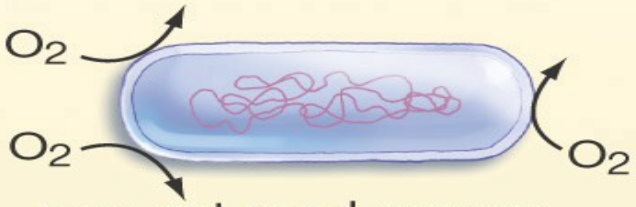
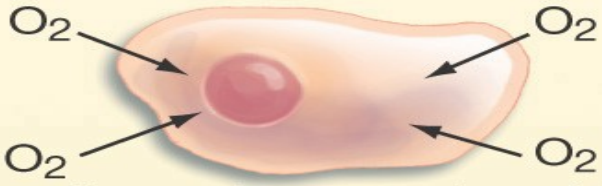
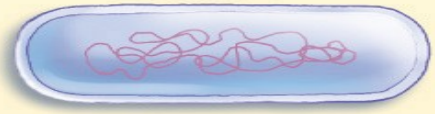
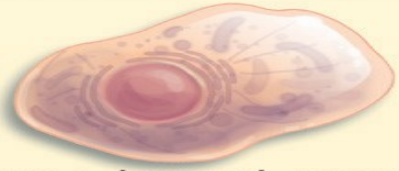
## Prokaryotic cell

- The word **prokaryote** comes from two Greek words, **pro** meaning before (primitive) & **karyo** means nucleus.
- Therefore, prokaryotic cells are cells lacking a membrane-bound nucleus or membrane-bound organelles, e.g. bacteria, blue-green algae, spirochetes, etc. Prokaryotic cells were probably the first form of life on earth.

## Eukaryotic cell

- **Eukaryotic cells** (Eu = good, true or well, karyo = nucleus) are cells characterized by membrane - bound nucleus and other organelles, e.g. in plants from algae (some of them) to angiosperms and in animals from protozoa to mammals.
- The cells of other multicultural organisms (like plants, animals and fungi) have a membrane

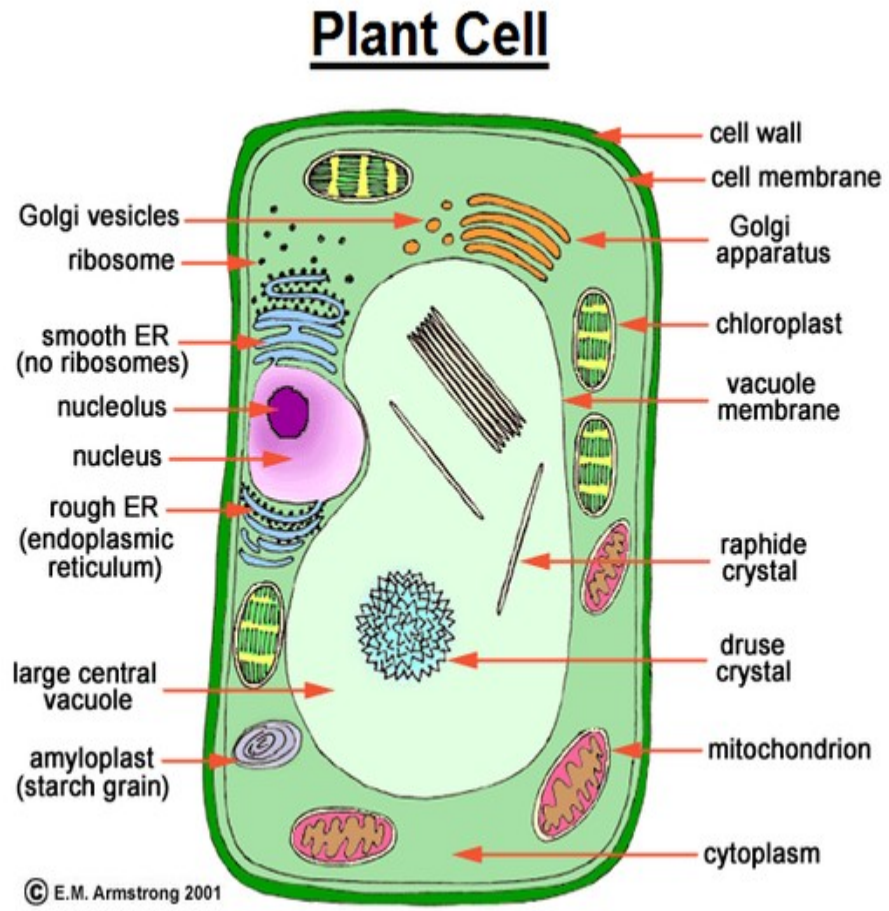
# Eukaryotes and Prokaryotes

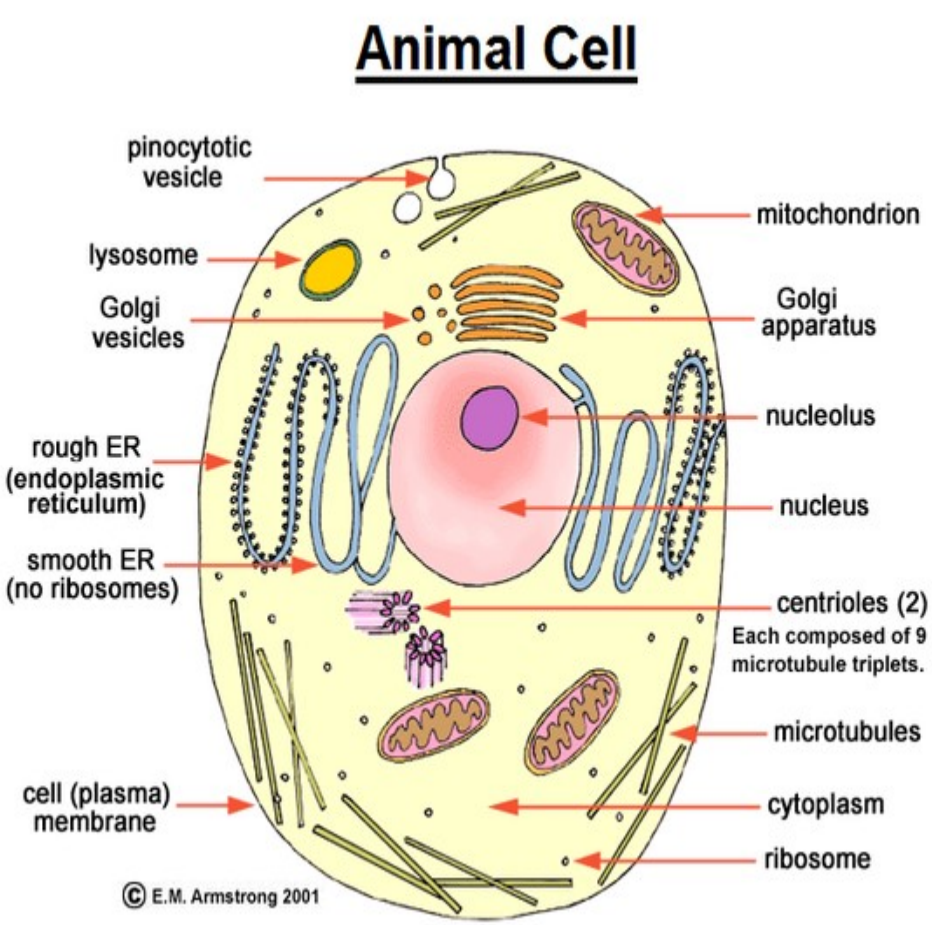
| | Prokaryotes | Eukaryotes |
|---|---|---|
| **DNA** |  in " nucleoid" region |  within membrane-bound nucleus |
| **Size** |  usually smaller |  usually larger |
| **Organization** |  usually single-celled |  often multicellular |
| **Metabolism** |   may not need oxygen |   usually need oxygen to exist |
| **Organelles** |  no membrane-bound organelles |  membrane-bound organelles |

**Features held in common by prokaryotic and eukaryotic cells:**

- Plasma membrane of similar construction.
- Genetic information encoded in DNA using identical genetic code.
- Similar mechanisms for transcription and translation of genetic information, including similar ribosomes.
- Shared metabolic pathways (e.g., glycolysis and TCA cycle)
- Similar apparatus for conservation of chemical energy as ATP (located in the plasma membrane of prokaryotes and the mitochondrial membrane of eukaryotes).
- Similar mechanism of photosynthesis (between cyanobacteria and green plants).
- Similar mechanism for synthesizing and inserting membrane proteins.

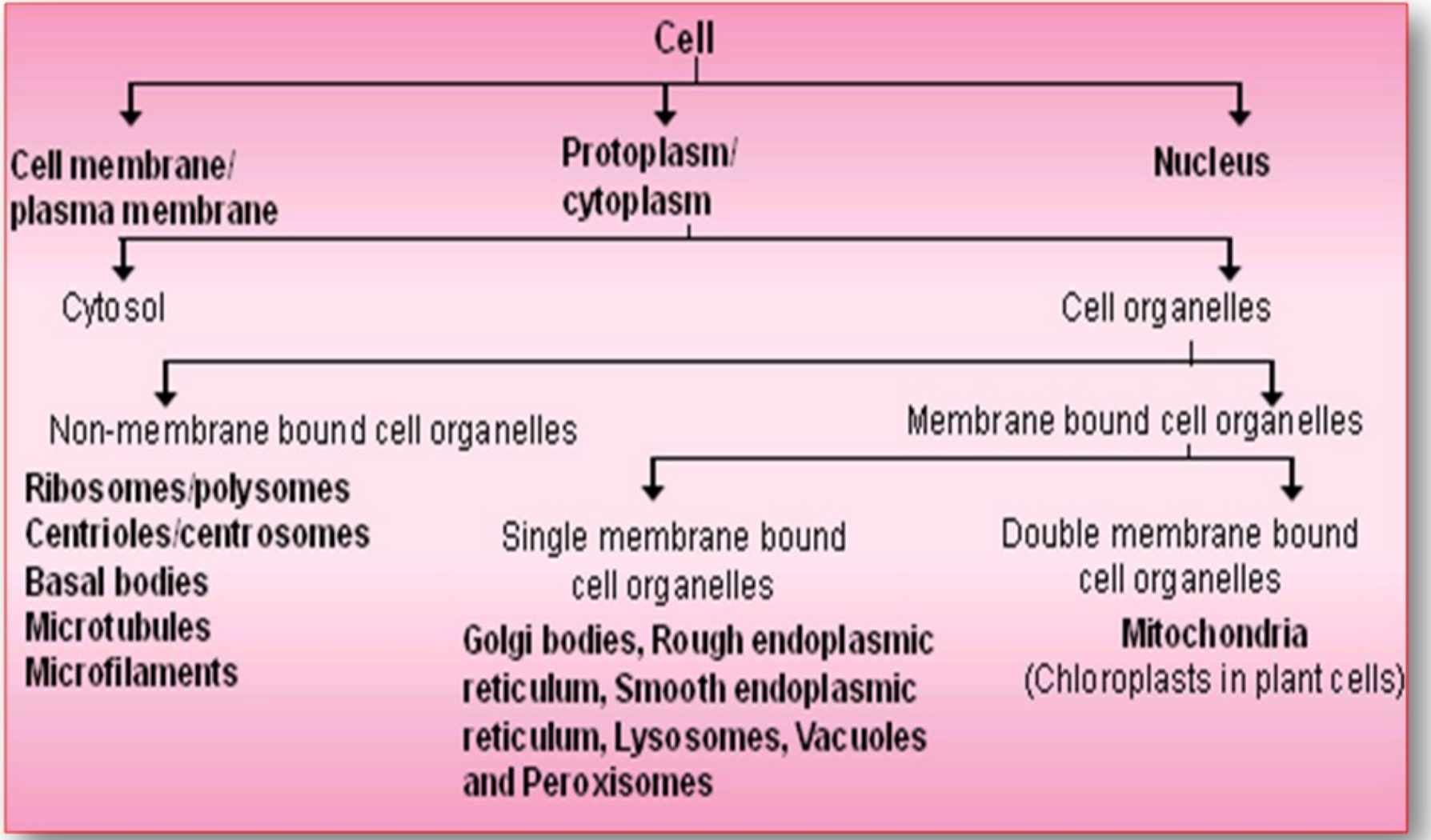
# Other categories of cell



A typical **eukaryotic** cell has 4 major parts:

**1. Cell wall 2. Nucleus 3. Cytoplasm 4.**



## 1.Cell Wall

- Cell wall is the outer thick cellulose wall around the cell membrane of plant, algae, bacteria and fungi cells.
- It contains pores called **plasmodesmata** that facilitate free passage of materials in and out of the cell.
- It gives strength & rigidity to the cell & also acts as protective structure.
- For example, the cell walls of most bacteria are made up of a polysaccharide called

## 2. Nucleus

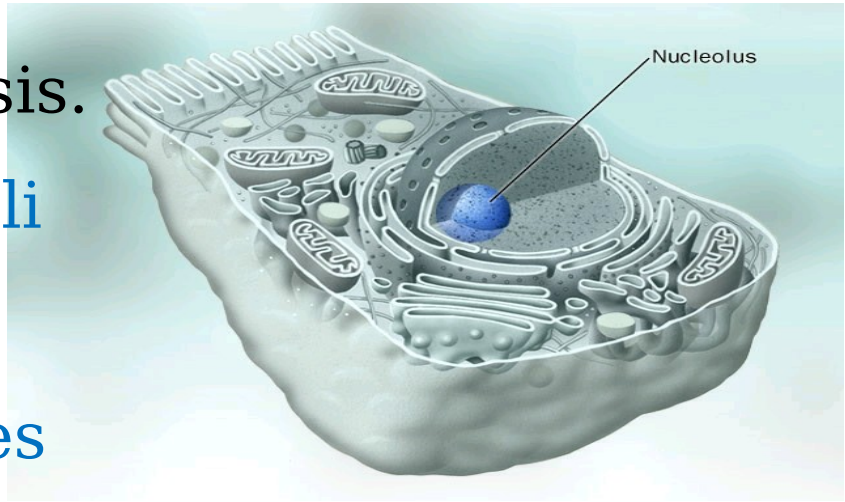
- The nucleus is the largest organelle in the eukaryotic cell.
- This is a cell with membrane bounded or clearly defined nucleus.
- The nucleus includes the nuclear envelope (membrane) the nucleoplasm, and nucleoli.

❖ ***Nuclear envelope*** is a double membrane with perforated nuclear pores approximately 9 nm in diameter.

❖ The ***nucleoplasm*** includes the chromosomes

## Nucleolus

- Are an assembly site for ribosome sub units or they are centers of ribosome synthesis.
- Cell may have 1 to 3 nucleoli inside nucleus.
- Disappears when cell divides
- Makes ribosomes that make proteins



## 3. Cytoplasm

- Refers to clear watery liquid or jelly-like substance & organelles contained between the cell membrane & the nuclear membrane.
- May be divided into two parts, i.e. cytoplasmic matrix/cytosol & the cytoplasmic organelles.

### A. Cytoplasmic matrix/cytosol

- Is a translucent, homogenous liquid that fills the space b/n cell membrane & the nucleus.
- It consists of various inorganic molecules such as water; salts of sodium, potassium & others.

- Organic compounds such as carbohydrates, lipids, proteins, nucleotides ATP, a variety of enzymes, etc. are also found in it.

## B. Cytoplasmic organelles

- Cytoplasm contains various organelles with specific functions.

### Cell organelles on the basis of membrane covering

1. **Membranous organelles**: E.g. Endoplasmic reticulum (Rough and Smooth), Golgi bodies, mitochondria, chloroplasts, nucleus, lysosomes, peroxisomes and vacuoles.
2. **Non-membranous organelles**: E.g., ribosomes (70S and 80S), centrosomes, cilia and flagella, microtubules, basal bodies and microfilaments

# i. Vacuoles

- They are sacs bounded by a single membrane called **tonoplast.**
- Even though vacuoles are present in protozoans they have their greatest development in plant cells.
- Plant cells, have a large vacuole which may occupy 30% to 90% of cell volume.
- Vacuoles c acuoles play an important r s water from the cell.

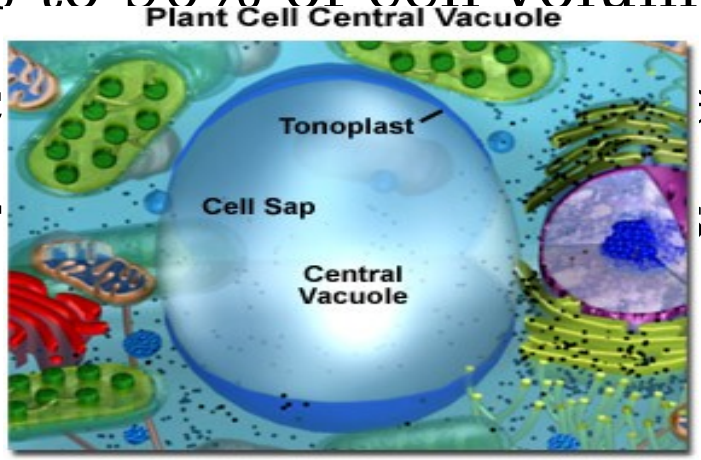



Figure 1

## ii. Endoplasmic reticulum(ER)

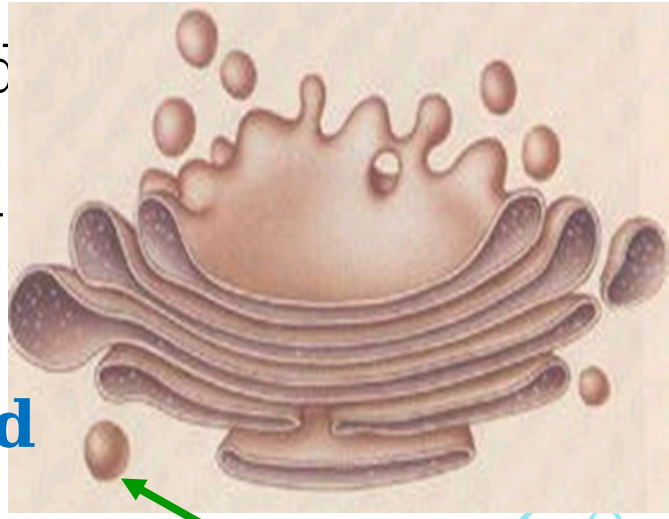
- **It** is a network of hollow tubular or flattened sacs extending from the outer membrane of the nuclear membrane of the nuclear envelope. There are two kinds of ER, i.e.
- **Rough ER:** contains ribosomes attached to their membrane
- **Smooth ER:** contains no ribosomes.

✓ **Functions of ER are:**

- Synthesizing proteins, especially enzymes by rough ER and lipids & steroids by smooth ER.
- Its coils & folds increase surface or location for

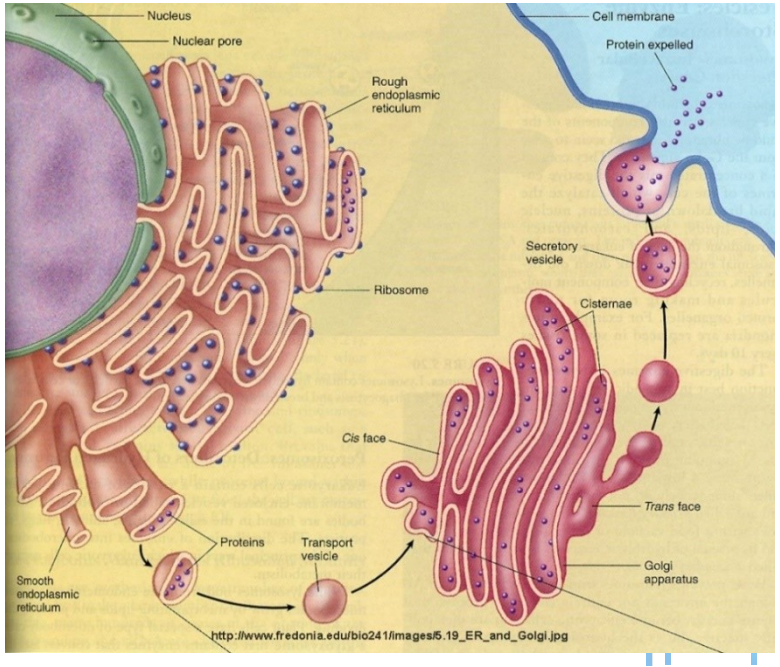
## iii. Golgi Complex /Golgi bodies

- Contains sets of flattened, curved, membrane-enclosed sacs, or cisternae, stacked in layers
- Number of stacks vary in cells
- Have a shipping side & a receiving side
- Receive & **modify proteins** mad
- **Transport vesicles** with modified proteins pinch off the ends
  - ✓ **The majority of newly formed molecules budding off from the smooth ER**



**Transport vesicle**

- ✓ Processing the raw material into finished products
- ✓ **Sorting and directing finished** product to their final destination
- ✓ Responsible for the **detoxification and inactivation of drugs**
- ➢ Responsible for labeling, sorting and packaging chemicals (proteins) and secreting (releasing) them from the cell.



## iv. Ribosomes

- **They** are granules which consist of two sub-units (RNA and protein)
- Ribosomes are synthesized by the **nucleoli**.
- Ribosomes are not surrounded by membranes.
- ribosomes are involved in protein synthesis under the direction of the DNA.

❖Ribosomes are found in three places of eukaryotic cells.

- ✓ Freely suspending in the cytoplasm.
- ✓ Attached to the surface of the ER.
- ✓ In the chloroplast’s and the matrix of mitochondria

## v. Lysosomes

**They** are membrane bounded sacs found in animal cells.

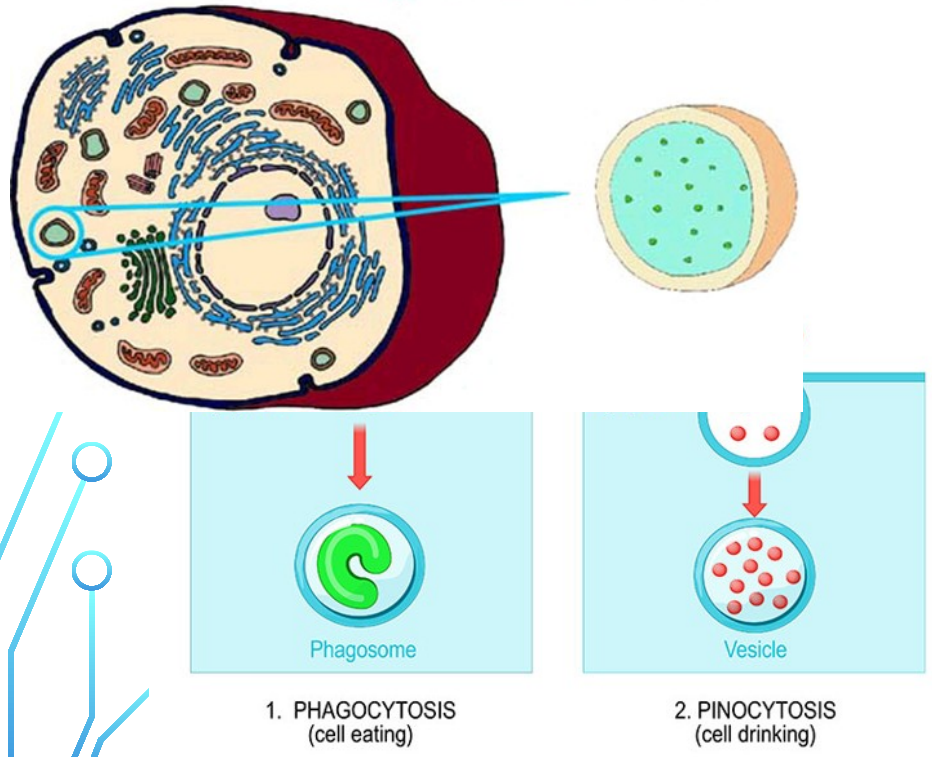
- They are commonly absent in plant cells.
- They contain different powerful hydrolytic enzymes.
- They breaks down food particles, invading objects, or worn out cell parts.
- They are also called **suicidal bags** of the cells

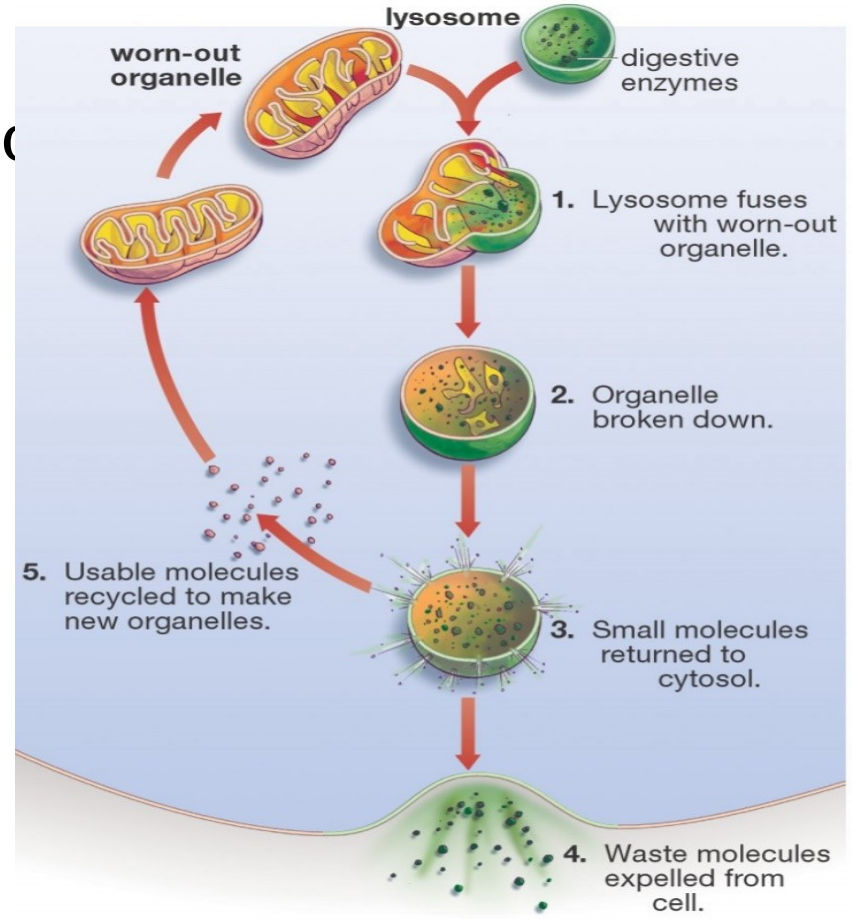
Programmed for cell death (**lyse & release enzymes to break down & recycle cell parts or components**

## *Ways of lysosome engulfing particles*

1. **Pinocytosis**: fluid is internalized by endocytosis
2. **Phagocytosis**: large

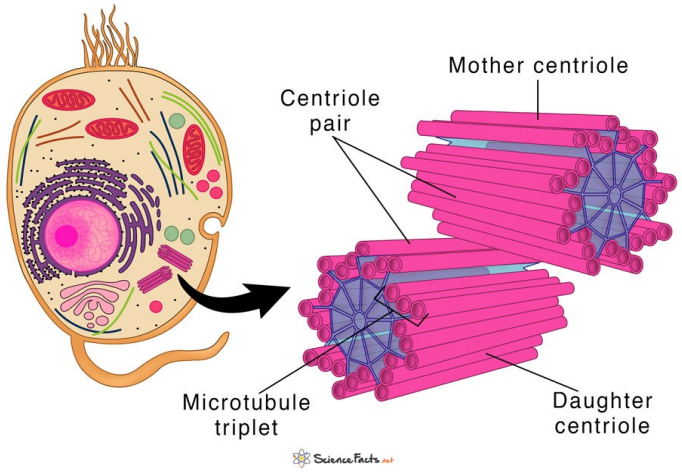
Lysosome



# vi. Centrioles

- Are paired barrel-shaped organelles located in the cytoplasm of animal cells near the nuclear envelope.
- Centrioles play a role in organizing microtubules that serve as the cell's skeletal system.
- They help determine tl cleus and other organelles wi



## vi. Microbodies

- A microbody (or cytosome) is a type of organelle that is found in the cells of plants, protozoa, and animals.
- Organelles in the micro body family include peroxisomes, glyoxysomes, glycosomes and hydrogenosomes.

### a. Peroxisomes

- Peroxisome is membrane-enclosed sacs containing oxidative enzymes and catalase that **detoxify various wastes.**
- It is found in both plant and animal cells.

- Eg. peroxismes of potato cells are rich sources of the enzyme Catalase.
- This enzyme converts hydrogen peroxide ($H_2O_2$) which is toxic and a common product of cellular respiration, into water and oxygen.

**b. Glyoxsomes:-** are found only in plant cells.

- They are more abundant in the cells of young plants and serve as sites where stored lipids are converted into carbohydrates.

**c. glycosome** is a membrane-enclosed organelle that contains the glycolytic enzymes.

- The main function that the glycosome serves is of the glycolytic pathway that is done inside its membrane.

**d. hydrogenosome,** membrane-bound organelle found in the cytoplasm of eukaryotic cells.

- It releases molecular hydrogen (H2) as a by-product of energy generation under anaerobic (oxygen-deficient) conditions.

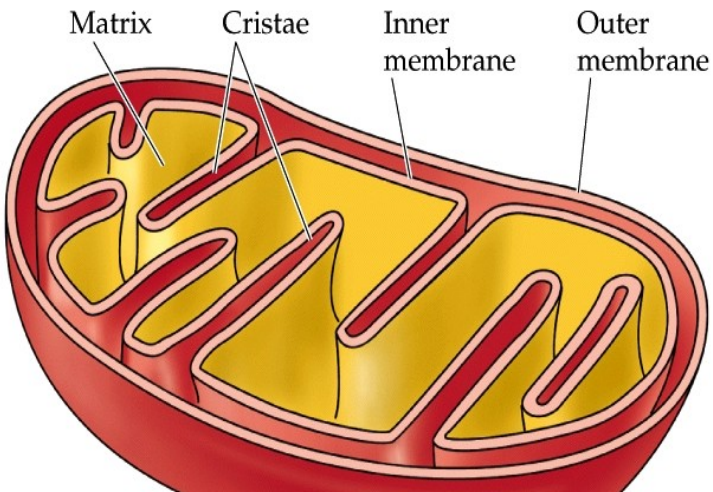
## vii. Mitochondria

- It is called **power house** because a large amount of energy is harvested from food in the form of ATP inside the mitochondria.

✓ Mitochondria are rod or oval shaped

✓ Each is enclosed by a **double** membrane

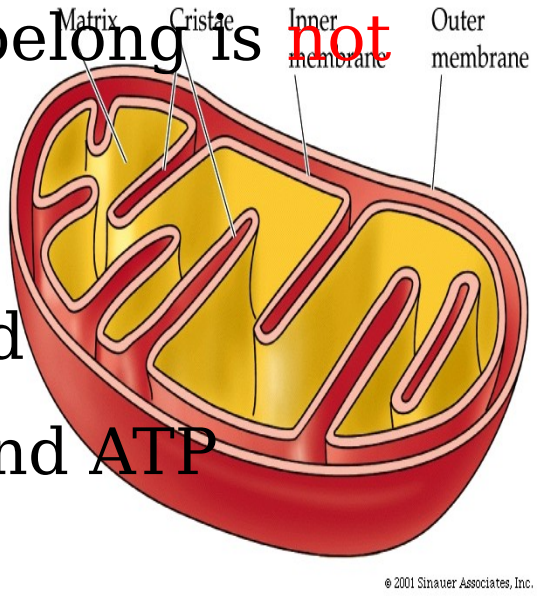
❖ Outer smooth, an inner folded called **cristae**, which p cavity filled with a jelly-lik



- Mitochondria are **unusual organelles** in two ways:
  - 1. have their **own unique DNA** called mitochondrial DNA
  - 2. have the ability to **replicate themselves** even when the cell to which they belong is not undergoing cell division.

Makes Energy for Cell, releases energy called **ATP**

- **Site of Cellular Respiration**
  - It takes in oxygen and glucose and releases Carbon dioxide , water and ATP

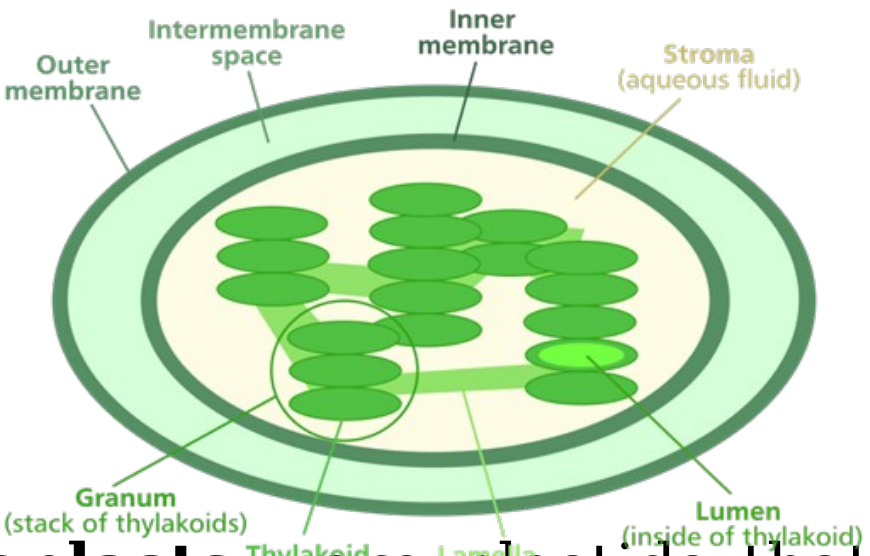


## viii. Plastids

- Are spherical bodies bounded by a double membrane.
- They are found in all plants and plant-like protists.
- There are **3** major types of plastids performing specific functions.

**a). Chloroplasts:-** are the most familiar of the plastids.

- ✓ They are sites for photosynthesis.
- ✓ They contain the green pigment chlorophyll




**b). Chromoplasts:-** are plastids that contain red, orange and yellow pigments which are derived from carotenoids.

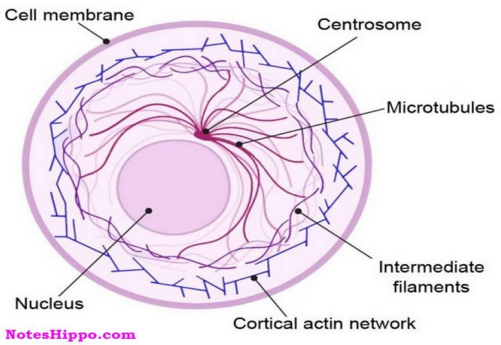
- They are common in fruits and flowers. For example, they give color to petals which help flowers to attract insects (pollinators).

**c). Leucoplasts:-**are colorless plastids which serve as a storage depots for starch and fats.

**ix. Cytoskeleton-**The cytoskeleton is a complex protein network that act as the “bone and muscle” of the cell

- It Provides intracellular scaffoldings supports
- it organizes cellular components arrangements to control their movements
- gives distinct shape, size to the cell

This network has at least four distinct elements: microtubules, micro ıtermediate filaments and microtubu



**a. Microfilaments:** are long, narrow and helically intertwined polymers made up of many molecules of protein called actin.

- ***Its function:***
  - Change cell shape, including cell length as in the contraction of muscle.
  - Take in part in cytoplasmic streaming (a flowing movement observed in lower organisms).
  - Radiate as spindle fiber which is essential to a separate duplicated chromosomes during nuclear division.

**b. Microtubules:** are long structures with a wider diameter.

- They are formed from a chain of protein molecules called **tubulin.**

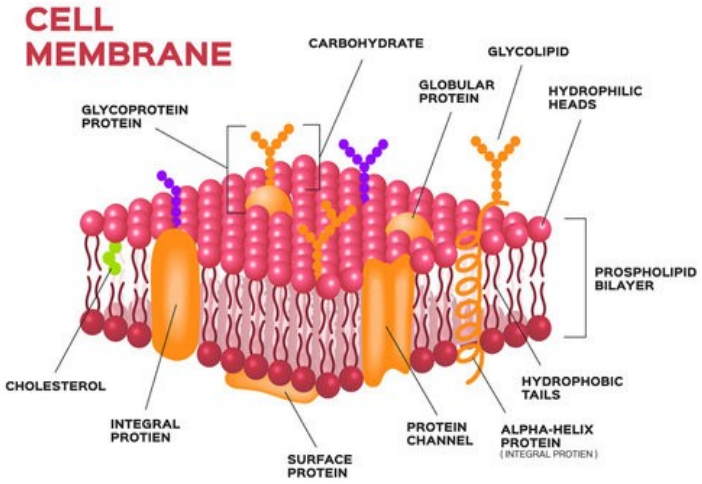
- Microtubules play an important role in the structure and movement of cilia and flagella.

- Such as in paramecium and Euglena respectively.

**c. Intermediate filaments:** are made up of fibrous proteins organized into tough, rope like assemblages that stabilizes a cell's structure and maintain its shape.

- Some intermediate filaments hold neighboring cells together.

# 4. Plasma/cell membrane




- semipermeable membrane, extremely thin layer of lipids and proteins forming outermost boundary of living cell and enclosing the intracellular fluid (ICF).
- Cell membrane separates the components of a cell from its **environment**-surrounds the cell.
- "**Gatekeeper**" of the cell-regulates the flow of materials into and out of cell-**selectively permeable**
- Cell membrane helps cells maintain

## Functions of cell membrane-

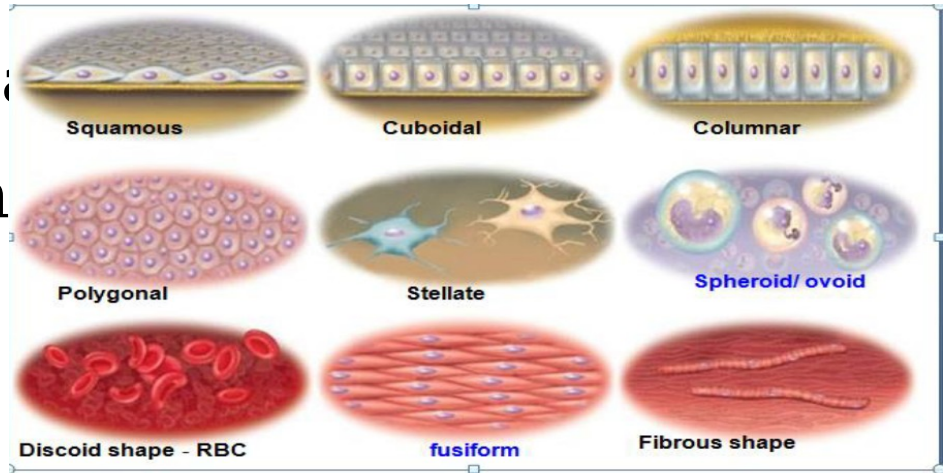
- ✓ Acts as semi permeable barrier –(selective permeable ).
- ✓ Protects cell from toxic substances
- ✓ Excretion of waste products
- ✓ Transport of nutrients

- Receives signals from the outside
  - Chemical signals
  - Electrical signals, Site for attachment to the neighboring cells

## Cellular diversity

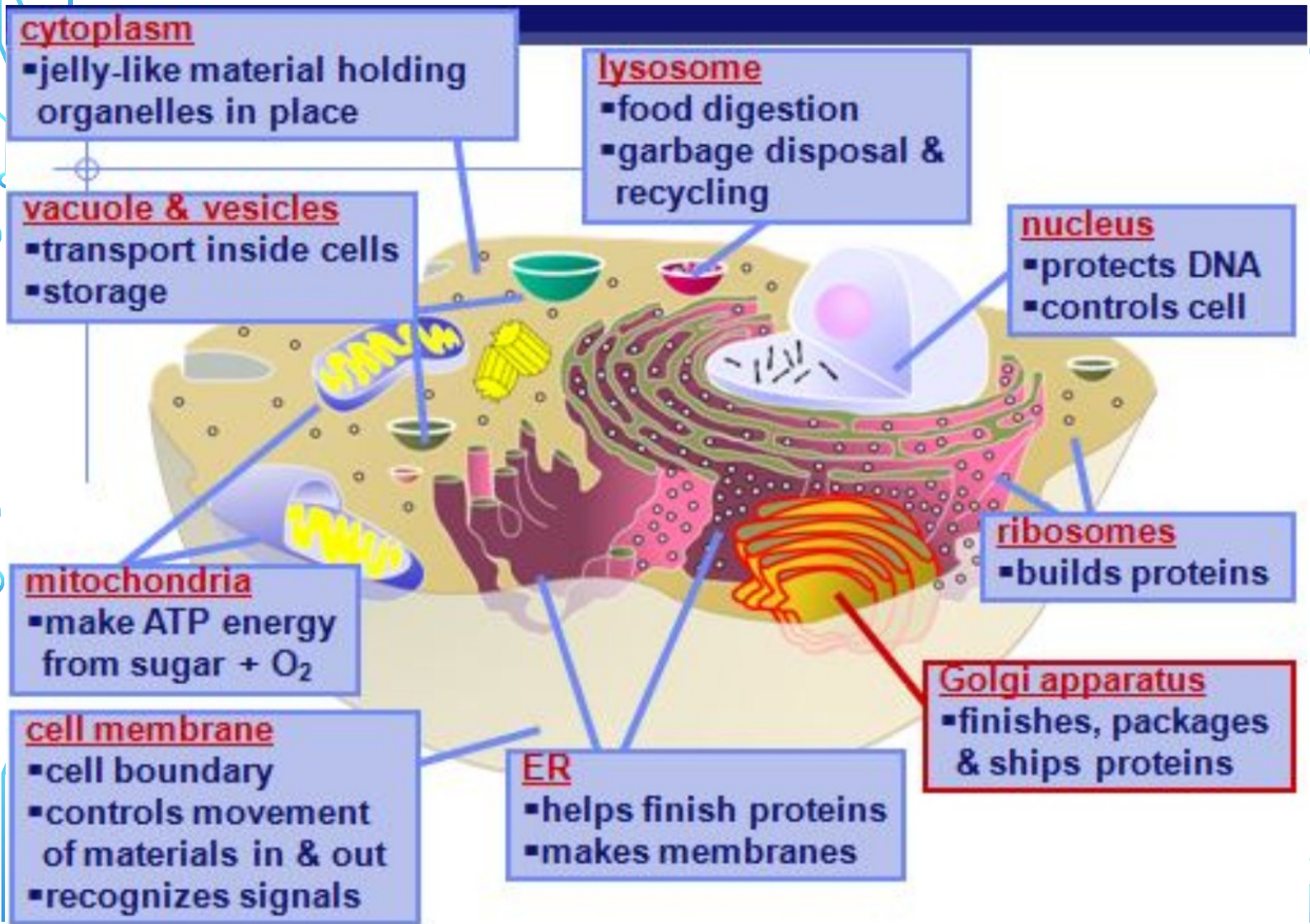
- Cells are found in different organisms, and are very diverse in their size, shape and their internal structure.
- Example, **egg** of **birds/reptiles** and a **neuron** cell of giraffe, is 2 meters in length

## Cell Shape

- Cells ha

appropriate function

# Summary


cytoplasm
▪jelly-like material holding organelles in place
lysosome
▪food digestion
▪garbage disposal & recycling
vacuole & vesicles
▪transport inside cells
▪storage
nucleus
▪protects DNA
▪controls cell
ribosomes
▪builds proteins
mitochondria
▪make ATP energy from sugar + $O_2$
Golgi apparatus
▪finishes, packages & ships proteins
cell membrane
▪cell boundary
▪controls movement of materials in & out
▪recognizes signals
ER
▪helps finish proteins
▪makes membranes

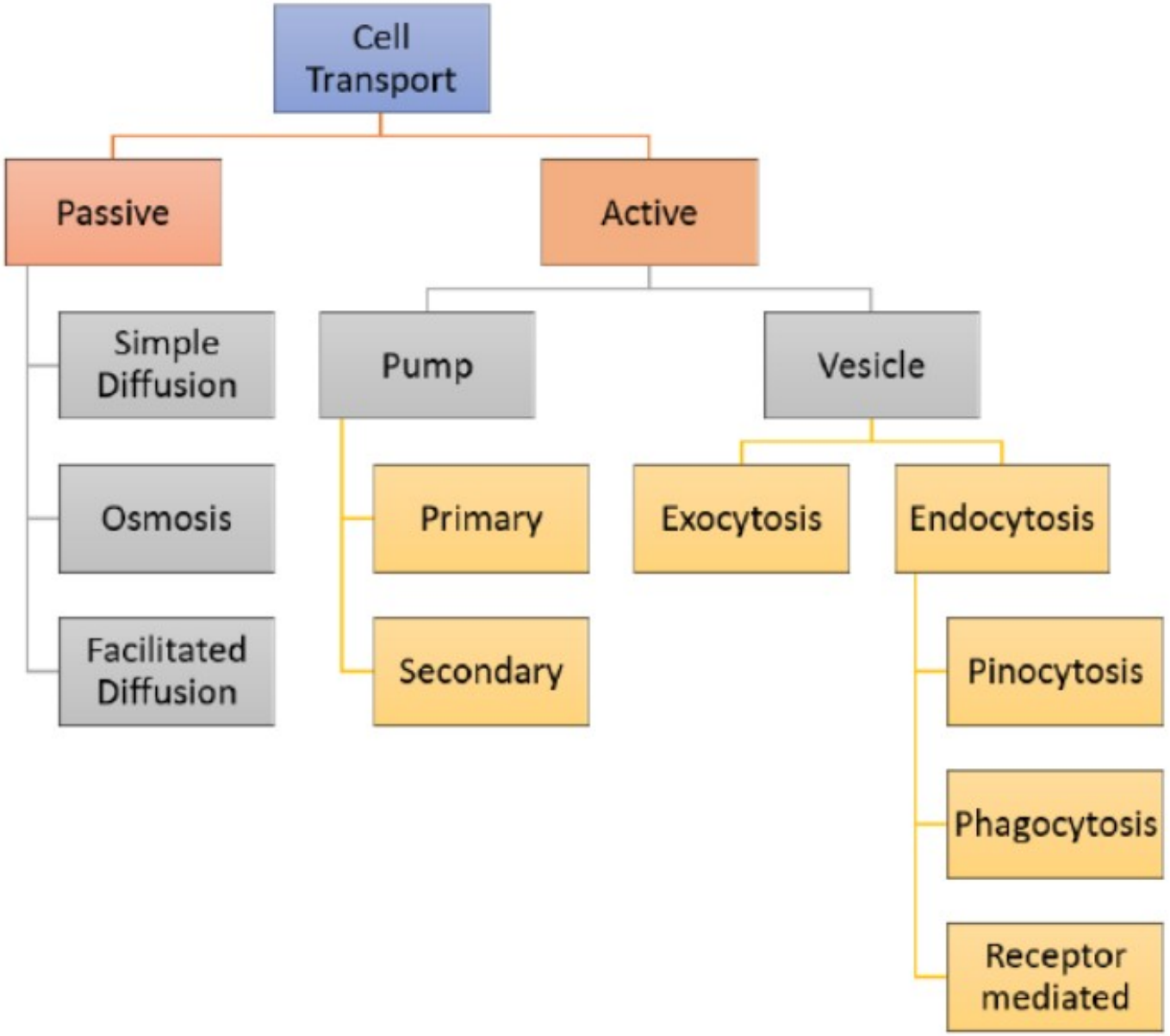
## Transport across the cell membranes

- The cell membrane acts as a barrier between the interior of the cell and its surrounding.
- Materials move into and out of the cell across this membrane.
- This characteristic of a membrane is called permeability.
- The plasma membrane is **selectively permeable**
- **Lipid-soluble substances and small ions** can passively diffuse through the plasma membrane down their **electro-chemical gradients**

- **Two forces** are involved in facilitating movement across the plasma membrane:

1. Forces that do not require the cell to expend energy for movement – **passive force**
2. Forces requiring energy (as ATP) to be expended to transport across the membrane - **active force**

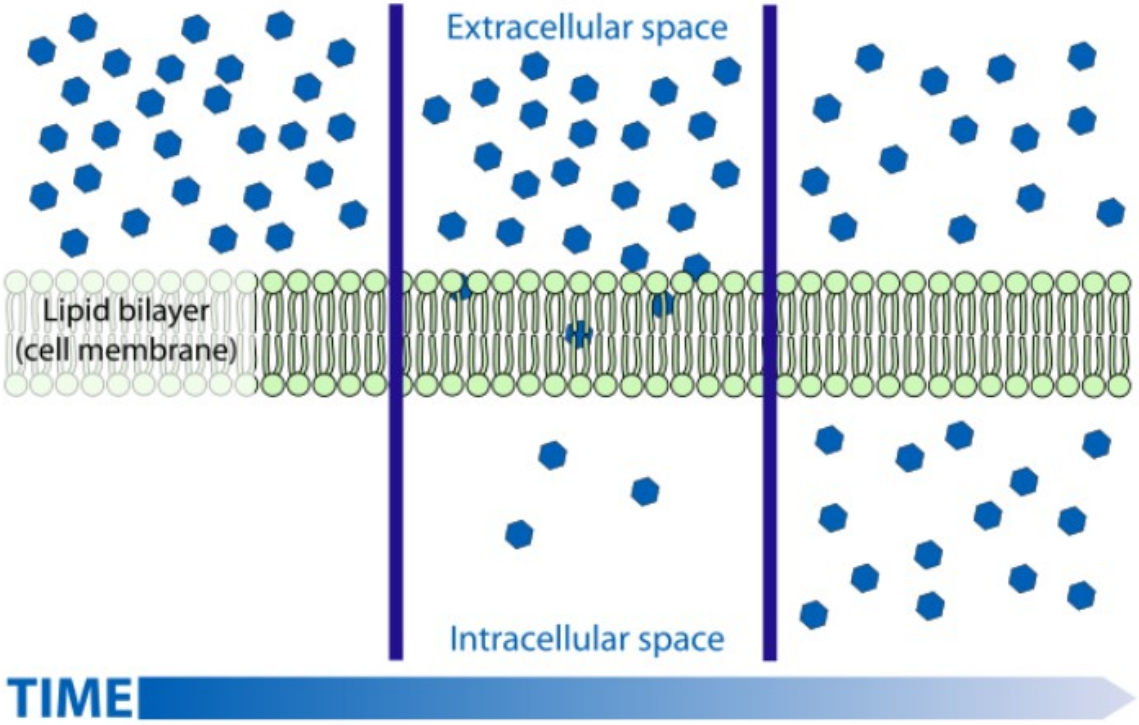
# Transport across the cell membranes



## 1. Diffusion

- is the **net movement** of molecules (or ions) from a region of their high concentration to a region of their lower concentration.
- The molecules move down a concentration gradient
- Molecules have kinetic energy, which makes them move about randomly.
- All molecules in liquid and gases are in continuous random motion in any direction as they have more room to move before colliding with another

- **Diffusion** is the movement of **small** particles across a **selectively permeable** membrane like the cell membrane until **equilibrium** is reached.
- These particles move from an area of **high concentration** to an area of **low concentration**.



## Factors affecting rate of diffusion

- Lipid solubility
- Molecular size & wt.
- Temperature
- Thickness of membrane
- Surface area
- Concentration gradient
- Pressure gradient
- Electrical gradient

Molecular

Membrane related

Gradients

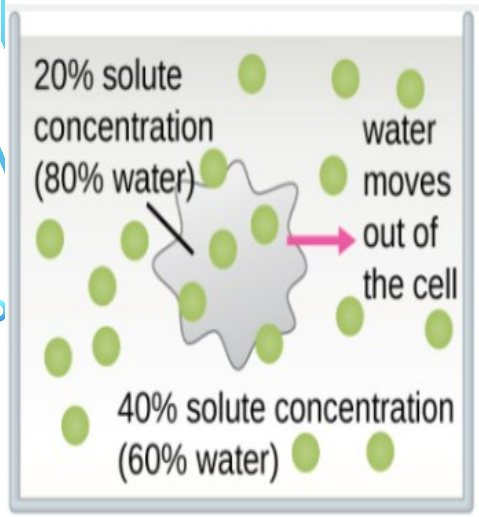
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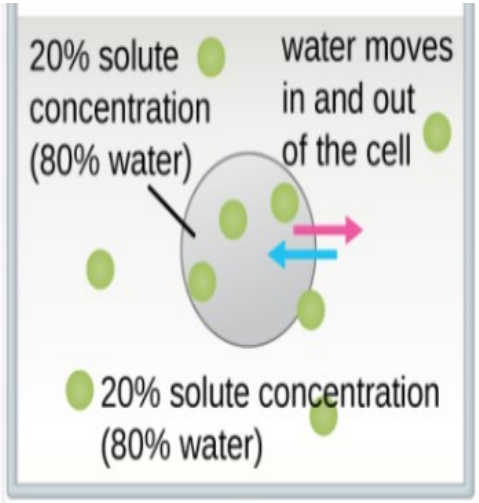
- ✓ They decrease the rate of diffusion; and
- ✓ if molecular weight is increased, rate of diffusion is decreased

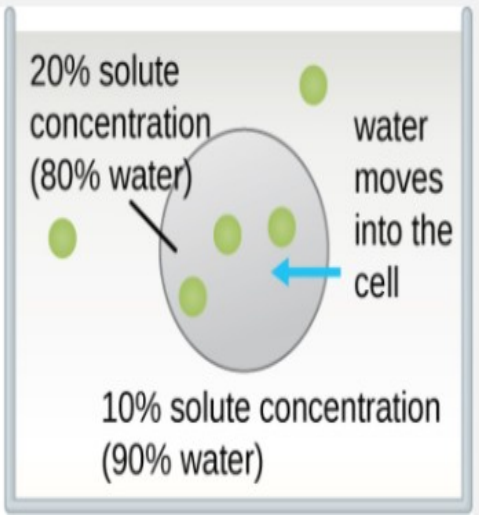
# Osmosis

- It is the net diffusion of water down its own concentration gradient.
- The driving force for diffusion of water is its concentration gradient from area of higher water concentration (low solute) to the area of lower water (high solute) concentration.
  - The classic example used to demonstrate osmosis and osmotic pressure is to immerse cells into sugar solutions of various concentrations.

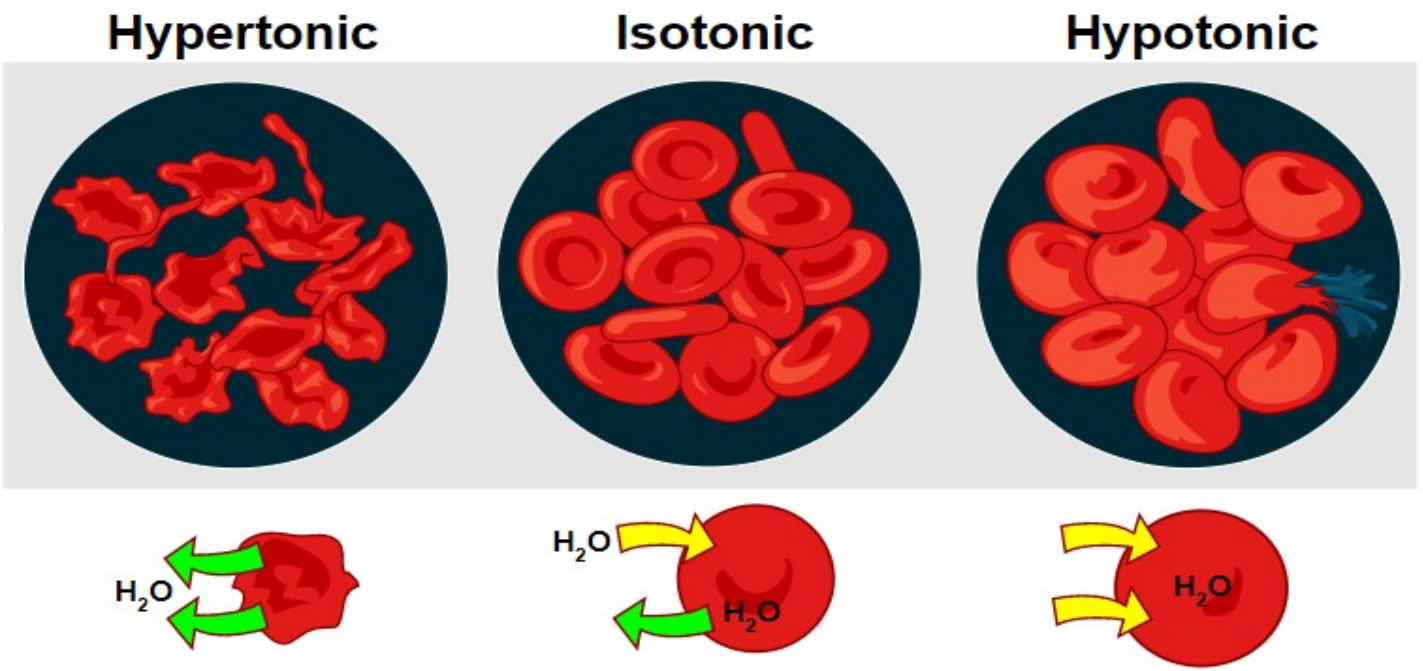
- **Hypotonic Solution:** The solution has a lower concentration of solutes and a higher concentration of water than inside the cell (Low solute; High water)
- **Hypertonic Solution:** The solution has a higher concentration of solutes and a lower concentration of water than inside the cell. (High solute; Low water) :
- **Isotonic Solution:** The concentration of solutes in the solution is equal to the concentration of solutes inside the cell.



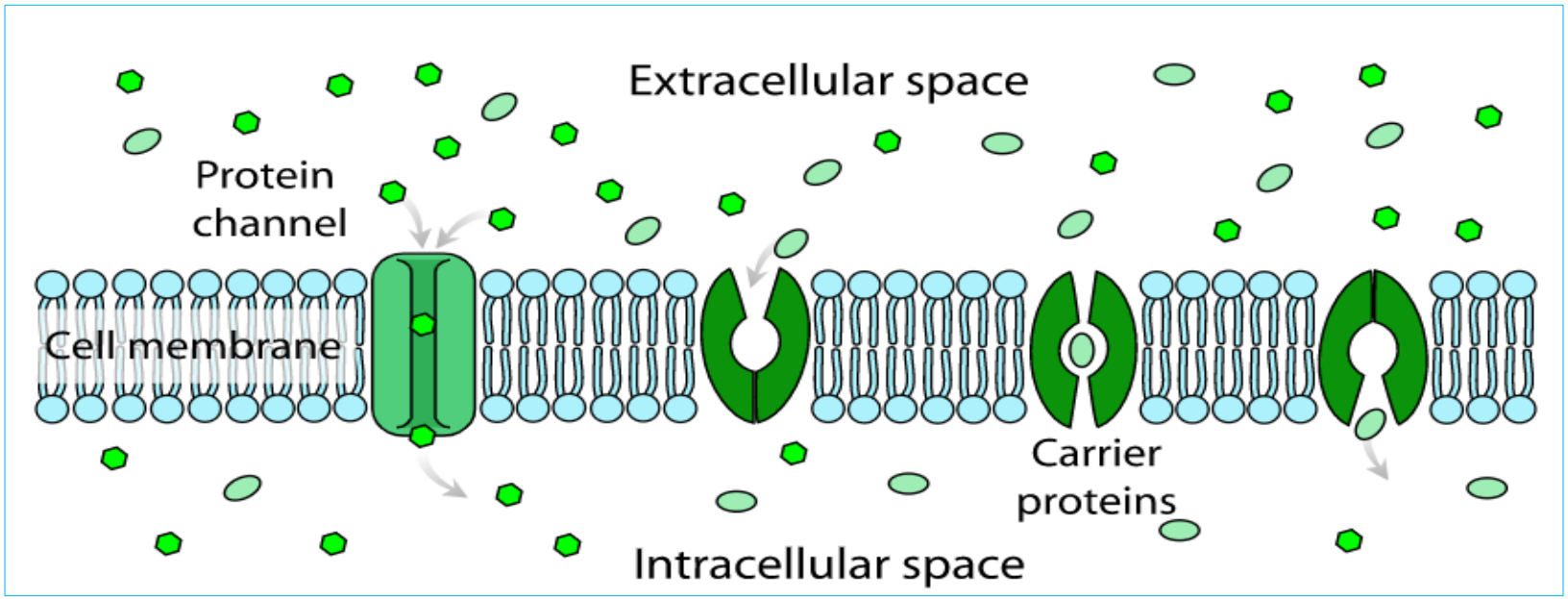

**Hypertonic** **Isotonic** **Hypoton ic**

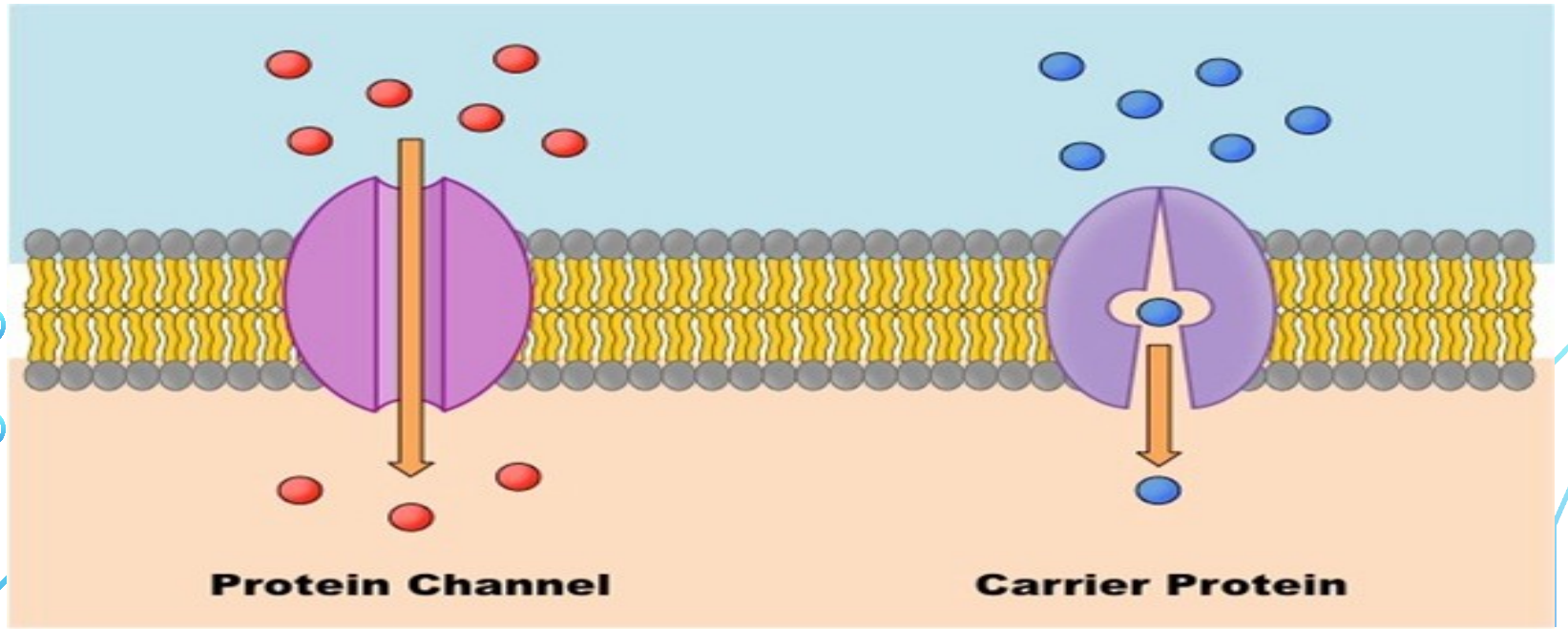


- **Turgor pressure** is the pressure exerted by the content of the cell against the cell wall (due to the entrance of water into the cell when the cell is hypertonic).
- The importance of turgor pressure is:
  - ✓ in non-woody plants it is important in supporting the plant body (maintaining the form of the plant).
  - ✓ in young cells it provides the force to stretch cell wall & makes possible cell growth.
- **Plasmolysis** is the shrinking of the cell content away from the cell wall (due to removal of water from the cell when the cell is hypotonic).
- The term used for animal cell is **crenation**

- **Facilitated Diffusion**
- is the movement of **larger molecules** like glucose through the cell membrane with the help of **transport proteins.**
- Hydrophilic molecules, charged ions, and relatively large molecules such as glucose all need help with diffusion.
- There are two types of proteins that assist the passage of particles from one side of the membrane to the other.

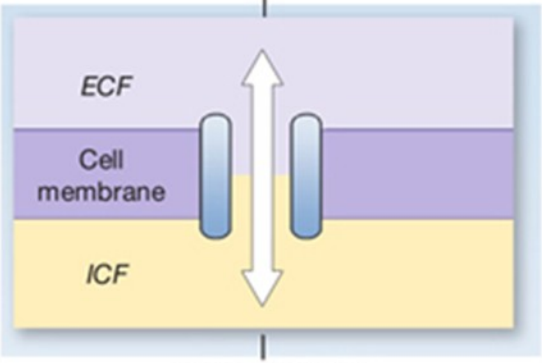
- **Channel protein:-**are proteins that can generate hydrophilic holes in cell membranes, allowing molecules to go down a concentration gradient.
- **Carrier proteins:-**are integral proteins that can transport substances across the membrane, both down and against the concentration gradient.
- It bind with specific ions or molecules, and in doing so, they change shape.
- Then, they carry the ions or molecules across the membrane.


Extracellular space
Protein channel
Cell membrane
Carrier proteins
Intracellular space


Protein Channel
Carrier Protein

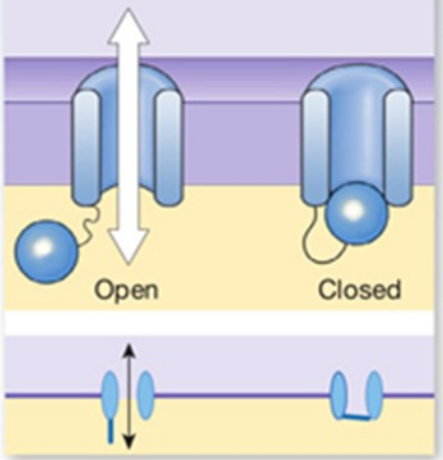
# MEMBRANE TRANSPORTERS

**Channel proteins** create a water-filled pore

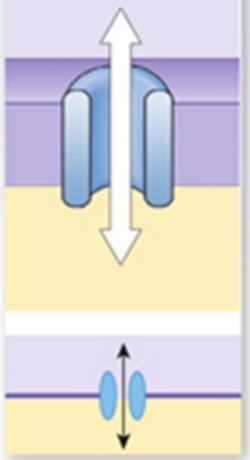



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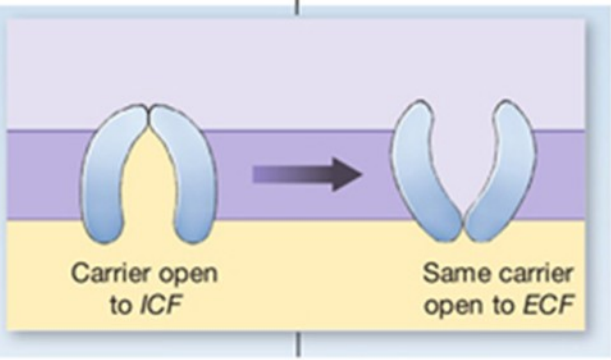
**Gated channels** open and close in response to signals.




**Open channels** or pores are usually open.



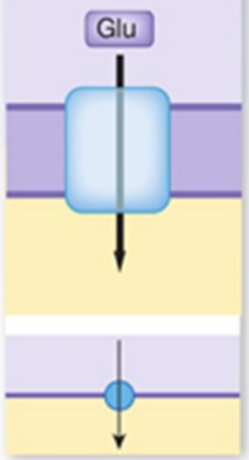
**Carrier proteins** never form an open channel between the two sides of the membrane



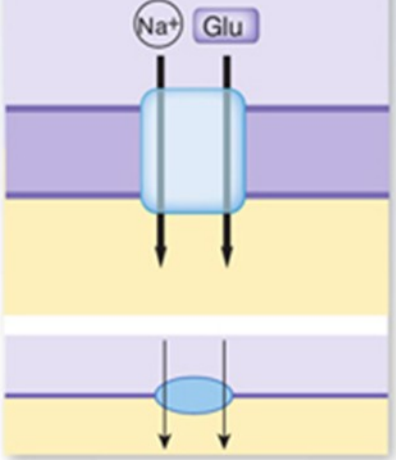

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Cotransporters

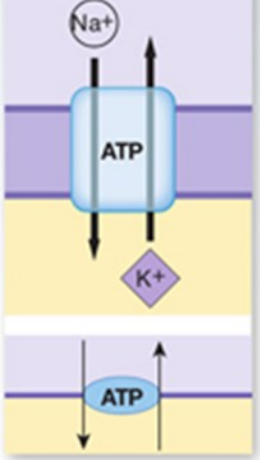
**Uniport carriers** transport only one kind of substrate.




**Symport carriers** move 2 or more substrates in the same direction across the membrane.




**Antiport carriers** move substrates in opposite directions.



- Carrier-mediated transport is an energy-dependent pathway generally used by small hydrophilic molecules.
- There are specific receptors on the membrane of carriers that recognize the target molecules and transport them across the cell.

- **This transport displays three characteristics**

**a. Specificity**: each cell possesses protein specified to transport a specific substance or few closely-related chemical compounds amino acid cannot bind to glucose carrier, but similar amino acids may use the same carrier

**b. Saturation:** in a given time only a limited amount of a substance can be transported via a carrier.

- This limit is known as **transport maximum** (Tm).
- The substance's rate of transport across the membrane are directly related to its concentration.
- When the Tm is reached, the carrier is saturated, and the rate of transport is maximum

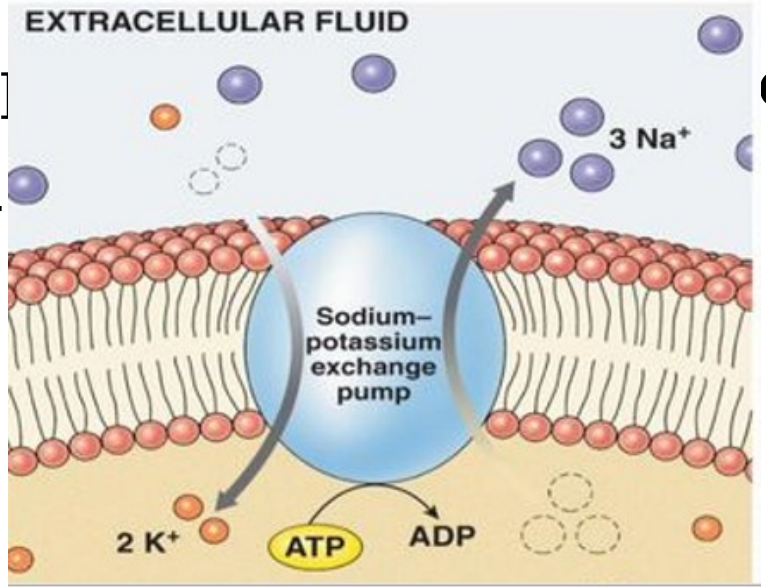
**c. Competition:** Several closely related compounds may compete for ride across the plasma membrane on the same carrier.

## Active Transport

- **Active transport** is the movement of molecules from **low to high** concentration.
- **Energy is required** as molecules must be **pumped against** the concentration gradient.
- Proteins that work as pumps are called **protein pumps.**
- Ex: Body cells must pump carbon dioxide out into the surrounding blood vessels to be carried to the lungs for exhale. Blood vessels are high in carbon dioxide compared to the cells, so energy is required to move the carbon dioxide across the cell membrane from **Low to high** concentration.

# Primary active transport

- One of the most important pumps in animal cells is the **sodium-potassium pump**, which moves Na+ out of cells, and K+ into them. Since the transport process uses ATP as an energy source, it is considered as a primary active transport.
- Sodium-potassium pump maintains correct concentrations of Na+



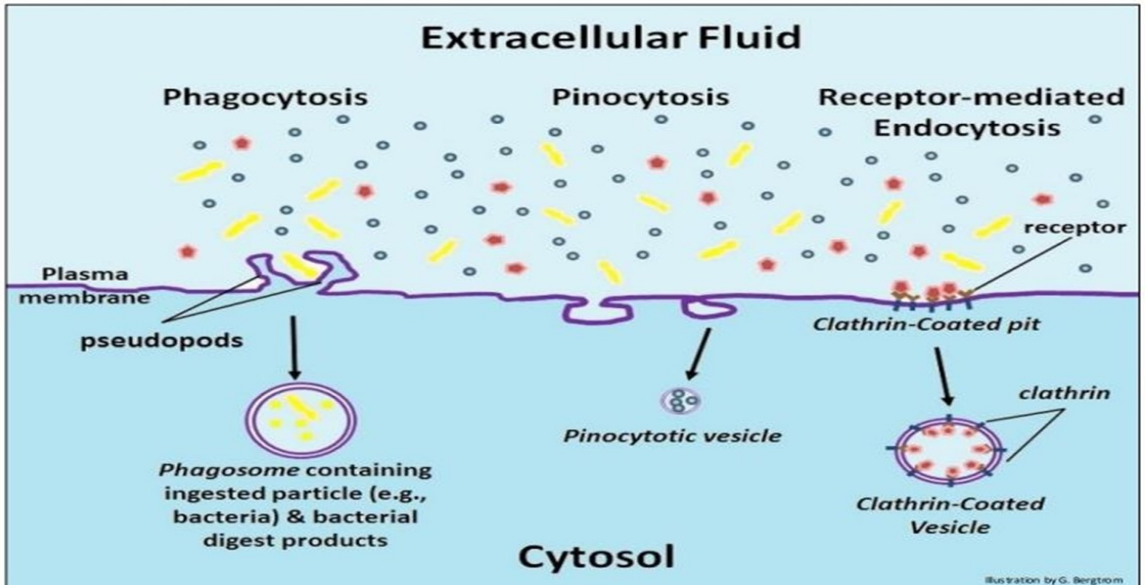
- **Secondary active transport**
- Secondary active transport uses the energy stored in these gradients to move other substances against their own gradients.
- Eg. suppose we have a high concentration of sodium ions in the extracellular space.
- If a route such as a channel or carrier protein is open, sodium ions will move down their concentration gradient and return to the interior of the cell.
- The movement of the sodium ions down their

# Endocytosis

- Is the transport into the cytoplasm of substances which are too large to be transported by protein carriers.
- In humans, Cholesterol is one of the most common substances.
- Endocytosis can be of two forms:-
  - **Phagocytosis-** If the substances taken up are solid. Known as cell eating
  - **Pinocytosis-** If the substances taken up are liquid or colloid. Known as cell drinking

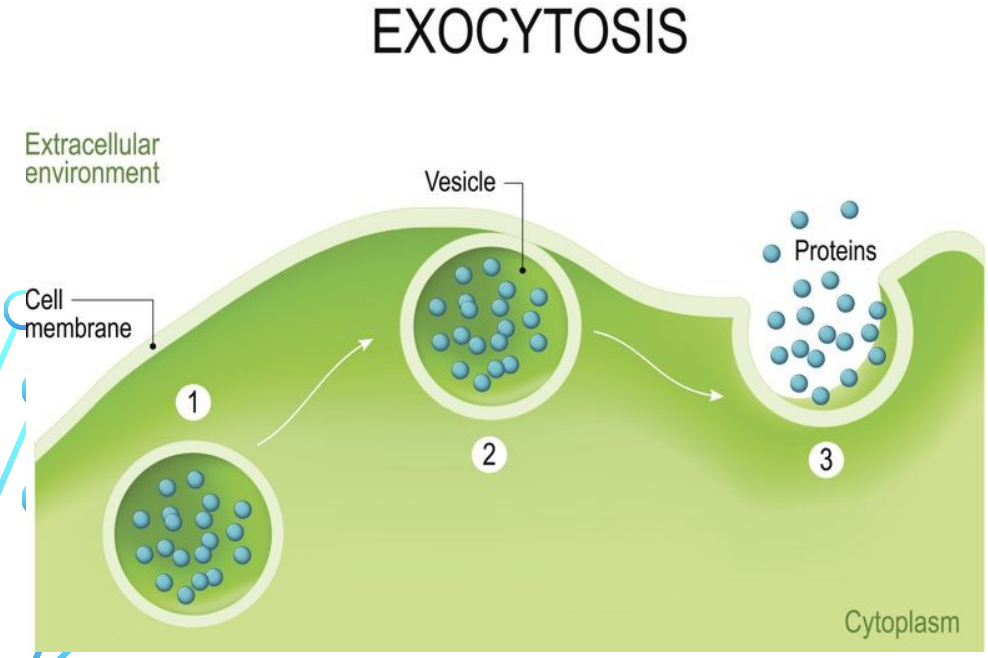
## Significance of endocytosis

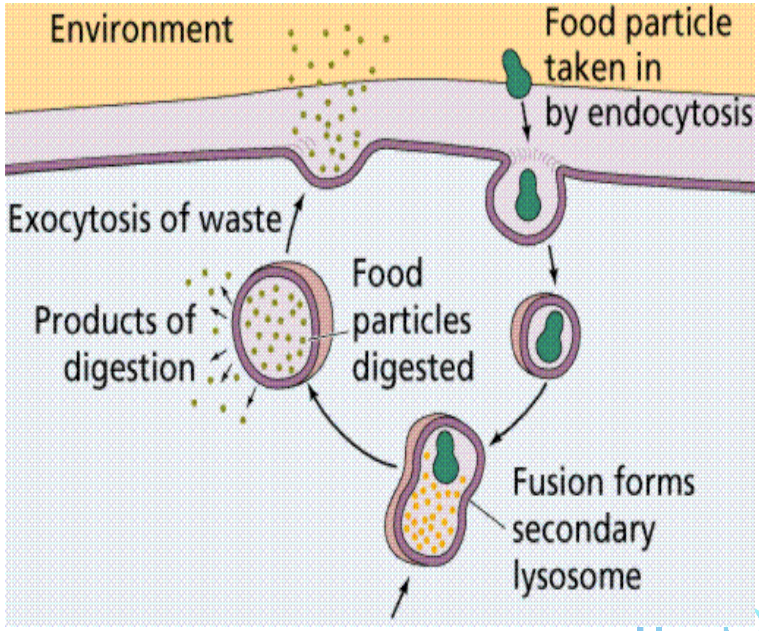
- It is the main mechanism of feeding in amoeba and other members of protozoa.
- White Blood Cells, which are part of the immune system, surround and engulf bacteria by endocytosis.
- Disposa debris in mamma



# Exocytosis

- is the fusion of secretory vesicles with the plasma membrane and results in the discharge of vesicle content into the extracellular space. E.g. Wastes are moved out of the cell by Exocytosis



# Cellular respiration

- is the pathway of yielding energy in the form of (ATP).
- Depending upon the oxygen demand, cellular respiration is of two types- **aerobic** and **anaerobic** respiration.
- Most living organisms obtain energy by breaking down organic molecules (catabolism) during cellular respiration
- The function of cellular respiration is to harvest

## Aerobic Respiration

- Aerobic respiration is the burning or oxidation of glucose in the presence of oxygen to release energy (ATP).
- The whole process takes place in three steps: glycolysis, Krebs' cycle, and electron transport system.
- Sites of respiration are cytoplasm and mitochondria.
- **This catabolic process can be divided into 3**

**Phase II -** These building blocks are usually oxidized to a common intermediate, acetyl – CoA.

Additionally, pyruvate or other citric acid cycle intermediates may also be formed

**Phase III** – This consists of the **citric acid cycle** (i.e. oxidation of acetyl - CoA to CO2, formation of NADH and FADH2) followed by electron transport and oxidative phosphorylation

- Energy released by electron transport to O2 is coupled to ATP synthesis
- Release of much energy ( **TCA** cycle and **ETC**).

## 1. Glycolysis: anaerobic respiration

- Is the first step of cellular metabolism which breaks down glucose to pyruvate.
- Glucose is a key metabolite in metabolism
- Purpose of glycolysis is the generation of energy (ATP).
- A modest amount of ATP is produced in **glycolysis** directly, but much more ATP is formed downstream of glycolysis through the complete **oxidation of pyruvate**

- Common pathway for glucose degradation to pyruvate is found in animals, plants and microorganism.
- Under aerobic, the pyruvate formed in glycolysis undergoes oxidative degradation to CO2 and H2O
- **Pyruvate** intended for complete degradation is transported to the mitochondria by pyruvate dehydrogenase.
- **Acetyl-CoA** is degraded in the citric acid cycle (or tricarboxylic acid cycle).
- The “H2” that is produced here is not gaseous but bound to co-substrates, as NADH and FADH2, which is subsequently oxidized in the respiratory chain

**Glycolysis** involves **ten** enzymatic reactions as described below

- The first five are preparatory phases or investment phase
- two phosphate groups coming from ATP

**1. Glucose to glucose 6- phosphate (G6P)**

- phosphorylation process by hexokinase enzyme
- This reaction consumes ATP

**2. Glucose-6-phosphate to fructose-6-phosphate(F6P)**

- by phosphohexose isomerase
- The change in structure is an isomerization
- reversible under normal cell conditions

**3. fructose-6-phosphate to fructose 1,6-bisphosphate**

- phosphorylation process by phosphofructokinase

**4. The cleavage of fructose-1,6-bisphosphate by aldolase.**

- yields, dihydroxyacetone phosphate and glyceraldehyde-3-phosphate,
- split by **aldolase** into two triose sugars:
  - dihydroxyacetone phosphate (a ketose), and
  - glyceraldehyde 3-phosphate (an aldose).

## Two classes of aldolases:

- class I aldolases, present in animals and plants, and
- class II aldolases, present in fungi and bacteria

## 5. dihydroxyacetone phosphate to glyceraldehyde-3-phosphate

- isomerization process by triose phosphate isomerase,
- advantageous, as it directs dihydroxyacetone phosphate down the same pathway as glyceraldehyde 3-phosphate, simplifying

## 7. 1,3-bis-phosphoglycerate to 3-phosphoglycerate

- by phosphoglycerate kinase

## 8. 3-phosphoglycerate to 2-phosphoglycerate

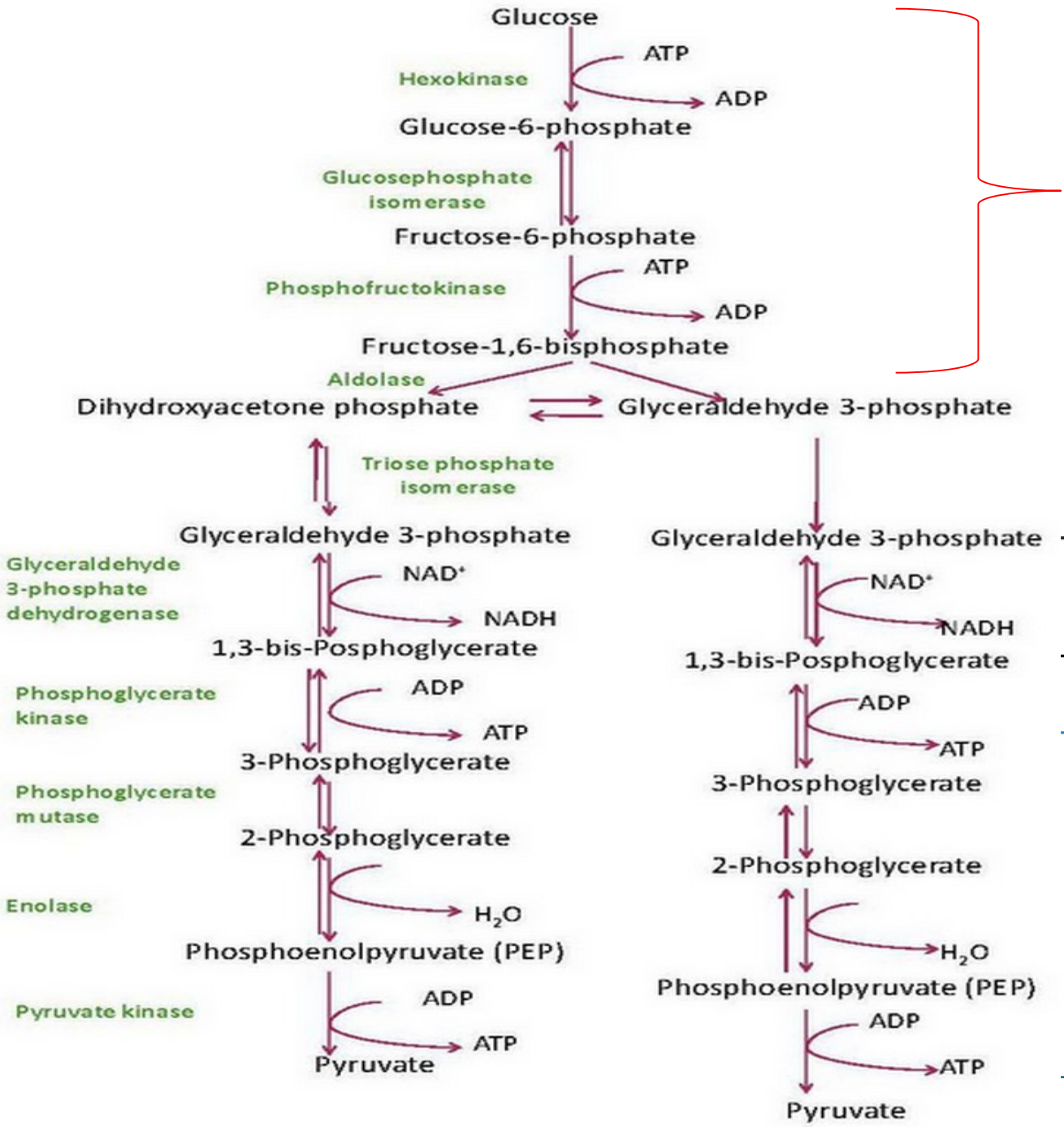
- The isomerization
- by phosphoglycerate mutase(PGAM)

## 9. 2-phosphoglycerate to phosphoenolpyruvate

- by enolase
- dehydration

## 10. Phosphoenol pyruvate to pyruvate molecule

- by pyruvate kinase

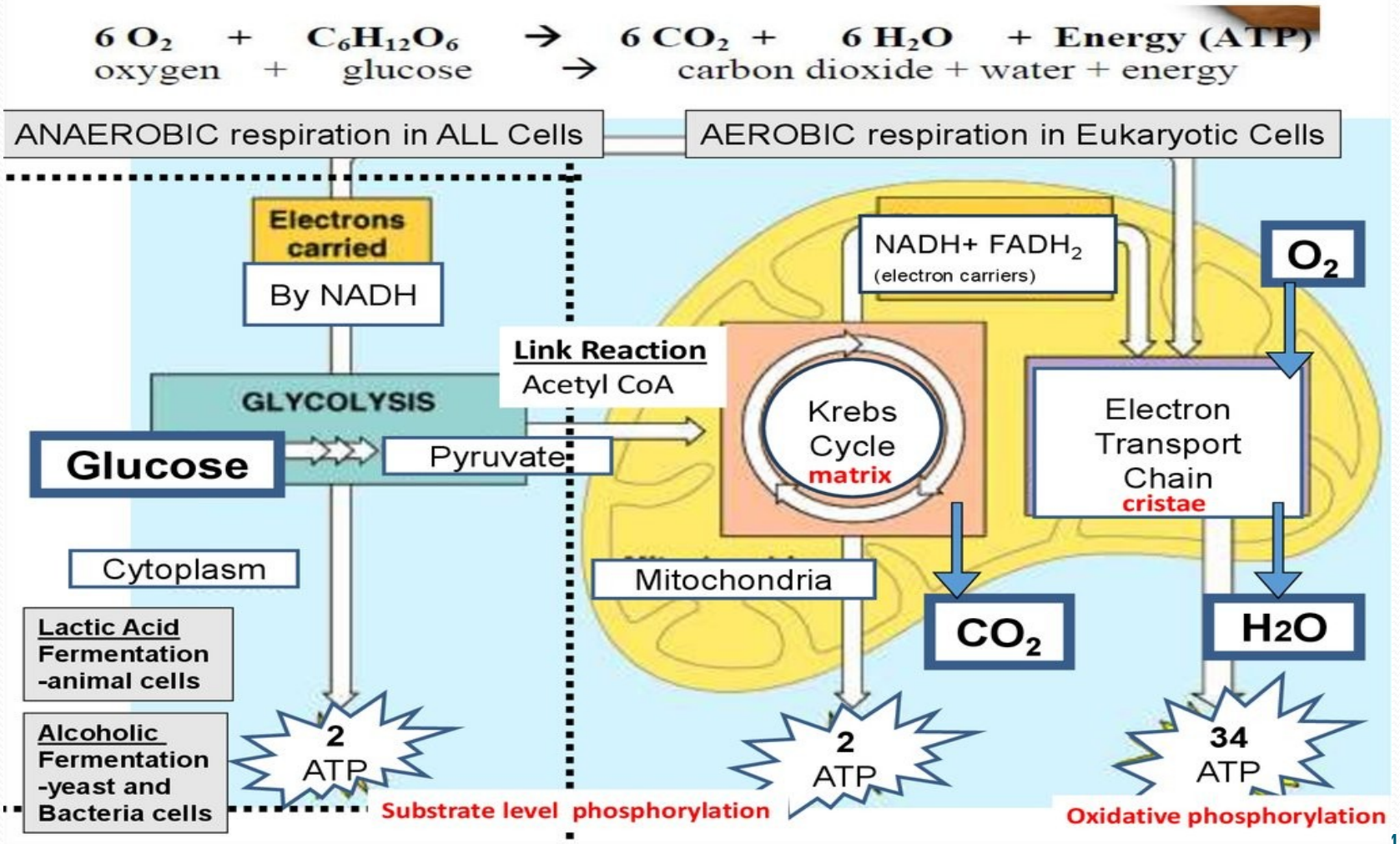



**Energy investment phase**

**Oxidation Phase**

**Energy Harvesting Phase**

- Glucose + 2ADP + 2Pi + 2NAD+ → 2Pyruvate +2NADH + 2ATP +2H2O



## 2. TCA (krebs cycle): Aerobic respiration

- One fate of pyruvate is that it enters to TCA cycle for complete oxidation.
- But there are intermediate processes that convert pyruvate to a acetyl coA
- The enzyme complex converts pyruvate into Acetyl-CoA by the following chemical changes:
- Decarboxylation of pyruvate (loss of CO2)
- Formation of acetyl group
- Linkage of acetyl group to coenzyme A forming acetyl - CoA.

- It is considered as central pathway of aerobic metabolism, as it serves two purposes- bioenergetics and biosynthesis:

1. **Bioenergetic**: degradation of acetyl group in acetyl - CoA to $CO_2$, resulting in release of energy (ATP or GTP) and reducing power (NADH and $FADH_2$)

- TCA oxidizes **two-carbon units**, producing two molecules of $CO_2$, one molecule of GP, and high-energy electrons in the form of NADH and $FADH_2$

## Steps of the Krebs cycle

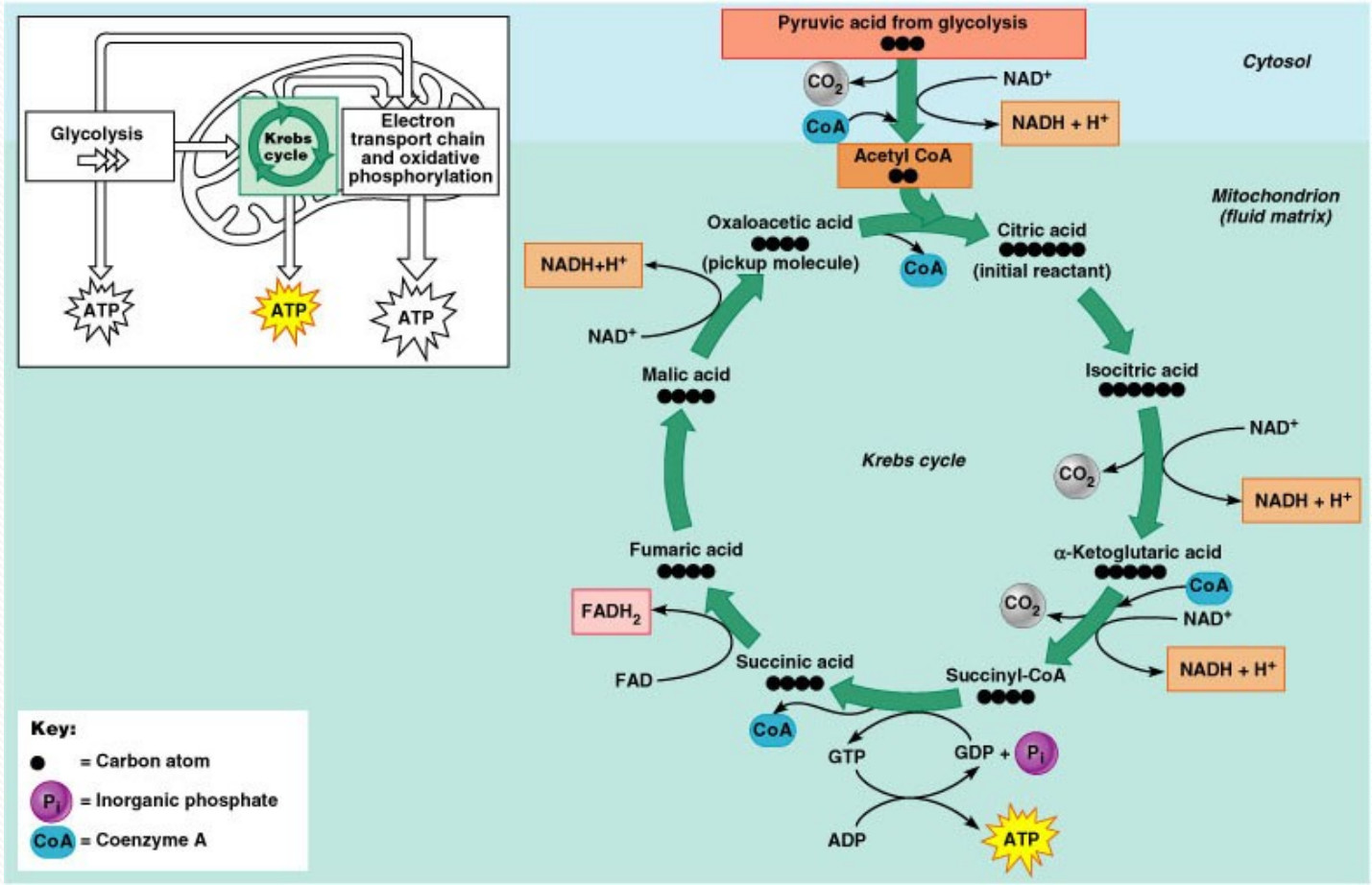
- Pyruvate first reacts with coenzymeA (CoA) to form a 2-carbon intermediate called acetyl CoA.
- Carbon dioxide is released and NAD is converted to NADH
- Acetyl CoA then moves to the mitochondrial matrix.
- Results in the production of two CO2 and two NADH

**2. Biosynthesis** - It supplies precursors for several biosynthetic pathways of amino acids, pyrimidines, purines etc.

- important source of biosynthetic precursors

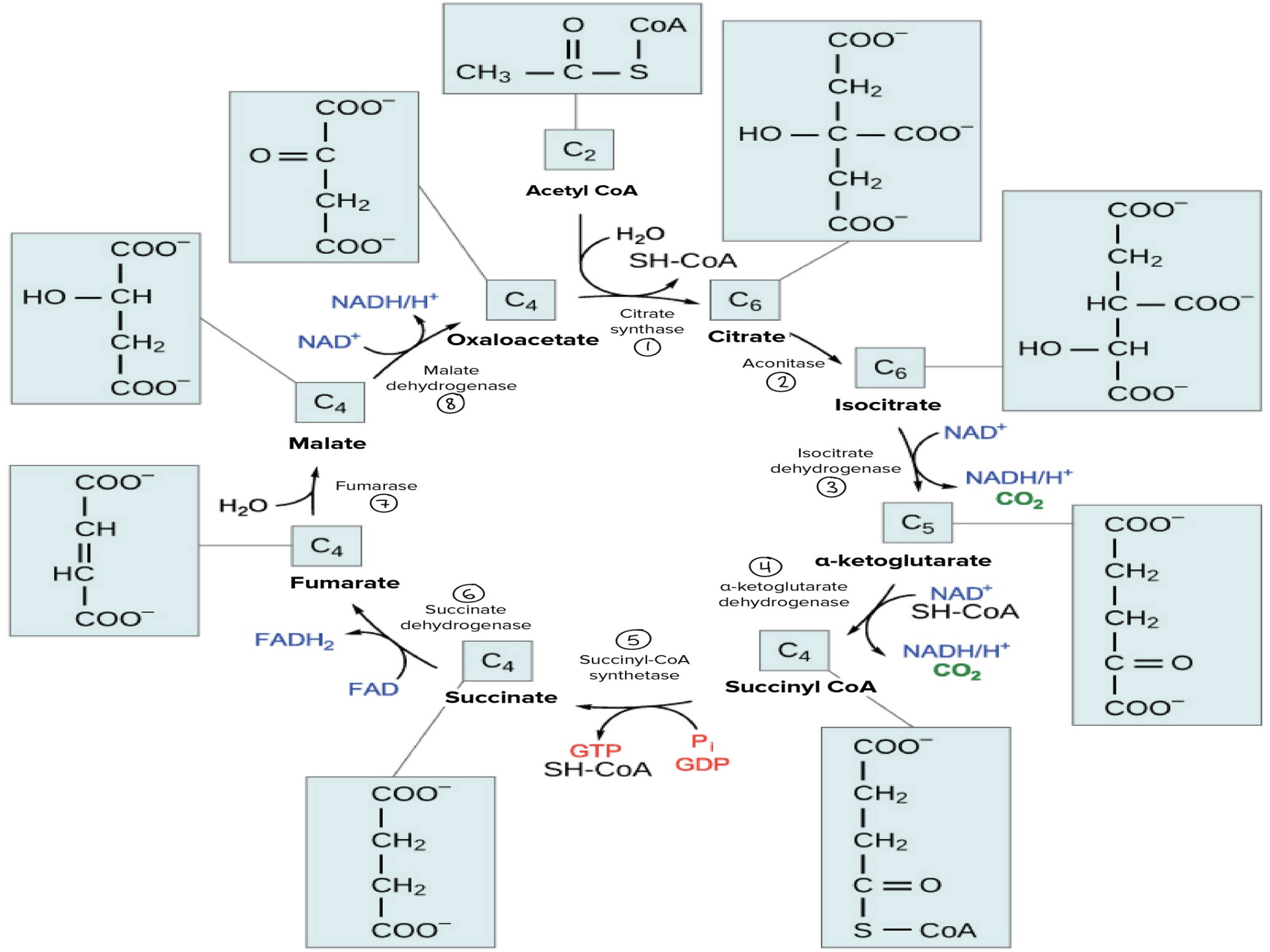
  e.g. α-ketoglutarate and oxaloacetate are used for synthesis of a number of amino acids like glutamic acid, asparatic acid etc

# Steps of kreb's cycle




**The net reaction of Krebs cycle**

**2acetyl-CoA + 6NAD $^{+}$ + 2FAD $^{+}$ + ~~2ADP~~ + 2Pi → 6NADH + 2FADH2 + 2ATP + 4CO2**


C2
Acetyl CoA
H2O
SH-CoA
Citrate synthase
1
C6
Citrate
Aconitase
2
C6
Isocitrate
Isocitrate dehydrogenase
3
NAD+
NADH/H+
CO2
C5
α-ketoglutarate
4
α-ketoglutarate dehydrogenase
NAD+
SH-CoA
NADH/H+
CO2
C4
Succinyl CoA
5
Succinyl-CoA synthetase
GTP
SH-CoA
Pi
GDP
C4
Succinate
6
Succinate dehydrogenase
FADH2
FAD
C4
Fumarate
Fumarase
7
H2O
C4
Malate
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8
NADH/H+
NAD+
C4
Oxaloacetate

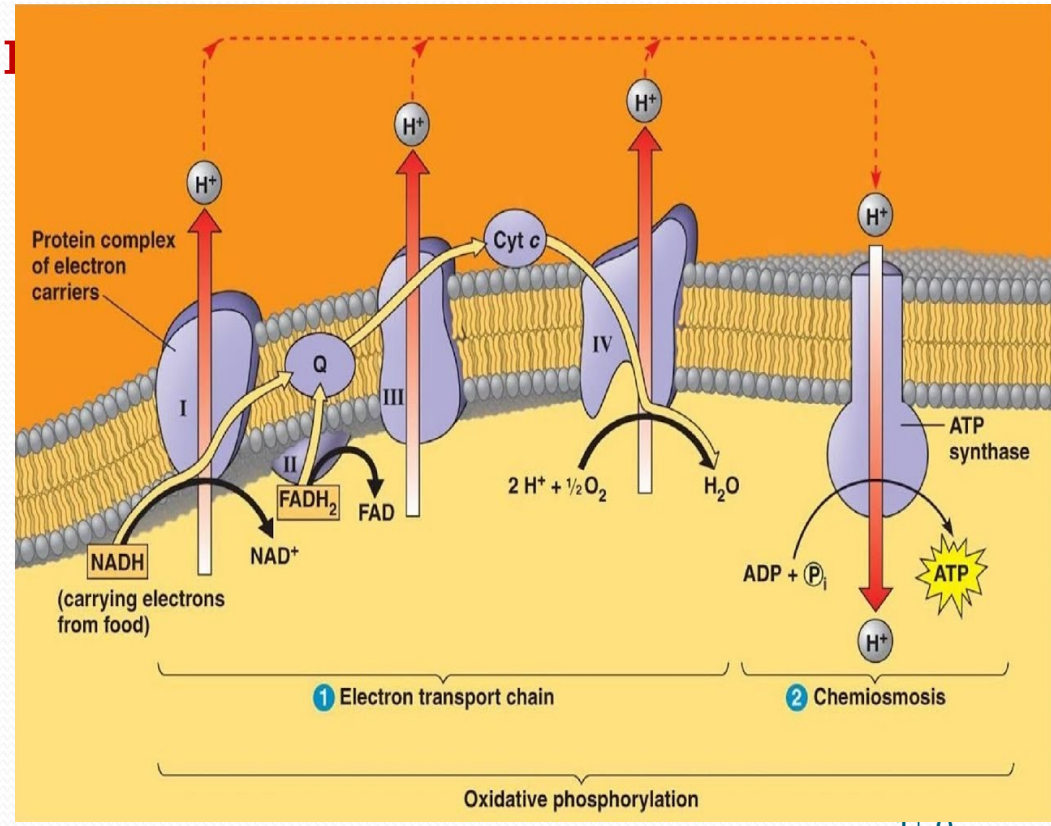
- Succinyl - CoA is used to form porphyrin ring of cytochromes, chlorophyll etc.
- Oxaloacetate can also be converted to phosphoenolpyruvate, which is a precursor of glucose.
- Acetyl - CoA is the starting material for fatty acid biosynthesis

**3. Electron Transport Chain**

- In aerobic respiration, electron transport is the **final** step in the break-down of glucose
- It also is the point at which **most of the ATP is produced**
- High-energy electrons and hydrogen ions from NADH and FADH2 produced in the Krebs cycle are used to convert ADP to ATP

- Electrons move along the mitochondrial membrane from one protein
- NADH and FADH2 electrons, the energy carriers are converted to NADH release and FAD, and H ions are released into the mitochondrial matrix
- The H ions are pumped into the mitochondrial matrix across the inner mitochondrial membrane
- H ions then diffuse down their **concentration gradient** back across the membrane and into the matrix through ATP synthase molecules in **chemiosmosis**

- Electron transport and **chemiosmosis** in cellular respiration are similar to these processes in photosynthesis
- **Oxygen** is the final electron acceptor in ETC.
  - **Protons** and **electron**
  - Occur in inner membrane.
  - to form water
  - Electrons from NADH and FADH2 are moved across **ETC.**
  - **e-, H+** and **O2** combine to make H2O.



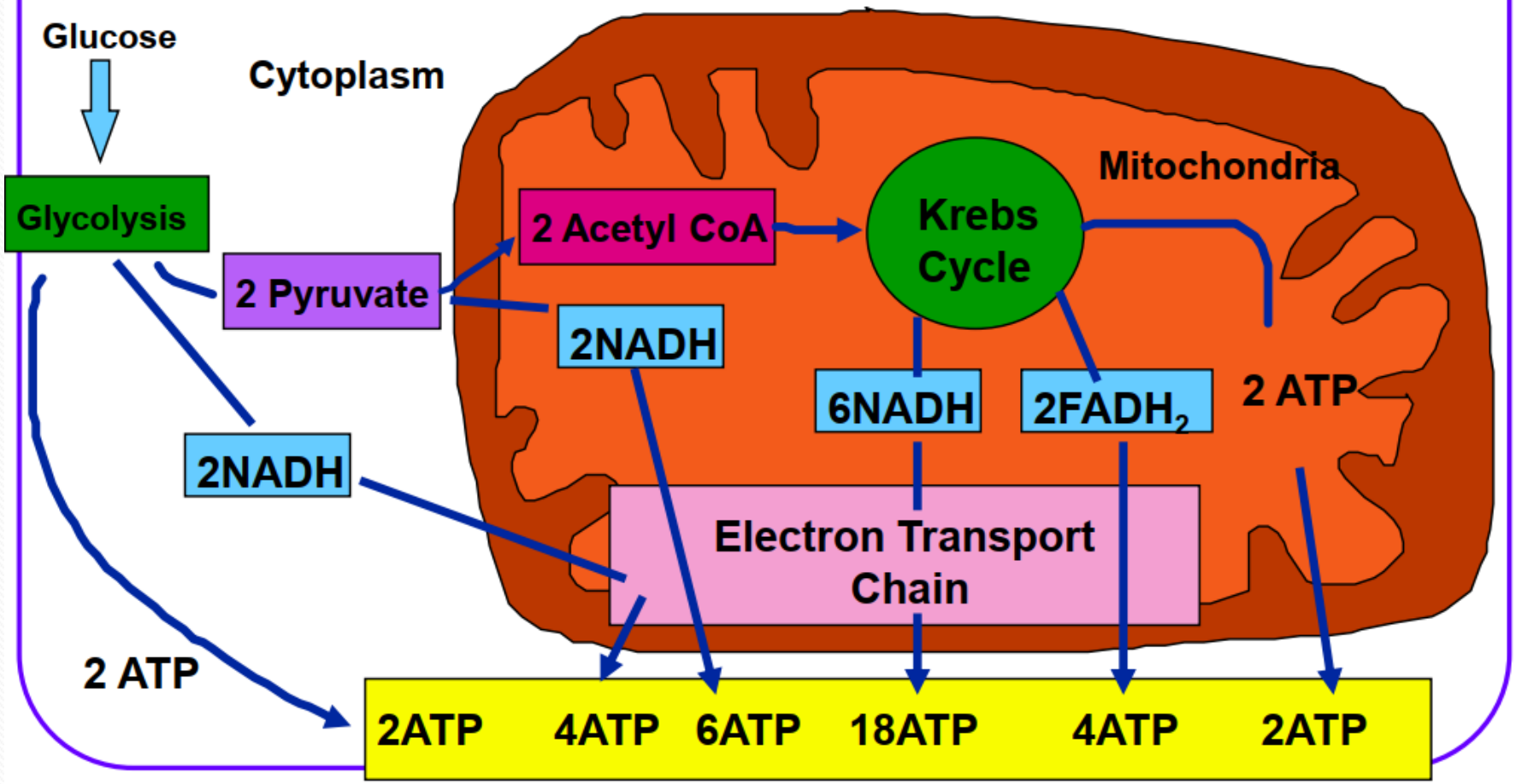
In the electron transport chain, electrons are passed from one molecule to another, and energy released in these electron transfers is used to form an electrochemical gradient. In chemiosmosis, the energy stored in the al ATP

| | Substrate level Phosphorylation | Oxidative Phosphorylation | Photophosphorylation |
|---|---|---|---|
| **Source of Phosphate** | Organic molecule | Inorganic phosphate $PO4^{3-}$ | Inorganic phosphate |
| **Energy Source** | High energy phosphate bond of donor | Proton motive force | Proton motive force |
| **Location in Eukaryotes** | Cytosol and mitochondrial matrix | Inner membrane of mitochondrion | Thylakoid of chloroplast |
| **Location in Prokaryotes** | Cytosol | Cytoplasmic membrane | Thylakoid on chromatophores |

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| Pathway | Substrate-Level Phosphorylation | Oxidative Phosphorylation | Total ATP |
|---|---|---|---|
| **Glycolysis** | 2 ATP | 2 NADH = 4 | 6 |
| **CoA** | | 2 NADH = 6 ATP | 6 |
| **Krebs Cycle** | 2 ATP | 6 NADH = 18 ATP<br>2 $FADH_2$ = 4 ATP | 24 |
| **TOTAL** | 4 ATP | 32 ATP | 36 |

# Maximum ATP Yield for Cellular Respiration




38 ATP (maximum per glucose)