BIO 101

CELL STRUCTURE AND FUNCTION OF ORGANELLES

INTRODUCTION

- Cells are as fundamental to the living systems of biology as the atom is to chemistry
- Cells makes anything alive and is self-sufficient to carry out all the fundamental functions of an organism.
- Cells provide shape, structure and carry out different types of functions to keep the entire system active.
- For example, epithelial cells protect the surface of the body and cover the organs and body cavities within.
- Bone cells help to support and protect the body

- Cells of the immune system fight invading bacteria. Additionally, red blood cells carry oxygen throughout the body.
- Each of these cell types plays a vital role during the growth, development, and day-to-day maintenance of the body.
- A cell is the smallest unit of a living thing. A living thing, like you, is called an organism.
- Thus, cells are the basic building blocks of all organisms.
- In multicellular organisms, several cells of one particular kind interconnect with each other and perform shared functions to form tissues (e.g. muscle tissue, connective tissue, and nervous tissue).

- Several tissues combine to form an organ (for example, stomach, heart, or brain).
- Several organs make up an organ system (such as the digestive system, circulatory system, or nervous system).
- Several systems functioning together form an organism (such as an elephant).
- There are many types of cells, and all are grouped into one of two broad categories: prokaryotic and eukaryotic.
- Animal cells, plant cells, fungal cells, and protist cells are classified as eukaryotic.
- Bacteria and archaea cells are classified as prokaryotic.

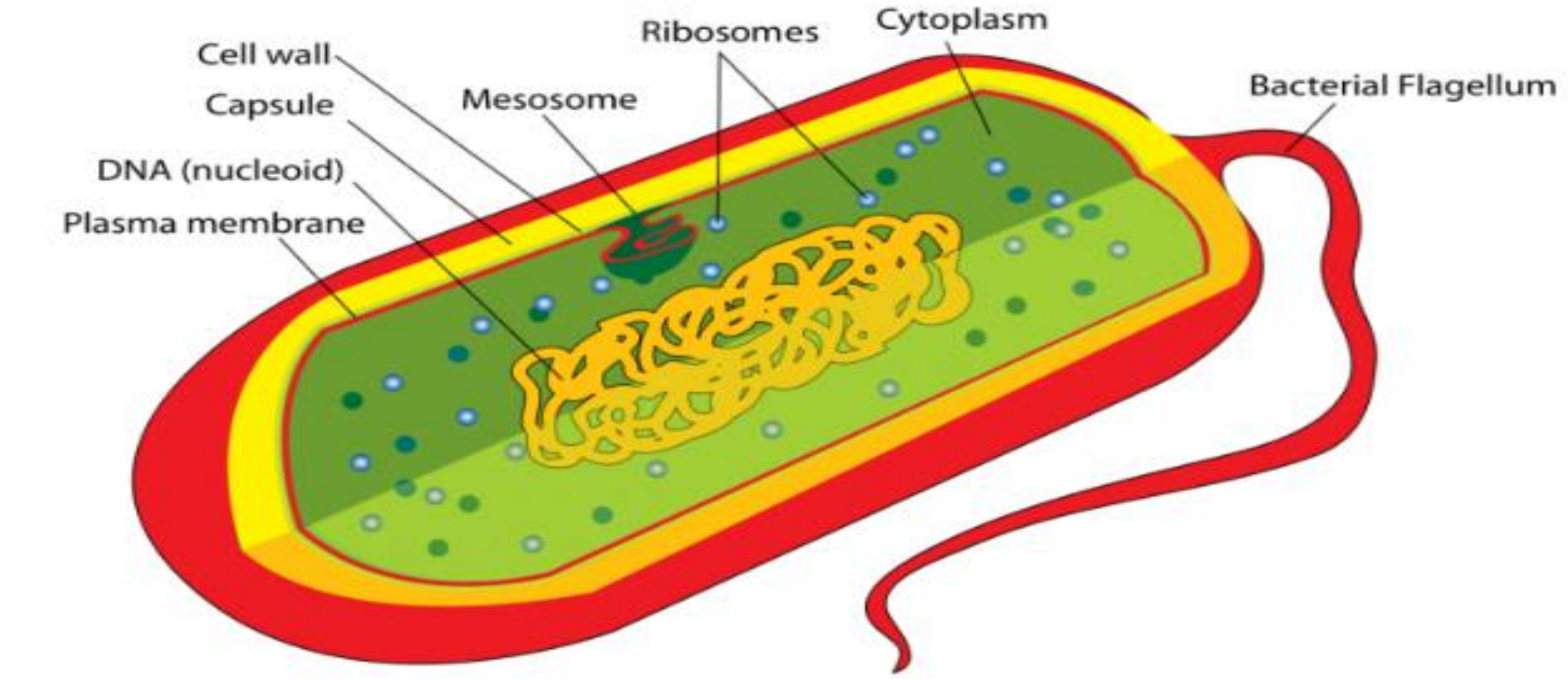

Fig. 1: Schematic diagram of a prokaryotic cell showing its cellular structure and parts

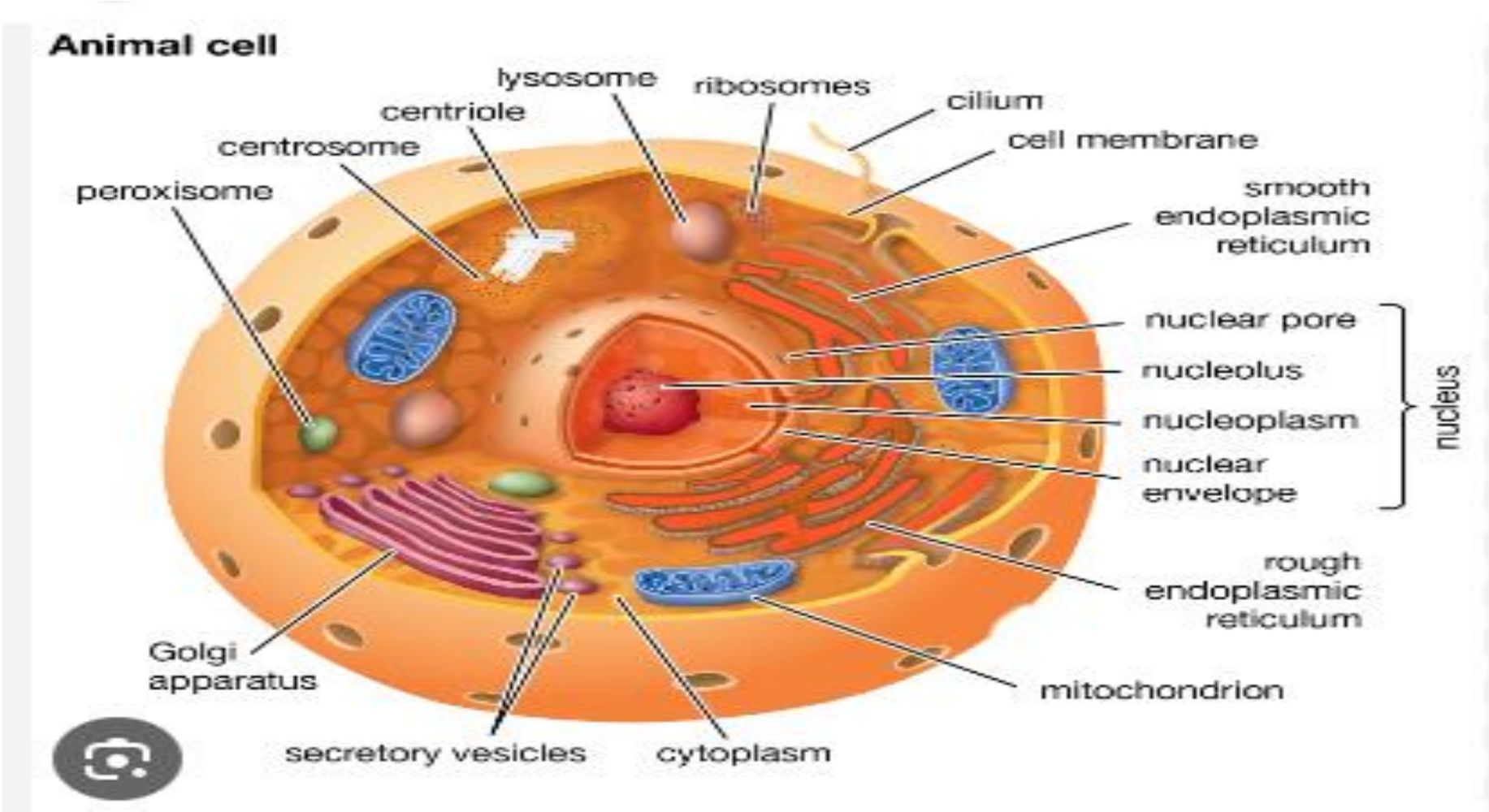

Figure 2: Schematic diagram of a Eukaryotic cell showing its cellular structure and parts

- The prokaryotic cells are the most primitive cells from the morphological point of view.

- They occur in the bacteria (*Pseudomonas aeruginosa*, *Escherichia coli*, *Staphylococcus aureus*, *Mycoplasma*, *Cyanobacteria* or blue-green algae).

- A prokaryotic cell is essentially a **one-envelope system** organized in depth.

- It consists of central nuclear components (*viz*., DNA molecule, RNA molecules and nuclear proteins) surrounded by cytoplasmic ground substance, with the whole enveloped by a plasma membrane

- The cytoplasm of a prokaryotic cell lacks in well-defined cytoplasmic organelles such as endoplasmic reticulum, Golgi apparatus, mitochondria, centrioles etc.

- They also do not contain nucleoli, cytoskeleton (microfilaments and microtubules), centrioles and basal bodies.

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- The eukaryotic cells are essentially **two envelope systems** and they are very much larger than prokaryotic cells.

- The eukaryotic cells are the true cells which occur in the plants (from algae to angiosperms) and the animals (from Protozoa to mammals).

➢ Though the eukaryotic cells have different shape, size, and physiology; all the cells are typically composed of ;

- plasma membrane, cytoplasm and its organelles, *viz*., mitochondria, endoplasmic reticulum, ribosomes, Golgi apparatus, etc., and a true nucleus.

DIFFRENCES BETWEEN PROKARYOTIC AND EUKARYOTIC CELLS

Features	Prokaryotes	Eukaryotes
Organisms	Bacteria	Protoctists, fungi, plants, animals
Size	0.5-10µm	10-100µm
Form	Mainly unicellular	Mainly multicellular except Protists
Cell Division	Binary fission, no spindle	Mitosis, meiosis, or both, spindle formed
Genetic materials	DNA is circular and lies free in the cytoplasm	DNA is linear and contained in a nucleus
Protein synthesis	No Endoplasmic reticulum	Ribosomes are present and attached to ER
Cell Wall	Rigid and contain polysaccharides	Contain polysaccharides, chitin in fungal, cellulose in plants cell
Respiration	Mesosomes in bacteria, except cytoplasmic membrane in b	Mitochondria for aerobic respiration
Photosynthesis	No chloroplast	Chloroplast containing membrane

- Loewy and Siekevitz (1963), defined a cell as “a unit of biological activity delimited by a semipermeable membrane and capable of self-reproduction in a medium free of other living systems”.

- Wilson and Morrison (1966) have defined the cell as “an integrated and continuously changing system.”

- John Paul (1970) has defined the cell as “the simplest integrated organization in living systems, capable of independent survival.”

- A virus is neither an organism nor a cell, yet it consists of a core of nucleic acid (DNA or RNA) enclosed in an external mantle of protein.

- In the free state, viruses are quite inert. They become activated only when they infect a living host cell and, in the process, only the nucleic acid core enters the host’s cell.

- The nucleic acid which is the genetic substance, takes over the metabolic activity of the host cell and utilizes the cell machinery for the formation of more viruses, ultimately killing the host cell.

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

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

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

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

- The basic shape of the eukaryotic cell is **spherical**; however, the shape is ultimately determined by the specific function of the cell. Thus, the shape of the cell may be **variable** (*i.e.*, frequently changing the shape) or **fixed**.

- In unicellular organisms the cell shape is maintained by tough plasma membrane and exoskeleton.

- In a multicellular organism, the shape of the cell depends mainly on its (i) functional adaptations and (ii) partly on the surface tension (iii) viscosity of the protoplasm (iv) cytoskeleton of microtubules (v) microfilaments and intermediate filaments (vi) the mechanical action exerted by adjoining cells and (vi) rigidity of the plasma membrane.

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CELL SIZE

- The eukaryotic cells are typically larger (mostly ranging between 10 to 100 µm) than the prokaryotic cells (mostly ranging between 1 to 10 µm).
- *Amoeba proteus* is biggest among the unicellular organisms; its length being 1mm (1000 µm).
- Another ciliate, *Paramecium caudatum* is from 150 to 300 µm (0.15 to 0.3 mm) in length.

- The size of the cells of multicellular organisms ranges between 20 to 30 µm. For instance, the human erythrocytes being 7 to 8 µm in diameter. Largest animal cell is the egg of ostrich, having a diameter of 18 cm

CELL WALL AND PLASMA MEMBRANE

- The outermost structure of most plant cells is a dead and rigid layer called **cell wall**
- It is mainly composed of carbohydrates such as cellulose, pectin, hemicellulose and lignin and certain fatty substances like waxes.
- There is a pectin-rich cementing substance between the walls of adjacent cells which is called **middle lamella**.
- The cell wall which is formed immediately after the division of cell, constitutes the **primary cell wall** (consist of pectin and hemicellulose).
- **Secondary cell wall** (Consist of cellulose, hemicellulose and lignin).
- The cell wall constitutes a kind of exoskeleton that provides protection and mechanical support to the plant cell. It determines the shape of plant cell and prevents it from desiccation.

- Every kind of animal cell is bounded by a living, extremely thin and delicate membrane called **plasmalemma, cell membrane** or **plasma membrane**.
- The plasma membrane exhibits three-layered structure with a translucent layer sandwiched between two dark layers.
- At molecular level, it consists of a continuous bilayer of lipid molecule (*i.e.*, phospholipids and cholesterol) with protein molecules embedded in it.
- Some carbohydrate molecules may also be attached to the external surface of the plasma membrane, they are glycoproteins or glycolipids.

- The plasma membrane is a **selectively permeable membrane** ; its main function is to control selectively the entrance and exit of materials.

- For bulk transport of large-sized molecules, plasma membrane performs **endocytosis** (*i.e*,endocytosis, pinocytosis, receptor-mediated endocytosis and phagocytosis) and **exocytosis** both of these processes also utilize energy in the form of ATP molecules.

- Various cell organelles such as chloroplasts, mitochondria, endoplasmic reticulum and lysosomes are also bounded by membranes similar to the plasma membrane.

CYTOPLASM

- The plasma membrane is followed by the colloidal organic fluid called **matrix** or **cytosol**.
- The cytosol is the aqueous portion of the **cytoplasm** (the extranuclear protoplasm) and of the **nucleoplasm** (the nuclear protoplasm).
- In many types of cells, the cytosol is differentiated into following two parts:

(i) **Ectoplasm** or **cell cortex** is the peripheral layer of cytosol which is relatively non-granular, viscous, clear and rigid.

(ii) **Endoplasm** is the inner portion of cytosol which is granular and less viscous.

- The cytosol serves to dissolve or suspend the great variety of small molecules concerned with cellular metabolism, *e.g.*, glucose, amino acids, nucleotides, vitamins, minerals, oxygen and ions.

ENDOPLASMIC RETICULUM (ER)

- Within the cytoplasm of most animal cells is an extensive network (reticulum) of membrane-limited channels, collectively called **endoplasmic reticulum.**
- The outer surface of **rough ER** has attached ribosomes, whereas **smooth ER** do not have attached ribosomes.
- Functions of smooth ER include **lipid metabolism** (both catabolism and anabolism; they synthesize a variety of phospholipids, cholesterol and steroids); **glycogenolysis** (degradation of glycogen; glycogen being polymerized in the cytosol) and **drug detoxification.**
- Rough ER (RER) contain certain ribosome specific, transmembrane glycoproteins, called **ribophorins I** and **II,** to which are attached the ribosomes that are engaged in polypeptide synthesis.

GOLGI APPARATUS

- It is a cup-shaped organelle which is located near the nucleus in many types of cells.
- Golgi apparatus consists of a set of smooth **cisternae** (*i.e.*, closed fluid-filled flattened membranous sacs or vesicles) which often are stacked together in parallel rows. It is surrounded by spherical membrane bound **vesicles** which appear to transport proteins to and from it.
- Golgi apparatus consists of at least three distinct classes of cisternae: **cis Golgi, median Golgi** and **trans Golgi**, each of which has distinct enzymatic activities.
- Synthesized proteins appear to move in the following direction: rough ER→ cis Golgi→ median Golgi →trans Golgi→secretory vesicles/ cortical granules of egg/ lysosomes or peroxisomes.

FUNCTION OF GOLGI APPARATUS

- 1. The packaging of secretory materials (*e.g.*, enzymes, mucin, lactoprotein of milk, melanin pigment, etc.) that are to be discharged from the cell.
- 2.The **processing** of proteins, *i.e.*, glycosylation, phosphorylation, proteolysis.
- 3. The synthesis of certain polysaccharides and glycolipids.
- 4. The sorting of proteins destined for various locations (*e.g.*, lysosomes, peroxisomes, etc.) in the cell.
- 5. Formation of the acrosome of the spermatozoa.

LYSOSOMES

- The cytoplasm of animal cells contains many tiny, spheroid or irregular-shaped, membrane-bounded vesicles known as **lysosomes**.

- The lysosomes originated from Golgi apparatus and contain numerous hydrolytic enzymes (*e.g.*, **acid phosphatase** that is cyto-chemically identified) for intracellular and extracellular digestion.

- They digest the material taken in by endocytosis (such as phagocytosis endocytosis and pinocytosis), parts of the cell (by autophagy).

- There are four major types (i) Primary (storage vacuoles) (ii) Secondary (digestive vacuoles), residual vacuole and autophagic vacuoles.

PEROXISOMES

- These are tiny circular membrane bound organelles containing a crystal-core of enzymes (such as urate oxidase, peroxidase, D-amino oxidase and catalase, *e.g.*, liver cells and kidney cells).
- They are required for detoxification of the cells.

- In green leaves of plants, peroxisomes carry out the process of
- **photorespiration**.

GLYOXYSOMES

- These organelles develop in a germinating plant seed (*e.g.*, castor bean or *Ricinus*) to utilize stored fat of the seed (*i.e.*, to metabolise the triglycerides).

- Enzymes of glyoxysomes are used to transform the fat stores of the seed into carbohydrates by way of **glyoxylate cycle**.

MITOCHONDRIA

- Mitochondria are oxygen-consuming ribbon-shaped cellular organelles of immense importance.
- The outer layer is rich in PORINS
- The inner layer is rich in enzymes e.g. enzymes and co-enzymes required for glycolysis and Kreb cycle.
- They are commonly found in cells where energy is needed e.g. tail of sperm cells, muscle cells, liver cells etc.

PLASTIDS AND CHROMOPLAST

- Plastids occur only in the plant cells and contain pigments that synthesize and accumulate various substances.e.g Amyloplasts, proteinoplasts, leucoplasts

- Chromoplasts impart a variety of colours to plant cells, such as red colour in tomatoes, red chillies and carrots, various colours to petals of flowers and green colour to many plant cells.
- The green coloured chromoplasts are called **chloroplasts**.

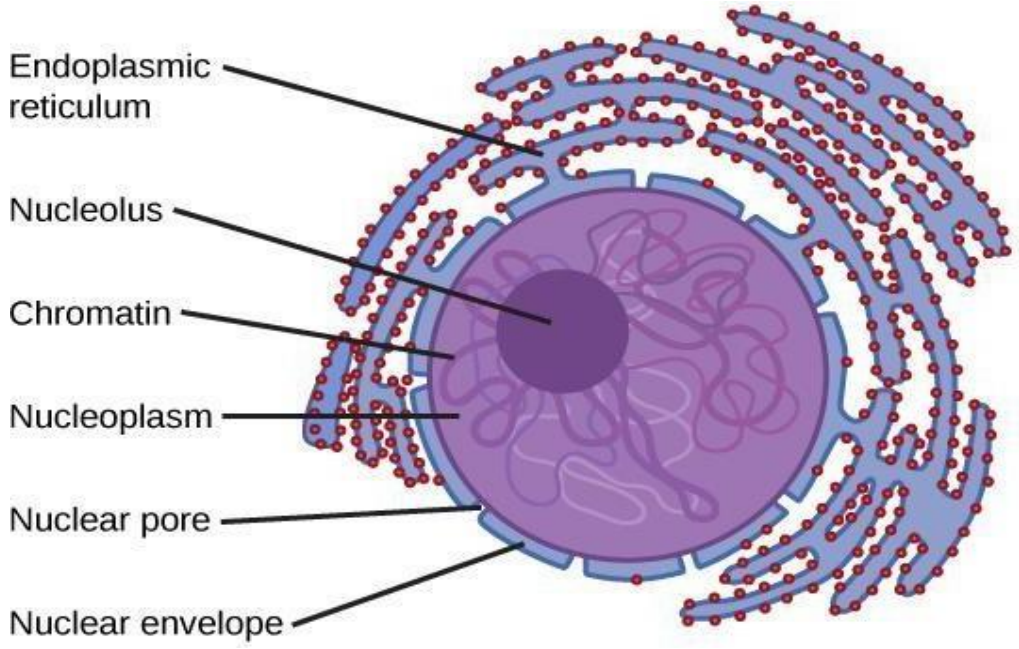
RIBOSOMES

- They are primarily found in all cells and serve as a scaffold for the ordered interaction of the numerous molecules involved in protein synthesis.

- Ribosome granules may exist either in the **free state (Smooth ER)** in the cytosol (*e.g.*, basal epidermal cells) or **attached** to (**Rough ER)** (*e.g.*, pancreatic acinar cells, plasma cells or antibodies-secreting lymphocytes, osteoblasts, etc.).

NUCLEUS

- The nucleus is centrally located and spherical cellular component which controls all the vital activities of the cytoplasm and carries the hereditary material the DNA in it. The nucleus consists of the following structures:
- Chromatin
- Heterochromatin



QUIZ

- Which structure is common to plant *and* animal cells? (A) chloroplast (B) central vacuole (C) mitochondrion (D) centriole.
- Which of the following is present in a prokaryotic cell? (A) mitochondrion (B) ribosome (C) nuclear envelope (D) chloroplast
- Which structure is *not* part of the endomembrane system? (A) nuclear envelope (B) chloroplast (C) Golgi apparatus (D) plasma membrane.
- Cyanide binds to at least one molecule involved in producing ATP. If a cell is exposed to cyanide, most of the cyanide will be found within the (A) mitochondria (B) ribosomes (C) peroxisomes(D) lysosomes.