Cell Biology
The First Stage

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Lecture 1

Introduction to Cell Biology

The Cell Theory: A Brief History

What's Cell Biology?

Cell Biology is a branch of biology focused on the study of cell structure and function, on how cells form and divide, and how they differentiate and specialize.

Cell Biology is the study of the **activities, functions, properties, and structures of cells.**

The Cell Theory:

by the late 1830s, biologists recognized that all organisms are composed of cells, a realization that is now known as **cell theory**, this theory, as initially proposed by botanist Matthias Schleiden and zoologist Theodor Schwann were studying tissues and proposed the unified cell theory.
The unified cell theory states three parts:

The first part states all organisms are made of cells.

The second part states that cells are the basic units of life.

The third part : new cells arise from existing cells.

Rudolf Virchow later made important contributions to this theory.

All cells only arise from pre-existing cells.

The generally accepted portions of the **Modern Cell Theory** are as follows:

The cell is the fundamental unit of structure and function in living things.
All organisms are made up of one or more cells.
Cells arise from other cells through cellular division.

The expanded version of the cell theory can also include:

- Cells carry genetic material passed to daughter cells during cellular division
- All cells are essentially the same in chemical composition
- Energy flow (metabolism and biochemistry) occurs within cells

What is a cell?

All living things are made from one or more cells. A cell is the simplest unit of life and they are responsible for keeping an organism alive and functioning. Cells are structural units that make up plants and animals; also, there are many single celled organisms and are known as single-celled or (**unicellular**) organisms.

Their single cell performs all the necessary functions to keep the organism alive. All species of bacteria and archaea are single-celled organisms.

On the other hand, large organisms like humans are made from many trillions of cells **(multicellular**) that work together to keep the organism alive**.**

General Structure and Chemistry of the Cell

Cells are composed of **water**, **inorganic ions**, and **carbon-containing (organic) molecules.**

Water is the most abundant molecule in cells, accounting for 70% or more of total cell mass.

The interactions between water and the other constituents of cells are of central importance in biological chemistry.

The critical property of water in this respect is that it is a polar molecule, in which the hydrogen atoms have a slight positive charge and the oxygen has a slight negative charge.

Because of their polar nature, water molecules can form hydrogen bonds with each other or with other polar molecules as well as interacting with positively or negatively charged ions.

As a result of these interactions, ions and polar molecules are readily soluble in water **(Hydrophilic).**

In contrast, nonpolar molecules, which cannot interact with water, are poorly soluble in an aqueous environment**(Hydrophobic)**.

Physical Properties of Water

Water is a liquid at standard temperature and pressure, but is also found in nature in its solid (frozen) and gaseous phases.

Water's boiling point is 100° Celsius and its freezing point is 0°C.

- Water is a universal solvent.
  - Water has a high heat capacity, which means it can absorb a great deal of energy without its temperature increasing greatly.

Biological Properties of Water:

- In the body, the major components of cells such as proteins, DNA and organelles are all dissolved in water and the cell is filled with watery cytoplasm.

Water transport into and out of the cell is strictly regulated, and the components of water (oxygen and hydrogen) are both used in many cellular processes.

Water's high heat capacity insulates our bodies from drastic temperature changes.

Water's chemical and physical properties contribute to all life on Earth at the planetary, organismal, cellular, and molecular levels.

Lecture 2

The Macromolecules of the Cell

The Macromolecules of the Cell

Biological macromolecules, or large molecules are necessary for life. These macromolecules are built from different combinations of smaller organic molecules.

Living organisms require four types of macromolecules, they are:

1-Carbohydrates **2-Proteins** **3-Lipds**
4- Nucleic acids

1-Carbohydrates

Pure carbohydrates have the formula $(CH_2O)_n$.

where **n** is the number of carbons in the molecule.

In other words, the ratio of carbon to hydrogen to oxygen is 1:2:1 in carbohydrate molecules.

. This formula also explains the origin of the term “carbohydrate”: the components are carbon (“carbo”) and the components of water (hence, “hydrate”). Carbohydrates are classified into three subtypes:

1-M**onosaccharides**

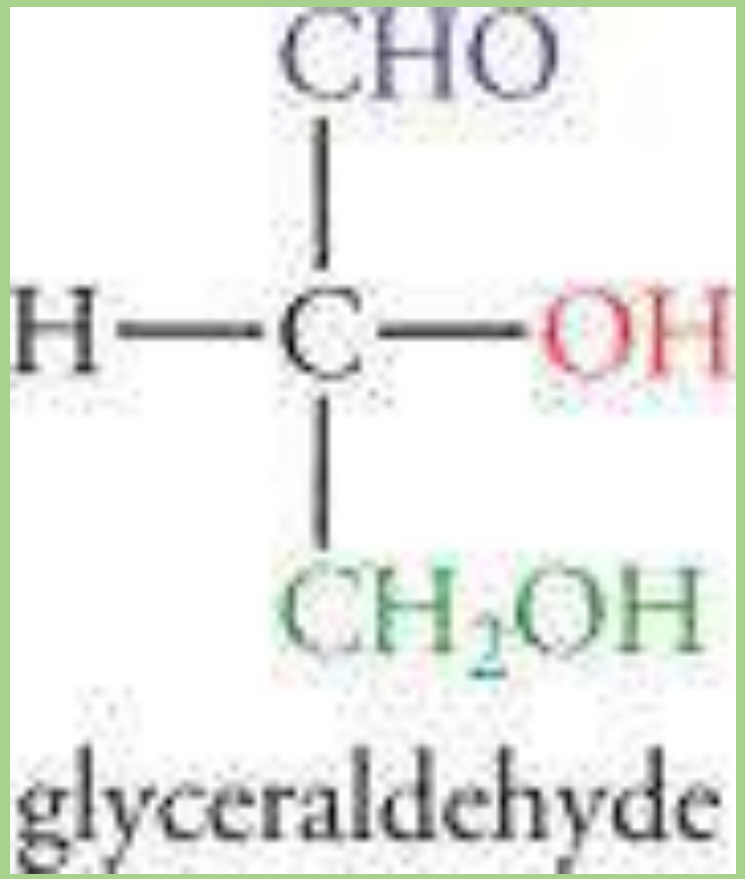
2-Disaccharides

3-Polysaccharides

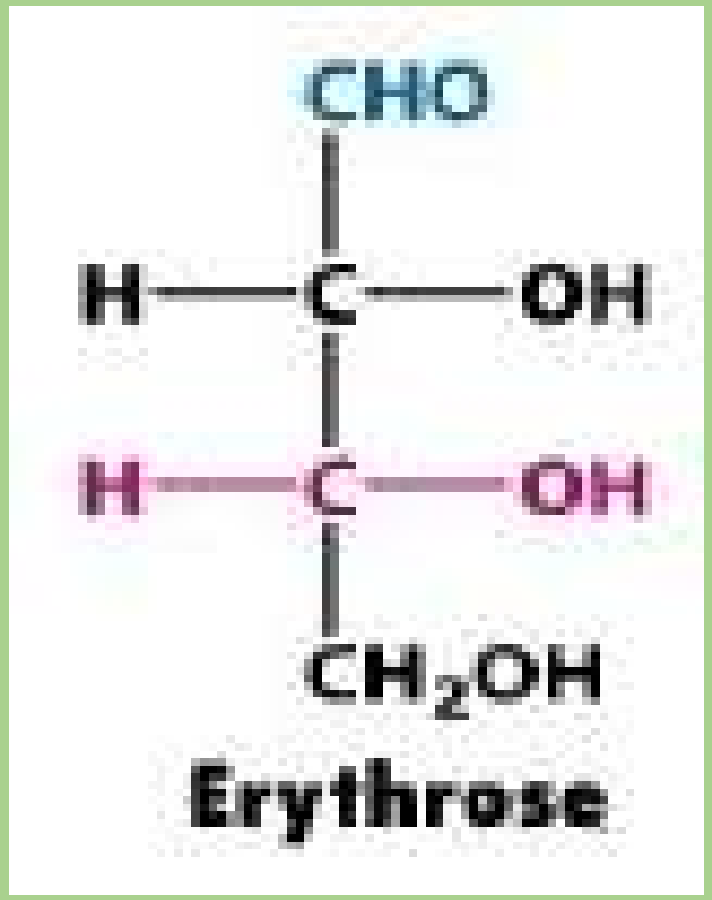
1-Monosaccharides:

Monosaccharides (mono- = “one”; sacchar- = “sweet”) are simple sugars, the most common of which is glucose. In monosaccharides, the number of carbons usually ranges from three to seven. Most monosaccharide names end with the suffix -ose. Depending on the number of carbons in the sugar, they also may be known as

1-Trioses (three carbons) like **glyceraldehyde**



2-Tetrose(four carbons) like **erythrose.**



3-Pentose (five carbons) such as **ribose and deoxyribose** that serve a structural role in the nucleic acids RNA and DNA.

4- Hexose (six carbons) : glucose is the sixcarbon monosaccharide used as a basic source of energy by most heterotrophic cells

2- Disaccharides (di = “two”) form when two monosaccharides connected by a glycosidic bond. Common disaccharides include lactose, maltose, and sucrose. Lactose is a disaccharide consisting of the monomers glucose and galactose. Maltose, or malt sugar, is a disaccharide formed of two glucose molecules. The most common disaccharide is sucrose, or table sugar, which is composed of the monomers glucose and fructose.

3-Polysaccharides

A long chain of monosaccharides linked by glycosidic bonds is known as a polysaccharide (poly- = “many”). The chain may be branched or unbranched, and it may contain different types of monosaccharides. The molecular weight may be 100,000 daltons or more depending on the number of monomers joined. Starch, glycogen, cellulose, and chitin are primary examples of polysaccharides. **Starch** is the stored form of sugars in plants and is made up of a mixture of amylose and amylopectin (both polymers of glucose).

- **Glycogen** is the storage form of glucose in humans and other vertebrates and is made up of monomers of glucose. Glycogen is the animal equivalent of starch and is a highly branched molecule usually stored in liver and muscle cells.
- Cellulose is made up of glucose monomers that are linked by *β* 1-4 glycosidic bonds.

- **Functions of Carbohydrates:**

1-Living organisms use carbohydrates as a source of energy.

2-Serve as energy stores, fuels. It is stored as glycogen in animals and starch in plants.

3-They form structural and protective components, like (cellulose) in the cell wall of plants and (chitin, structural elements in the cell walls of animals.

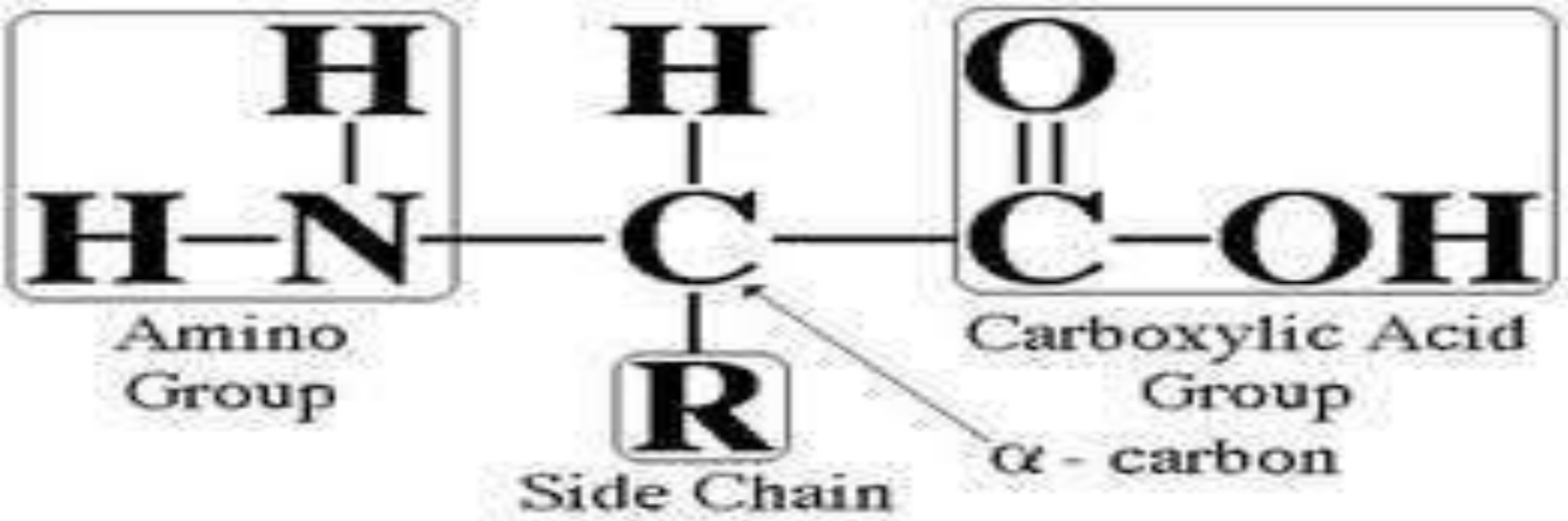
4-Carbohydrates are intermediates in the biosynthesis of fats and proteins.

5-Formation of the structural framework of RNA and DNA.

2-Proteins

The building blocks of proteins are amino acids, which are small organic molecules that consist of a basic amino group (—NH_2), an acidic carboxyl group (—COOH), and an organic *R* group (or side chain) that is unique to each amino acid. Each molecule contains a central **carbon** (C) atom, called the α-carbon, to which both an amino and a carboxyl group are attached.

Amino Acid Structure



- There are **20** amino acids that function as building blocks of proteins . **Nine** of these amino acids are considered :
- **Essential**—they must be consumed in the diet they are

(Histidine, Isoleucine, Leucine, Lysine, Methionine, Phenyl alanine, Threonine, Tryptophan, and Valine).

- **Non-essential amino acids**, meaning they can be synthesized in sufficient quantities in the body. These five are (Alanine, Aspartic acid, Asparagine, Glutamic acid, and Serine).

- **Conditional amino acids:** being essential only at certain life stages or in certain disease states. They include (arginine, cystein, glutamine, glycine, proline and tyrosine)

Within a protein, multiple amino acids are linked together by **peptide bonds**, thereby forming a long chain. All proteins are made up of one or more chains of amino acids (polypeptide chains).

Classification of Proteins

Proteins can be classified as:

(a) Simple proteins. On hydrolysis they yield only the amino acids and occasional small carbohydrate compounds. Examples are: albumins, globulins, glutelins,, histones and protamines.

(b) A conjugated protein is a protein that functions in interaction with other (non-polypeptide) chemical groups. Some examples of conjugated proteins are lipoproteins,glycoproteins,Nucleoproteins, Phosphoproteins,hemoproteins,metalloproteins,phytochr-omes, cytochromes, and chromoproteins.

(c) Derived proteins: These are proteins derived from simple or conjugated proteins by physical or chemical means. Examples are: denatured proteins and peptides

Functions of proteins:

1-Antibodies: are specialized proteins that protect the body against bacteria, viruses, and other foreign pathogens.

2-Contractile Proteins: are responsible for muscle contraction and movement. Examples of these proteins include actin and myosin.

3-Enzymes: are proteins that facilitate and speed up biochemical reactions.

4- Hormones: Coordinate the activity of different body systems. Examples :insulin and oxytocin.

5- Structural proteins are fibrous and stringy, this formation making them ideal for supporting various other proteins such as keratin, collagen, and elastin.

6- **Storage proteins** reserve amino acids for the body until ready for use.

7- **Transport proteins** are carrier proteins that move molecules from one place to another in the body.

Lecture 3

The Macromolecules of the Cell

3-Lipids:

compounds that are insoluble in water but soluble in organic solvents.

Functions of Lipids:

1- Acting as structural components of cell membranes.

2- Serving as energy storage sources.

3- They also provide insulation to the body.

4-Act as primary compounds for some vitamins and hormones.

5-It is considered a source of essential fatty acids.

Fatty Acids:

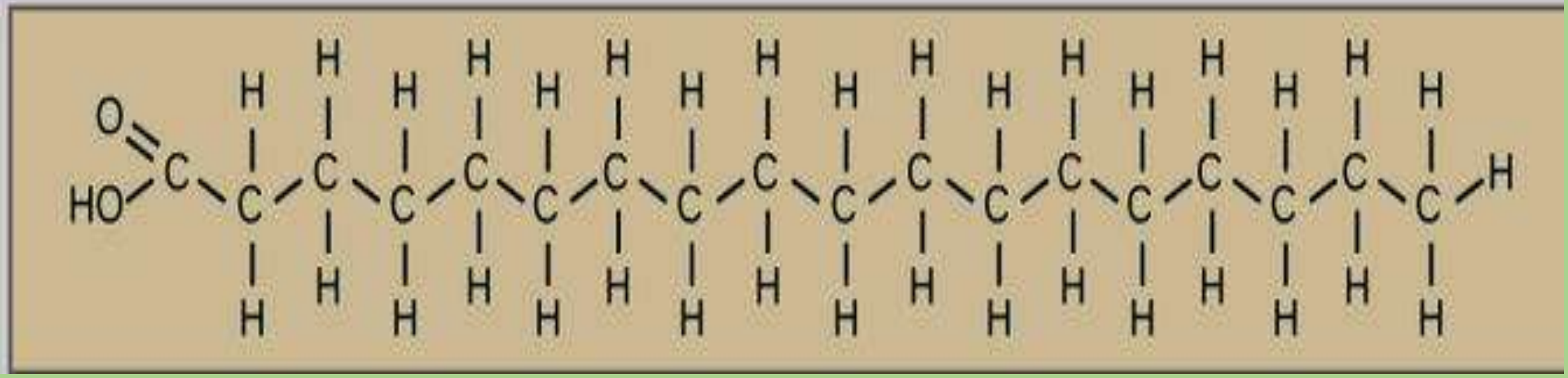
Fatty acids are carboxylic acids (or organic acid), usually with long chains, either unsaturated or saturated.

Saturated fatty acids:

Lack of carbon-carbon double bonds indicates that the fatty acid is saturated. Among the most common saturated fatty acids in animal fats are palmitic and stearic.

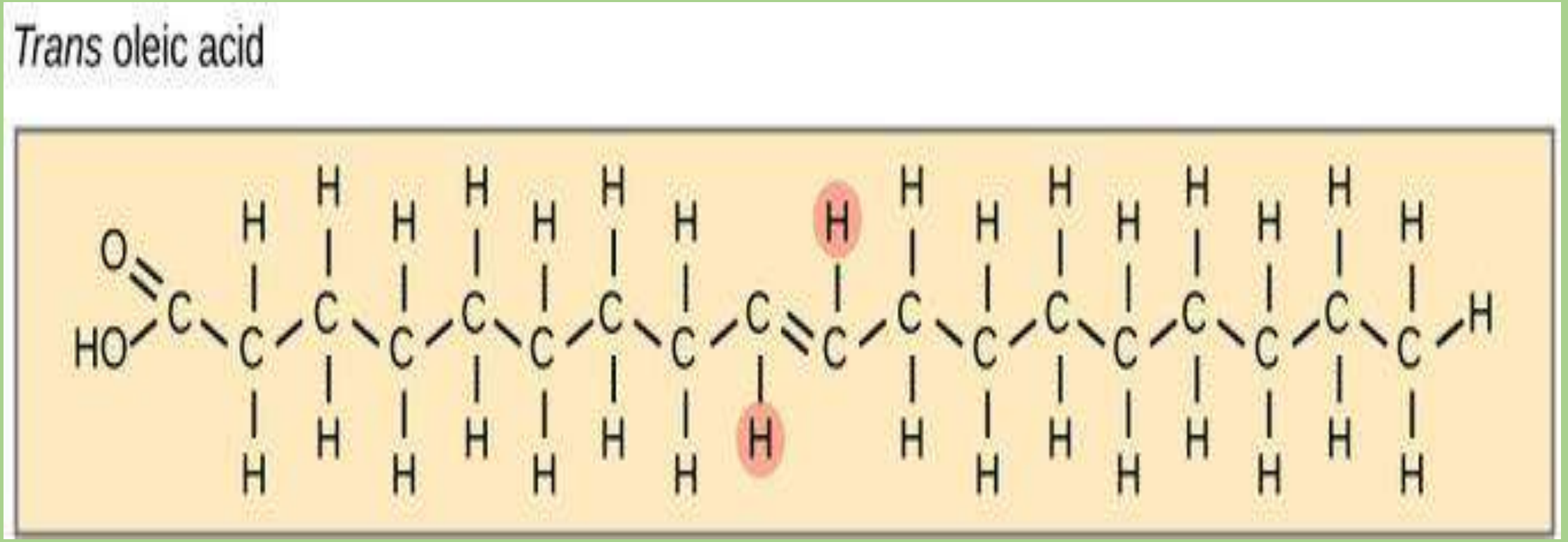
Saturated fatty acid

Stearic acid



Unsaturated fatty acids

Unsaturated fatty acid is indicated when a fatty acid has more than one double bond. Examples include oleic acid and linoleic acid.



Types of Lipids

Simple Lipids

They appear in the form of neutral fats and are usually called triglycerides.

Complex Lipids(Conjugated Lipids)

1. Phospholipids: containing a phosphoric acid residue in addition to fatty acids and alcohol.

2. Glycolipids: containing a fatty acid, sphingosine, and carbohydrate.

3. Other complex lipids: sulfolipids and amino lipids. Lipoproteins may also be placed in this category.

Derived Lipids

These include fatty acids, glycerol, steroids, fatty aldehydes, hydrocarbons, lipid-soluble vitamins, and hormones.

These compounds are produced by the hydrolysis of simple and complex lipids.

4. Nucleotides

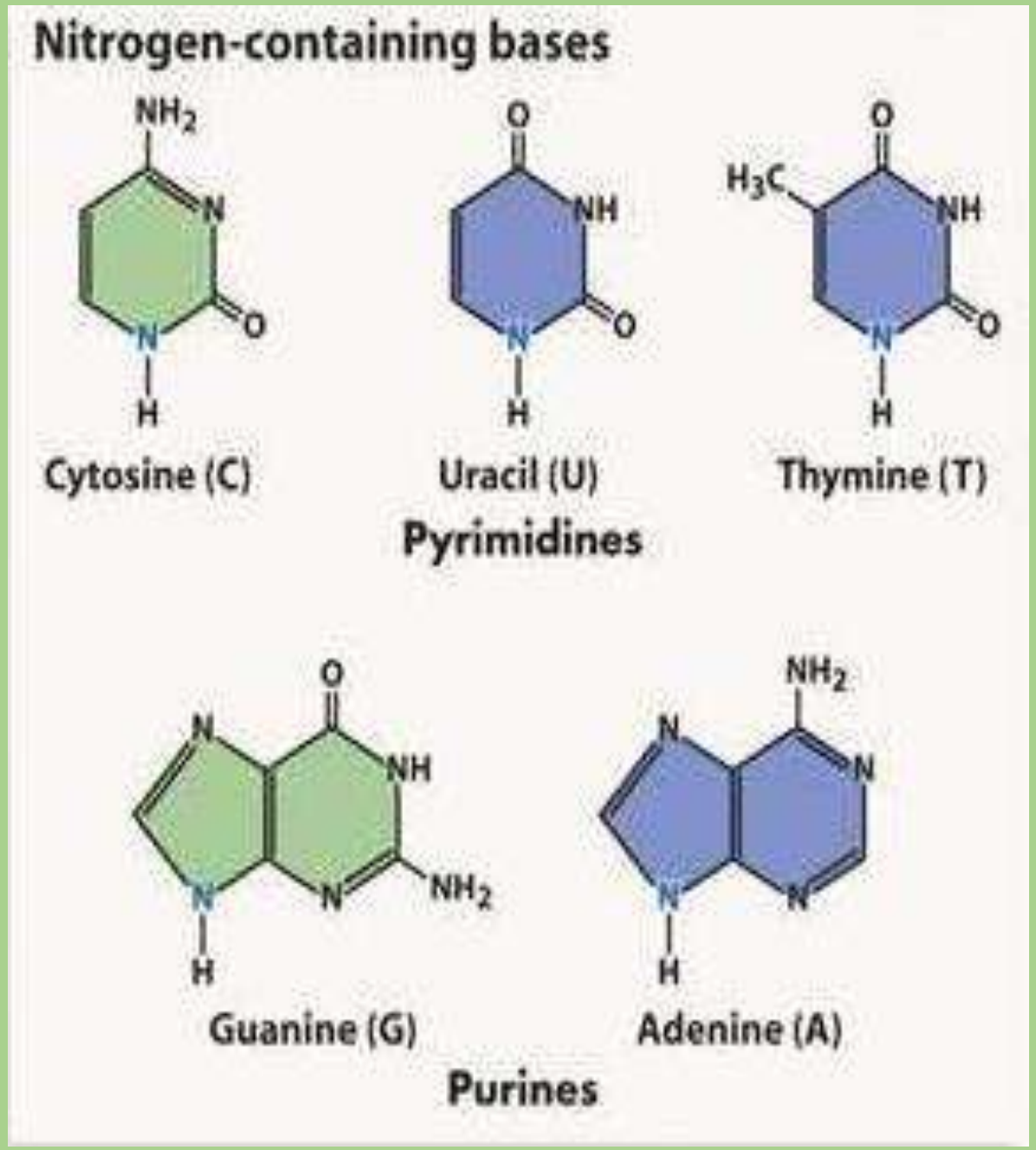
They are important cellular molecules, involved in many biological processes, and they may be free (such as adenosine triphosphate (ATP) or in the form of secondary units in nucleic acids (DNA and RNA),as they are the building block of these nucleic acids.

A nucleotide is made up of three parts:

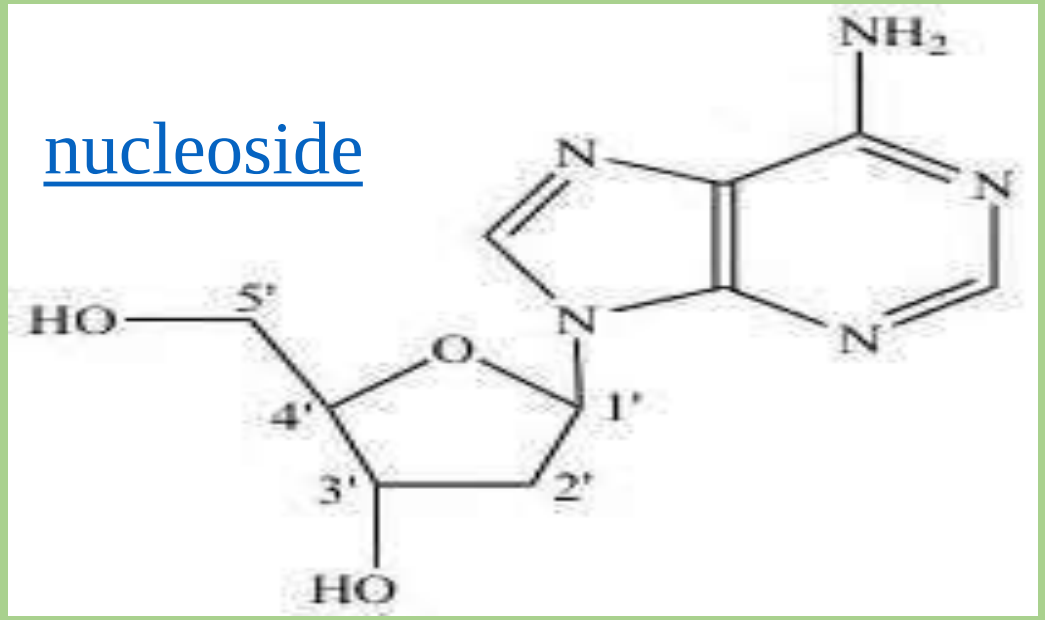
1-Nitrogenous base

2-Pentose sugar

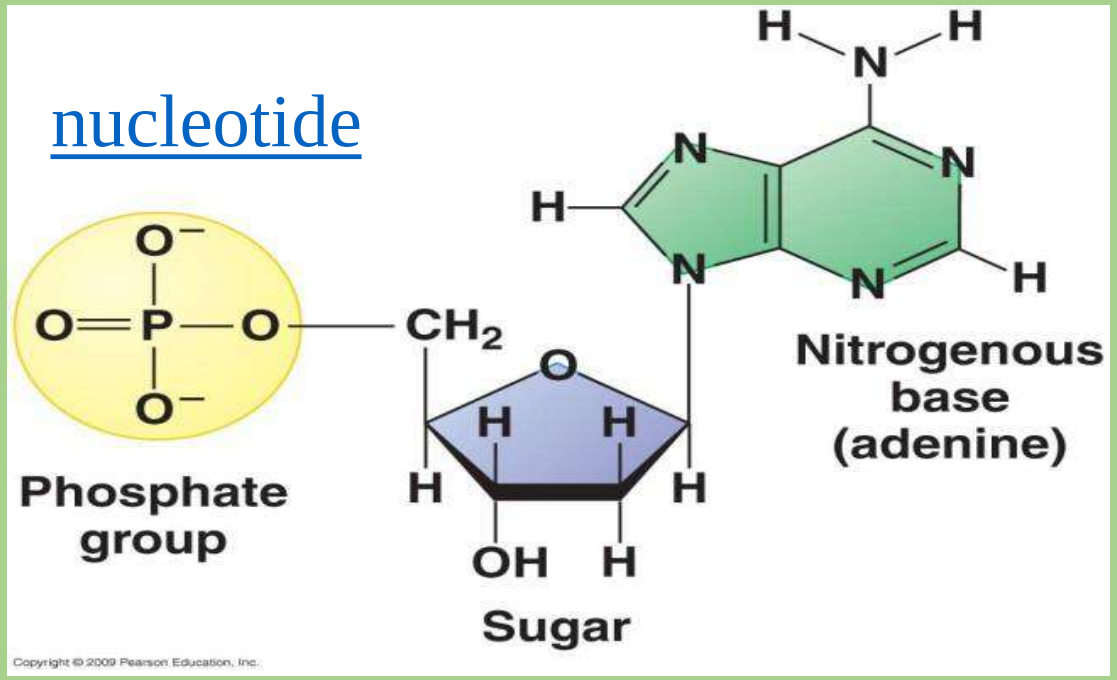
3- One or more phosphate groups



nucleoside



nucleotide



Functions of nucleotides

1-They are the building block **of (DNA) and** (**RNA).**

2- It is an energy-rich source in the form of ATP.

3-They act as regulatory indicators for various metabolic processes such as (cAMP) and (cGMP).

4- Are incorporated into important cofactors of enzymatic reactions (e.g. Coenzyme A , FAD , NAD and NADP+

Nucleic acids

DNA and RNA are long chains of repeated nucleotides

DNA nitrogen-containing bases **(A, T,G and C)**

A always pairs with **T** through two hydrogen bonds, and **G** always pairs with **C** through three hydrogen bonds.

Ribonucleic Acid (RNA)

RNA is a single-stranded nucleic acid polymer of the four nucleotides **A, C, G, and U.**

Types of RNA

1-Messenger RNA (mRNA)

2-Ribosomal RNA (rRNA)

3-Transfer RNA (tRNA)

1-Messenger RNA (mRNA)

Messenger RNA (mRNA) delivers the information encoded in one or more genes from the DNA to the ribosome, a specialized structure, or organelle, where that information is decoded into a protein.

Ribosomal RNA (rRNA)

Ribosomal RNA (rRNA) molecules are the structural components of the ribosome. The rRNAs form extensive secondary structures and play an active role in recognizing conserved portions of mRNAs and tRNAs. They also assist with the catalysis of protein synthesis.

Transfer RNA (tRNA)

Transfer RNA (tRNA) carries individual amino acids into the ribosome for assembly into the growing polypeptide chain. The tRNA molecules contain 70 to 80 nucleotides and fold into a characteristic cloverleaf structure. Specialized tRNAs exist for each of the 20 amino acids needed for protein synthesis, and in many cases more than one tRNA for each amino acid is present.

Lecture 4

Types of Cells

There are two types of cells:

- Prokaryotes
- Eukaryotes

What is a Prokaryotic Cell?

Prokaryotic cells are single-celled microorganisms known to be the earliest on earth. Prokaryotes include Bacteria and Archaea. The photosynthetic prokaryotes include cyanobacteria that perform photosynthesis.

Characteristics of Prokaryotic Cell

1. They lack a nuclear membrane, and the genetic material is present in a region called the nucleoid region.
2. Mitochondria, Golgi bodies, chloroplast, and lysosomes are absent. However, it contains ribosomes that appear as many small granules that build proteins.
3. The genetic material is present on a single chromosome.
4. The cell wall is made up of carbohydrates and amino acids.

- 5. The plasma membrane acts as the mitochondrial membrane carrying respiratory enzymes.
- 6. They divide asexually by binary fission. The sexual mode of reproduction involves conjugation.

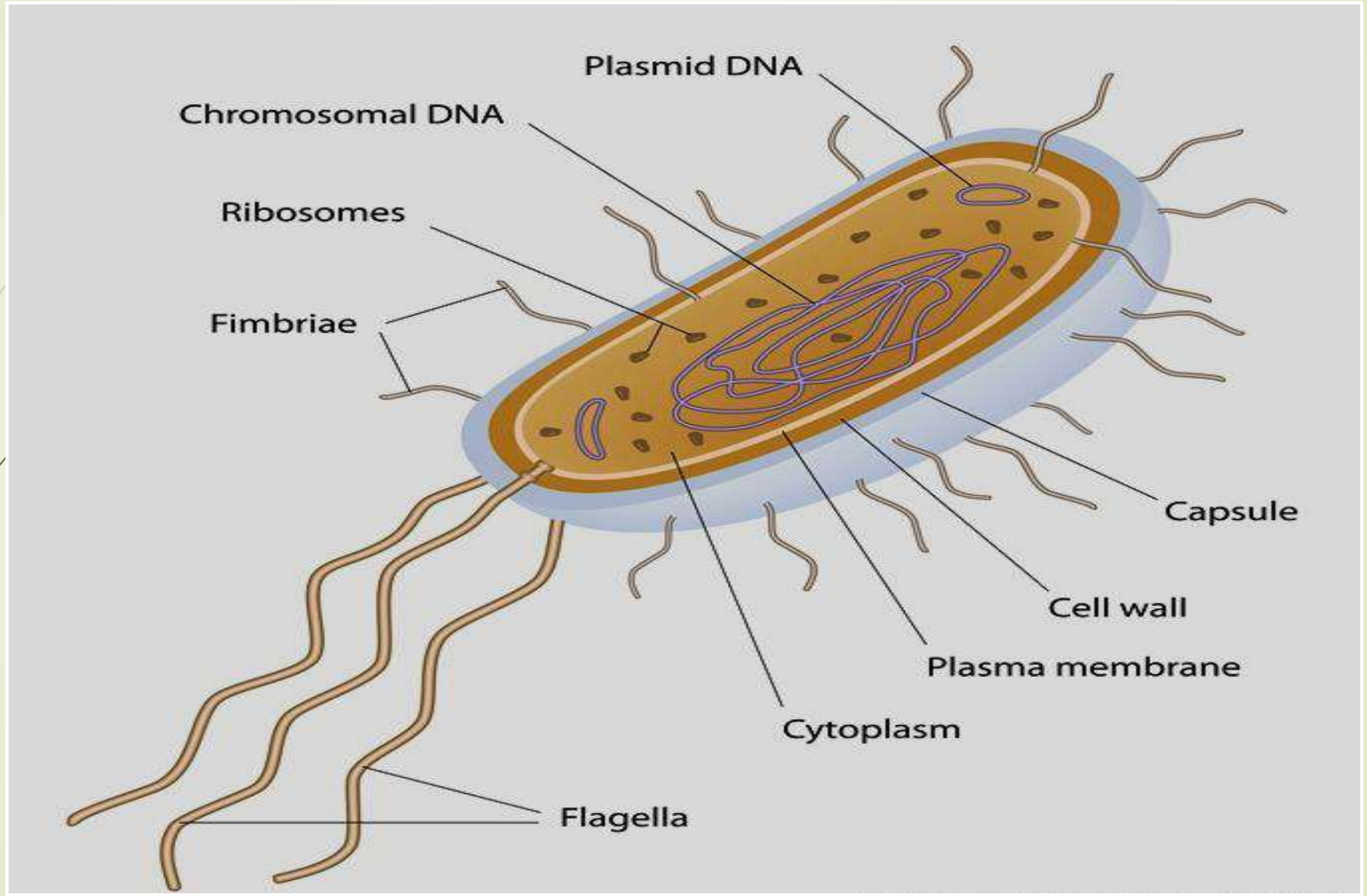
Examples of Prokaryotic Cells

1) Bacterial Cells:

1. Unicellular organisms found everywhere.
2. They have different shapes and structures.
3. Each bacterial cell represents a prokaryotic organism, and is surrounded by a solid wall that is more than 0.001 micrometers thick and contains protein, polysaccharides and lipid, the inside of this solid wall is the Plasma Membrane
4. In addition, the enzymes that participate in the oxidative metabolism process and those that compose the respiratory chain are also attached to the plasma membrane.

5. Bacteria have some unique structures such as pili, flagella and capsule.

6. It contains a small circular DNA called a plasmid, which is an extra DNA that is independent of chromosomal DNA and can be isolated and used in genetic engineering experiments


Plasmid DNA
Chromosomal DNA
Ribosomes
Fimbriae
Capsule
Cell wall
Plasma membrane
Cytoplasm
Flagella

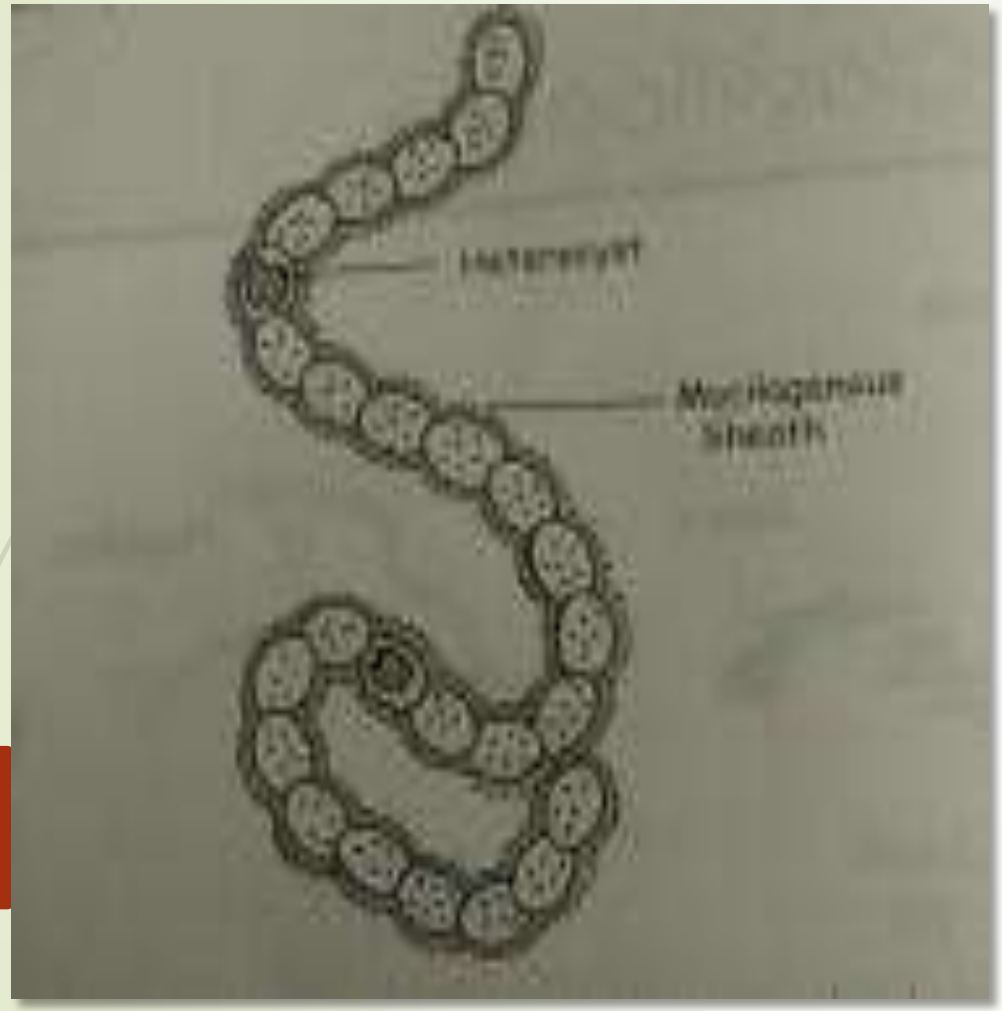
2) Blue-green algae(Cyanobacteria):

1. Its contain primitive nuclei consisting of the annular DNA that is not surrounded by a nuclear envelope and has no nuclear fluid.
2. Its cells divide by simple binary fission like bacteria.
3. Like some bacteria, its cells are Gram negative.
4. Some species move by sliding, which is similar to bacteria.
5. The color of these bacteria is due to the presence of chlorophyll pigment and phycocyanin blue dye, and in some types there is the phycoerythrin.
6.

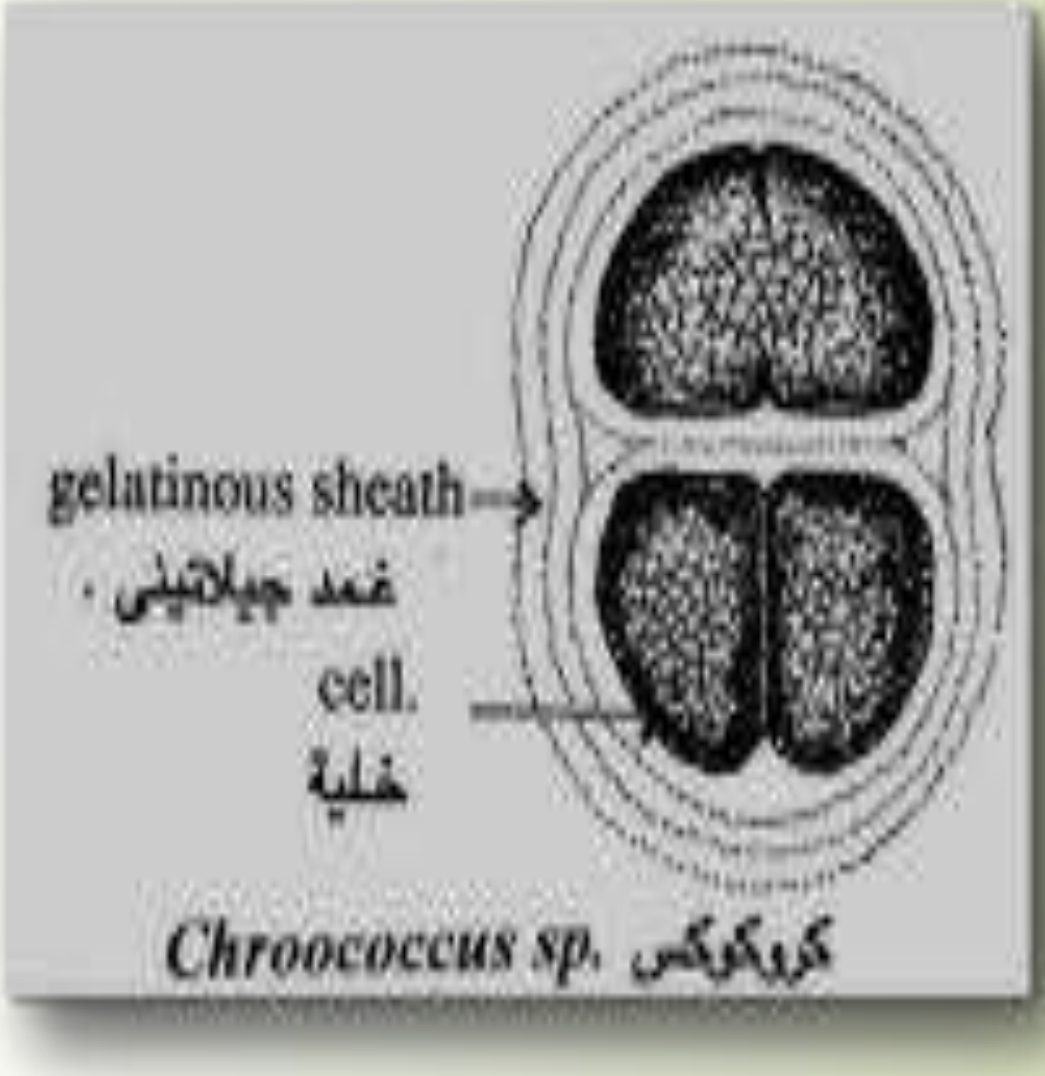
6. Most of its species, which are about 500 species, live in salt water, while the rest of the species live in salt water, fresh water, or wet areas.

7.They range from unicellular to filamentous and include colonial species. Each individual cell (each single cyanobacterium) typically has a thick, gelatinous cell wall.

8. They lack flagella. Blue-green algae are autotrophic as they perform photosynthesis. Among its types are *Nostoc* and *Chroococcus*.



Nostoc

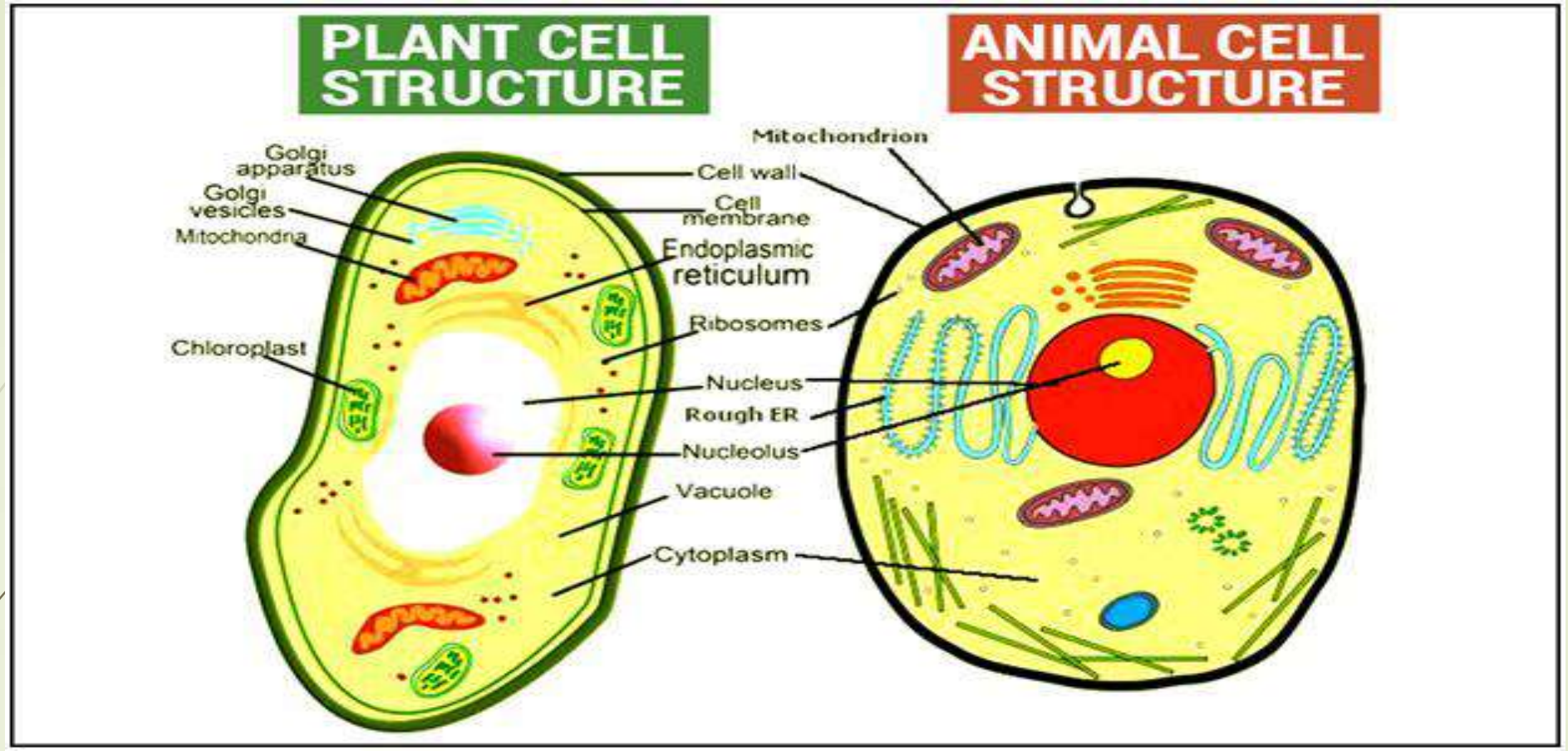


Chroococcus

Eukaryotic Cell

1. Eukaryotes are organisms that have a true nucleus cells that possess a membrane-bound nucleus (that holds DNA in the form of chromosomes).
2. Eukaryotic organisms may be multicellular or single-celled organisms.
3. Some of them have fixed shapes, including spherical, tubular, cubic, vertical, oval... etc.
4. Others have an inconsistent shape that changes from time to time, such as an amoeba.

5. All animals and plants are eukaryotes, other eukaryotes include, fungi, and protozoans .
6. They are large cells, have cytoplasmic organelles like mitochondria golgi complex, endoplasmic reticulum ….. etc.
7. The nuclear envelope is present and the genetic material in the form of chromosomes consist of DNA and histone protein, the cells are dividing by mitosis or meiosis division.



A comparison showing the shared and unique features of prokaryotes and eukaryotes All cells, whether prokaryotic or eukaryotic, share these four features:

1. DNA
2. Plasma membrane
3. Cytoplasm
4. Ribosomes

Prokaryote vs eukaryote: key differences

Properties	Prokaryote	Eukaryote
Nucleus	Absent	Present
Membrane-bound Organelles	Absent	Present
Cell structure	Unicellular	Mostly multicellular; some unicellular
Cell size	Smaller (0.1-5 µm)	Larger (10-100 µm)
Complexity	Simpler	More complex
DNA Form	Circular	Linear
Ribosomes	Smaller(70S) consist of a 50S large subunit and a 30S small subunit	Larger(80S) consist of a 60S large subunit and a 40S small subunit

Viruses

Viruses are infectious, obligate intracellular parasites composed of a nucleic acid core surrounded by a protein capsid. Viruses can be either naked (non-enveloped) or enveloped. The classification of viruses is complex and based on many factors, including type and structure of the nucleoid and capsid, the presence of an envelope, the replication cycle, and the host range.

- The replication cycle differs between viruses that infect bacteria (bacteriophages) and viruses that infect eukaryotic cells. Bacteriophages have either a lytic or lysogenic replication cycle, while eukaryotic viruses have a defined 6-step replication process

1. Viruses are a different group, as they do not come under eukaryotic or prokaryotic organisms.
2. They are obligate parasites, and cannot reproduce unless they are present in their own host cell.
3. Generally much smaller than bacteria. With a diameter of 220 nanometers, the measles virus is about 8 times smaller than *E.coli* bacteria. At 45 nm, the hepatitis virus is about 40 times smaller than *E.coli*.

4. They lack the capacity to thrive and reproduce outside of a host body.

5. Viruses teeter on the boundaries of what is considered life. On one hand, they contain the key elements that make up all living organisms: the nucleic acids, DNA or RNA (any given virus can only have one or the other).

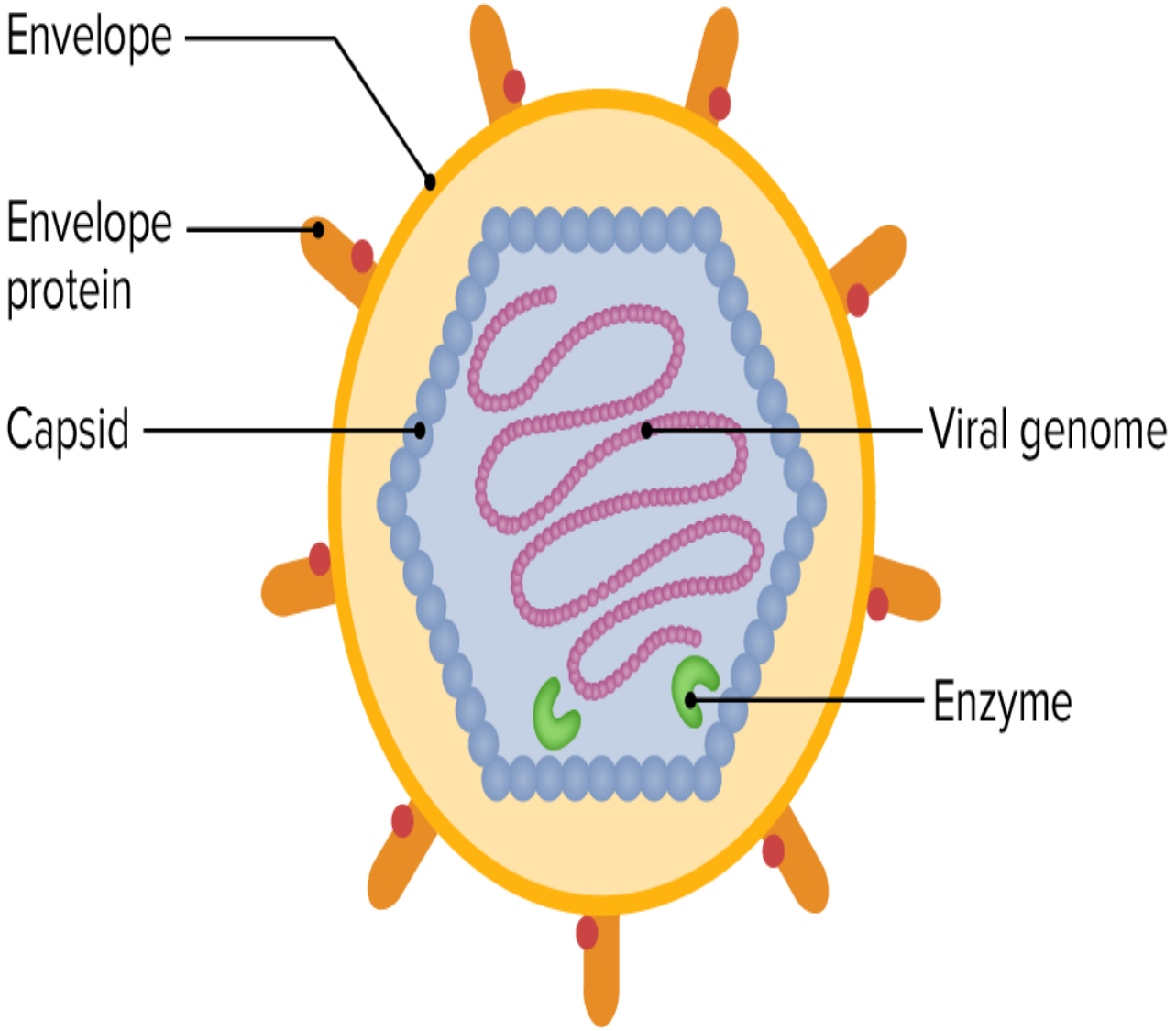
6. When a virus is completely assembled and capable of infection, it is known as a virion.

7. The structure of a simple virion comprises of an inner nucleic acid core surrounded by an outer casing of proteins known as the capsid.

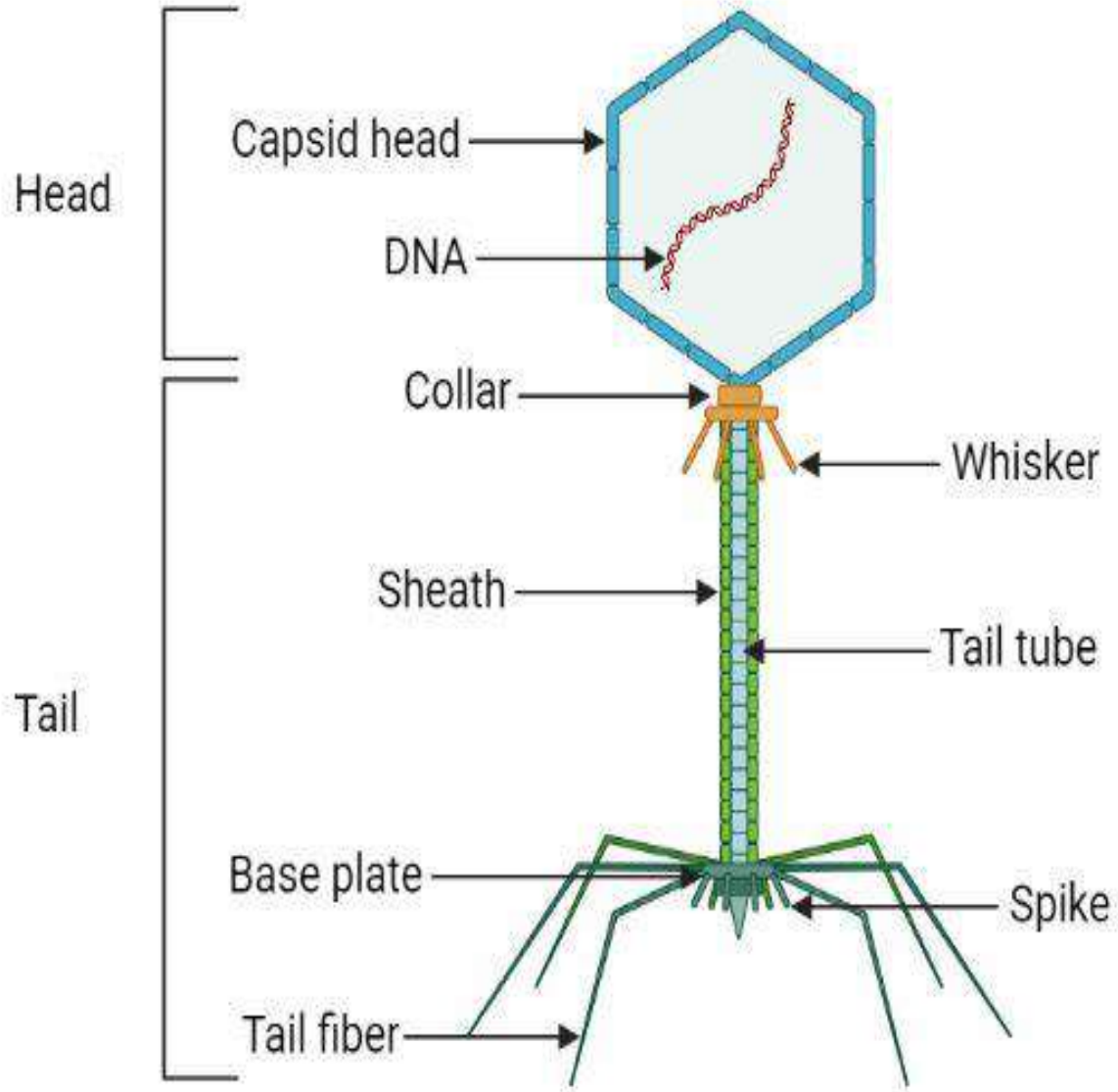
8. Capsids protect viral nucleic acids from being chewed up and destroyed by special host cell enzymes called nucleases.

9. The DNA or RNA found in the core of the virus can be single stranded or double stranded.

- 10. It constitutes the genome or the sum total of a virus's genetic information.
- 11. Viral genomes are generally small in size, coding only for essential proteins such as capsid proteins, enzymes, and proteins necessary for replication within a host cell.



Structure of Virus



Structure of Bacteriophage

Lecture 5

Cell Membrane

Cell Membrane

The cell membrane (also known as the plasma membrane or cytoplasmic membrane) thin membrane that surrounds every living cell.

Cell Membrane Functions

1. The primary function of the plasma membrane is to protect the cell from its surroundings.
2. It is a barrier keeping the constituents of the cell in and unwanted substances out.

3- It contains receptors and channels that allow specific molecules, such as ions, nutrients, wastes, and metabolic products that mediate cellular and extracellular activities to pass between the cell and the outside environment.

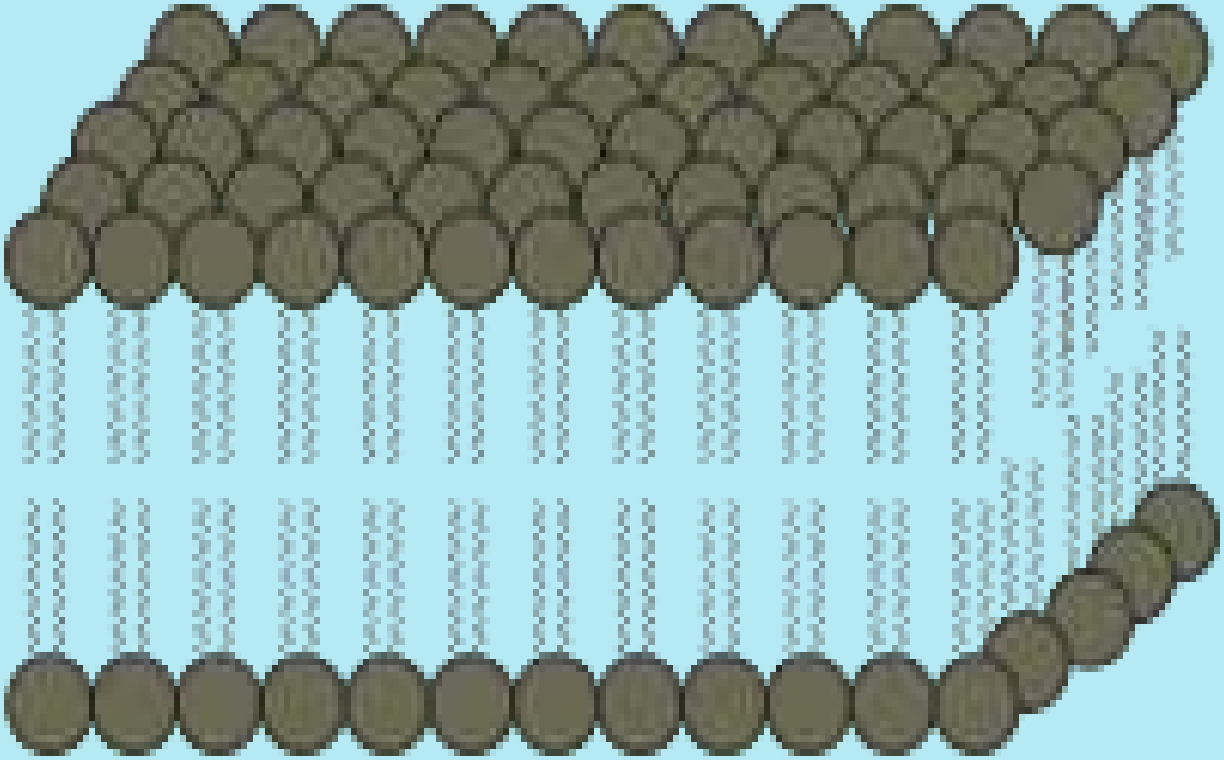
4.The plasma membrane also plays a role in attaching to the extracellular matrix and other cells to help group cells together to form tissues.

5. The cell membrane also provides some structural support for a cell.

Cell Membrane Structure (Models or cell membrane theories)

1- Model of bimolecular phospholipid membrane Gorter and Grendel (1925).

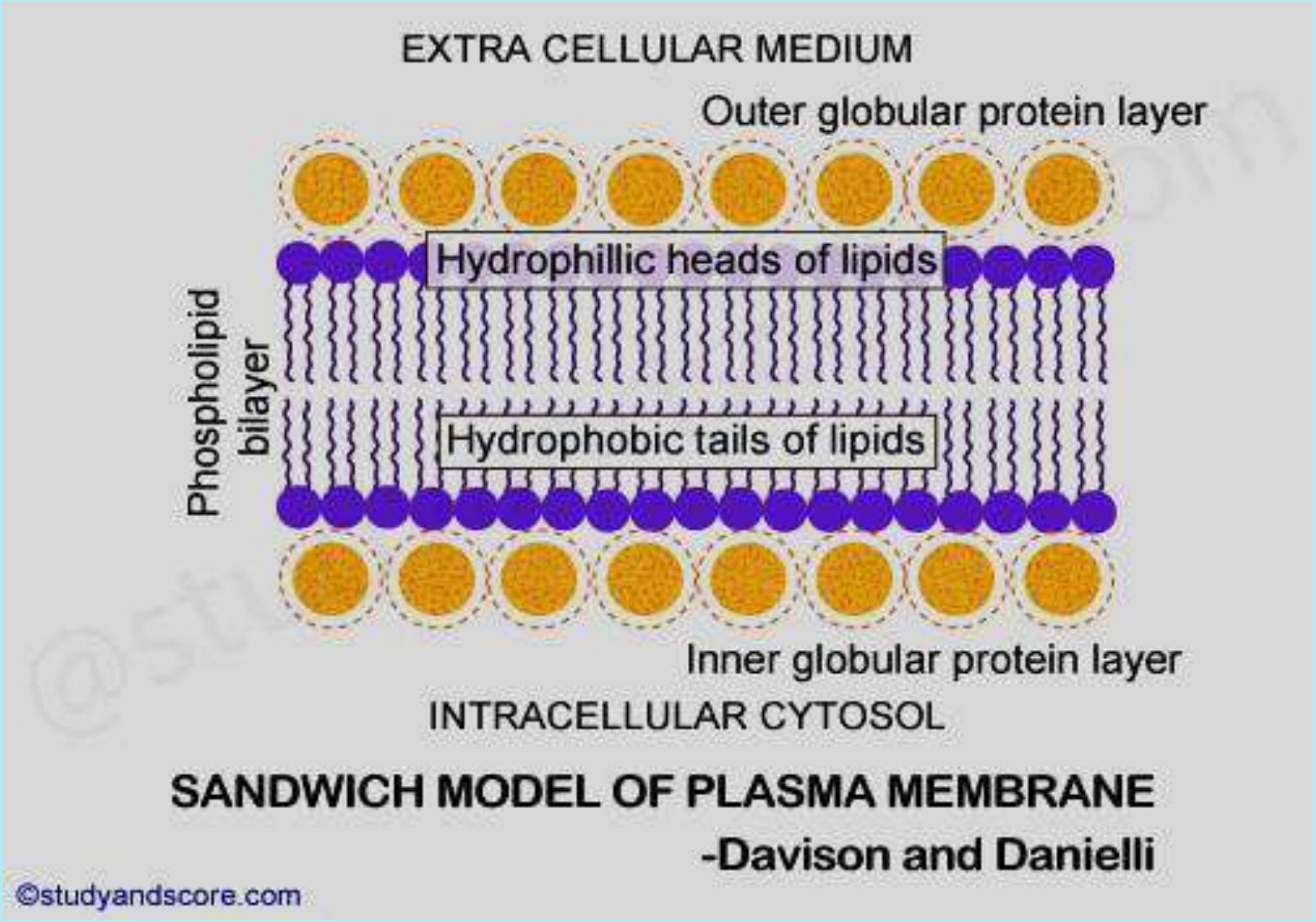
In 1925, Gorter and Grendel used acetone to extract lipids from a known quantity of red blood cells.



Model of bimolecular phospholipid membrane Gorter and Grendel (1925).

2- Sandwich model (Danielli and Davson in 1935)

Davson and Danielli postulate the presence of two films of globular proteins. protein associated with the polar head groups at each side of the bimolecular lipid leaflet, their model was **illustrated as a "sandwich" of protein-lipid-protein**


EXTRA CELLULAR MEDIUM
Outer globular protein layer
Hydrophillic heads of lipids
Phospholipid bilayer
Hydrophobic tails of lipids
Inner globular protein layer
INTRACELLULAR CYTOSOL
SANDWICH MODEL OF PLASMA MEMBRANE
-Davison and Danielli
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3- Unit membrane model

In 1950s David Robertson used electron microscope to propose the unit membrane model. He suggested that the membranes consist of a lipid bi-layer covered on both surfaces with thin sheets of proteins. The image appears as two dark lines, each about 25-30 Å thick, sandwiching a lighter zone

4- Fluid mosaic model

In 1972, Singer and Nicolson developed new ideas for membrane structure. Their proposal was **the fluid mosaic model** , which is the dominant model now. It has two key features:

1. A mosaic of proteins embedded in the membrane.
2. the membrane being a fluid bi-layer of lipids.

The lipid bi-layer suggestion agrees with previous models.

but views proteins as globular entities embedded in the layer instead of thin sheets on the surface.