Chapter 8: Cell: The Unit of Life

Exercises — Exercises

Q1 Which of the following is not correct?
(a) Robert Brown discovered the cell.
(b) Schleiden and Schwann formulated the cell theory.
(c) Virchow explained that cells are formed from pre-existing cells.
(d) A unicellular organism carries out its life activities within a single cell.

SOLUTION

The cell was first discovered and described by Robert Hooke (1665), not Robert Brown.
Robert Brown discovered the nucleus (1831).
Options (b), (c), and (d) are all correct statements:
- Schleiden (1838) and Schwann (1839) together formulated the cell theory.
- Virchow (1855) added the principle that all cells arise from pre-existing cells (Omnis cellula-e cellula).
- A unicellular organism such as Amoeba or Paramecium performs all life activities within a single cell.

Answer: (a) Robert Brown discovered the cell — is NOT correct. Robert Hooke discovered the cell; Robert Brown discovered the nucleus.

Q2 New cells generate from
(a) bacterial fermentation
(b) regeneration of old cells
(c) pre-existing cells
(d) abiotic materials

SOLUTION

This is based on the principle proposed by Rudolf Virchow (1855): Omnis cellula-e cellula — all cells arise from pre-existing cells.
New cells are formed by the division of already existing cells.
They do not arise from fermentation, regeneration of old (dead) cells, or from non-living (abiotic) materials.

Answer: (c) pre-existing cells

Q3 Match the following:

Column I	Column II
(a) Cristae	(i) Flat membranous sacs in stroma
(b) Cisternae	(ii) Infoldings in mitochondria
(c) Thylakoids	(iii) Disc-shaped sacs in Golgi apparatus

SOLUTION

(a) Cristae — (ii) Infoldings in mitochondria
Cristae are infoldings of the inner mitochondrial membrane that project into the matrix, increasing surface area for ATP synthesis.

(b) Cisternae — (iii) Disc-shaped sacs in Golgi apparatus
Cisternae are the flattened, disc-shaped membranous sacs (0.5-1.0 um diameter) stacked in parallel to form the Golgi complex.

(c) Thylakoids — (i) Flat membranous sacs in stroma
Thylakoids are organised, flattened membranous sacs present in the stroma of the chloroplast; they are stacked into grana.

Answer: (a)-(ii), (b)-(iii), (c)-(i)

Q4 Which of the following is correct:
(a) Cells of all living organisms have a nucleus.
(b) Both animal and plant cells have a well defined cell wall.
(c) In prokaryotes, there are no membrane bound organelles.
(d) Cells are formed de novo from abiotic materials.

SOLUTION

(a) Incorrect — Prokaryotic cells (bacteria, cyanobacteria) lack a membrane-bound nucleus. Mature mammalian erythrocytes and sieve tube cells of plants also lack a nucleus.
(b) Incorrect — Only plant cells (and fungi/bacteria) have a cell wall. Animal cells lack a cell wall; they are bounded only by the plasma membrane.
(c) Correct — Prokaryotic cells do not possess membrane-bound organelles such as mitochondria, endoplasmic reticulum, Golgi complex, or lysosomes. Ribosomes are present but are non-membrane-bound.
(d) Incorrect — Cells arise only from pre-existing cells (Virchow's principle), not from abiotic (non-living) materials.

Answer: (c) In prokaryotes, there are no membrane bound organelles.

Q5 What is a mesosome in a prokaryotic cell? Mention the functions that it performs.

SOLUTION

A mesosome is a specialised membranous structure found in prokaryotic cells, particularly bacteria.
It is formed by extensions (infoldings) of the plasma membrane into the cell interior. These extensions may be in the form of vesicles, tubules, or lamellae.

Functions of the mesosome:
1. Cell wall formation — assists in the synthesis and assembly of the new cell wall during cell division.
2. DNA replication and distribution — helps in the replication of the bacterial chromosome (genomic DNA) and its distribution to daughter cells.
3. Respiration — increases the surface area of the plasma membrane, providing additional sites for respiratory enzymes, thereby facilitating aerobic respiration.
4. Secretion — involved in secretory processes of the cell.
5. Increases surface area of the plasma membrane and enzymatic content of the cell.

Answer: A mesosome is an infolding of the plasma membrane in prokaryotes (appearing as vesicles, tubules, or lamellae). It aids in cell wall formation, DNA replication and segregation to daughter cells, respiration, and secretion.

Q6 How do neutral solutes move across the plasma membrane? Can the polar molecules also move across it in the same way? If not, then how are these transported across the membrane?

SOLUTION

Movement of neutral solutes:
Neutral (non-polar) solutes move across the plasma membrane by simple diffusion along the concentration gradient — from a region of higher concentration to a region of lower concentration. This process requires no energy (passive transport).

Movement of polar molecules:
Polar molecules cannot pass through the non-polar (hydrophobic) lipid bilayer by simple diffusion because the hydrophobic tails of the phospholipids repel them.

Polar molecules are transported across the membrane by two mechanisms:

1. Facilitated diffusion — Polar molecules (e.g., glucose, amino acids) are transported along their concentration gradient with the help of specific carrier proteins embedded in the membrane. No energy (ATP) is required.
2. Active transport — Some ions or molecules must move against their concentration gradient (from lower to higher concentration). This is an energy-dependent process that uses ATP. Example: Na+/K+ pump, which pumps sodium ions out and potassium ions into the cell against their respective gradients.

Answer: Neutral solutes move across the plasma membrane by simple diffusion (along concentration gradient, no energy needed). Polar molecules cannot cross the lipid bilayer this way; they are transported via carrier proteins by facilitated diffusion (along gradient, no ATP) or by active transport (against gradient, ATP-dependent, e.g., Na+/K+ pump).

Q7 Name two cell-organelles that are double membrane bound. What are the characteristics of these two organelles? State their functions and draw labelled diagrams of both.

SOLUTION

The two double membrane-bound cell organelles are:
1. Mitochondria
2. Chloroplasts (Plastids)

MITOCHONDRIA
Characteristics:
- Sausage-shaped or cylindrical; 0.2-1.0 um diameter, 1.0-4.1 um length.
- Bounded by two membranes: smooth outer membrane and inner membrane that forms infoldings called cristae into the matrix.
- The two membranes create two compartments: outer compartment (between membranes) and inner compartment (matrix).
- Matrix contains circular DNA, RNA, 70S ribosomes, and enzymes for protein synthesis.
- Divide by fission.

Functions of Mitochondria:
- Site of aerobic respiration (Krebs cycle in matrix; electron transport chain on inner membrane).
- Produce ATP — hence called the 'powerhouse of the cell'.

Labelled diagram of Mitochondria (longitudinal section):
Key labels: Outer membrane, Inner membrane, Inter-membrane space (outer compartment), Matrix (inner compartment), Cristae (infoldings of inner membrane), Ribosome (70S).

CHLOROPLAST
Characteristics:
- Lens-shaped, oval, spherical, discoid or ribbon-like; 5-10 um length, 2-4 um width.
- Bounded by two membranes: outer membrane (more permeable) and inner membrane (less permeable).
- Space enclosed by the inner membrane is the stroma, which contains enzymes for the synthesis of carbohydrates and proteins.
- Stroma contains double-stranded circular DNA and 70S ribosomes.
- Within the stroma are flattened membranous sacs called thylakoids; stacks of thylakoids form grana.
- Grana are connected by flat membranous tubules called stroma lamellae.
- Thylakoid membrane encloses a space called the lumen; chlorophyll pigments are located in the thylakoid membrane.

Functions of Chloroplast:
- Site of photosynthesis: light reactions occur on the thylakoid membranes (grana); dark reactions (Calvin cycle) occur in the stroma.
- Traps light energy using chlorophyll and carotenoid pigments and converts it to chemical energy (ATP, NADPH).

Labelled diagram of Chloroplast (sectional view):
Key labels: Outer membrane, Inner membrane, Stroma, Thylakoid, Granum (stack of thylakoids), Stroma lamellae (intergranal thylakoids), Lumen (inside thylakoid), DNA (circular), Ribosome (70S).

Answer: The two double membrane-bound organelles are mitochondria and chloroplasts. Mitochondria are the sites of aerobic respiration and ATP production ('powerhouse'); they have cristae (inner membrane infoldings) and a matrix with 70S ribosomes and circular DNA. Chloroplasts are the sites of photosynthesis; they contain thylakoids organised into grana (for light reactions) and stroma (for dark reactions), with 70S ribosomes and circular DNA.

Q8 What are the characteristics of prokaryotic cells?

SOLUTION

Characteristics of prokaryotic cells:

1. Size — Generally smaller than eukaryotic cells; they multiply more rapidly.
2. No membrane-bound nucleus — Genetic material is naked (not enclosed by a nuclear membrane). The chromosome is a single, circular DNA molecule.
3. Cell envelope — Most prokaryotes have a chemically complex cell envelope consisting of three layers: outermost glycocalyx, cell wall, and plasma membrane (except Mycoplasma, which lacks a cell wall).
4. Glycocalyx — May be a loose slime layer or a thick, tough capsule depending on the species.
5. Cell wall — Gives shape and provides structural support to prevent bursting or collapsing.
6. Plasma membrane — Selectively permeable; structurally similar to eukaryotic membrane.
7. Mesosome — A specialised infolding of the plasma membrane; aids in cell wall synthesis, DNA replication/distribution, and respiration.
8. No membrane-bound organelles — Organelles such as mitochondria, endoplasmic reticulum, Golgi complex, lysosomes, and plastids are absent.
9. Ribosomes — 70S type (50S + 30S subunits); non-membrane-bound; site of protein synthesis. Several ribosomes may form a polysome.
10. Plasmids — Many bacteria contain small, circular, extrachromosomal DNA called plasmids that confer special characters (e.g., antibiotic resistance).
11. Flagella (if present) — Composed of three parts: filament, hook, and basal body. Structurally different from eukaryotic flagella.
12. Pili and Fimbriae — Surface structures made of protein; not involved in motility; help in attachment to surfaces or host tissues.
13. Inclusion bodies — Reserve materials (e.g., phosphate granules, glycogen granules, cyanophycean granules) stored free in cytoplasm, not membrane-bound.
14. Chromatophores — Present in some prokaryotes (e.g., cyanobacteria); membranous extensions containing pigments.

Answer: Prokaryotic cells: small size; no membrane-bound nucleus (naked circular DNA); complex cell envelope (glycocalyx + cell wall + plasma membrane, absent in Mycoplasma); mesosome present; 70S ribosomes; no membrane-bound organelles; plasmids present in many; flagella (if present) of filament-hook-basal body structure; pili/fimbriae present; reserve materials stored as free inclusion bodies.

Q9 Multicellular organisms have division of labour. Explain.

SOLUTION

In multicellular organisms, the body is composed of millions of cells. Not all cells are identical; they differentiate structurally and functionally to perform specific tasks.

Division of labour means that different cells, tissues, and organs are specialised to carry out distinct functions, making the organism more efficient than if every cell had to perform all functions simultaneously.

Examples of division of labour at the cellular level:
- Nerve cells (neurons) are long, branched, and specialised for transmission of electrical signals.
- Muscle cells are elongated and contractile, specialised for movement.
- Red blood cells (erythrocytes) are disc-shaped, rich in haemoglobin, and specialised for oxygen transport.
- Mesophyll cells in leaves are packed with chloroplasts for photosynthesis.
- Gland cells are specialised for secretion of enzymes or hormones.

At the tissue and organ level:
- The digestive system handles food breakdown and nutrient absorption.
- The respiratory system manages gas exchange.
- The nervous system coordinates body functions.

This specialisation allows each type of cell to be highly efficient at its particular task. The collective functioning of all specialised cells keeps the whole organism alive and functional — just as a factory with specialised workers and departments is far more productive than each worker doing everything alone.

Thus, multicellular organisms show division of labour at cellular, tissue, organ, and organ-system levels.

Answer: In multicellular organisms, different cells are structurally specialised to perform specific functions (e.g., nerve cells for impulse conduction, muscle cells for contraction, RBCs for O2 transport). This division of labour at cellular, tissue, and organ levels makes the organism more efficient than if every cell performed all functions.

Q10 Cell is the basic unit of life. Discuss in brief.

SOLUTION

The cell is considered the basic structural and functional unit of all living organisms for the following reasons:

1. Structural unit — All organisms, whether unicellular (e.g., Amoeba, Paramecium, bacteria) or multicellular (e.g., plants, animals), are composed of cells. The cell is the smallest unit that has a definite organisation and is enclosed by a membrane.

2. Functional unit — All vital life processes occur within cells. Nutrition, respiration, excretion, reproduction, growth, and response to stimuli are all carried out at the cellular level.

3. Unicellular organisms — A single cell performs all life functions independently (e.g., Amoeba feeds, respires, reproduces, and responds to stimuli — all within one cell). Anything smaller than a complete cell cannot independently sustain life.

4. Multicellular organisms — Although composed of many specialised cells, every function ultimately occurs at the cellular level. Tissues, organs, and organ systems are aggregates of cells working in a coordinated manner.

5. Cell theory — Formulated by Schleiden, Schwann, and Virchow: all living organisms are composed of cells and products of cells, and all cells arise from pre-existing cells. This confirms the central role of the cell in biology.

6. Genetic continuity — Each cell contains DNA, the hereditary material. Cell division ensures transmission of genetic information from parent to daughter cells, ensuring continuity of life.

Thus, the cell is the fundamental unit of structure, function, and heredity in all life forms.

Answer: The cell is the smallest unit capable of independent existence and performing all essential life functions (nutrition, respiration, reproduction, etc.). All organisms are composed of cells; cell theory (Schleiden, Schwann, Virchow) confirms this. Unicellular organisms perform all functions in one cell; in multicellular organisms all functions are ultimately cellular. Cell also carries genetic material ensuring continuity of life.

Q11 What are nuclear pores? State their function.

SOLUTION

Nuclear pores are minute, circular openings (passages) present in the nuclear envelope.

Structure:

- The nuclear envelope consists of two parallel membranes separated by a perinuclear space (10-50 nm).
- At certain places, the two membranes fuse together, creating gaps called nuclear pores.
- Each nuclear pore is lined by a complex protein structure called the nuclear pore complex.

Function:

- Nuclear pores are the passages through which the movement of RNA molecules (including mRNA, rRNA, tRNA) and protein molecules takes place in BOTH directions between the nucleus and the cytoplasm.
- mRNA (carrying genetic information) moves from nucleus to cytoplasm for protein synthesis.
- Ribosomal proteins and other regulatory proteins move from the cytoplasm into the nucleus.
- They thus facilitate bidirectional exchange of materials between the nucleus and cytoplasm, allowing the nucleus to control cellular activities.

Answer: Nuclear pores are openings formed by the fusion of the two membranes of the nuclear envelope. They serve as passages for bidirectional movement of RNA (mRNA, rRNA, tRNA) from nucleus to cytoplasm and proteins from cytoplasm to nucleus, enabling the nucleus to regulate cellular activities.

Q12 Both lysosomes and vacuoles are endomembrane structures, yet they differ in terms of their functions. Comment.

SOLUTION

Both lysosomes and vacuoles are part of the endomembrane system (their functions are coordinated with ER and Golgi apparatus) and are membrane-bound organelles.

Lysosomes:
- Membrane-bound vesicular structures formed by the packaging process in the Golgi apparatus.
- Contain a variety of hydrolytic enzymes (hydrolases — lipases, proteases, carbohydrases) that are optimally active at acidic pH.
- Function: Intracellular digestion — digest worn-out cell organelles (autophagy), foreign particles (heterophagy), and macromolecules (carbohydrates, proteins, lipids, nucleic acids).
- Also called 'suicidal bags' because they can digest the entire cell if the membrane ruptures.

Vacuoles:
- Membrane-bound spaces in the cytoplasm, enclosed by a single membrane called the tonoplast.
- Contain water, sap, excretory products, and other materials not useful to the cell.
- In plant cells: large central vacuole occupies up to 90% of cell volume; the tonoplast actively transports ions and other materials into the vacuole against concentration gradients, maintaining turgor pressure.
- In Amoeba: contractile vacuole is specialised for osmoregulation and excretion.
- In protists: food vacuoles are formed by engulfing food particles (phagocytosis).

Key difference in function:
Lysosomes are primarily digestive organelles containing hydrolytic enzymes for breaking down macromolecules. Vacuoles are primarily storage/osmoregulatory organelles containing sap, excretory products, or food; they play a key role in maintaining turgor and storing metabolites.

Answer: Lysosomes are digestive vesicles (from Golgi) rich in hydrolytic enzymes at acidic pH; they digest macromolecules and worn-out organelles. Vacuoles are storage spaces bounded by tonoplast; in plants they maintain turgor and store ions/metabolites (up to 90% of cell volume); in Amoeba they aid osmoregulation; in protists they engulf food. Both are endomembrane structures but differ completely in contents and function.

Q13 Describe the structure of the following with the help of labelled diagrams.
(i) Nucleus
(ii) Centrosome

SOLUTION

(i) NUCLEUS

The nucleus was first described by Robert Brown (1831). It is the control centre of the cell.

Structure of the nucleus (interphase nucleus):

1. Nuclear envelope — A double membrane structure (two parallel membranes) that forms a barrier between the nuclear contents and the cytoplasm. The two membranes are separated by a perinuclear space (10-50 nm). The outer membrane is continuous with the endoplasmic reticulum and bears ribosomes on its surface.

2. Nuclear pores — Minute openings formed by the fusion of the two nuclear membranes. They allow bidirectional movement of RNA and protein molecules between nucleus and cytoplasm.

3. Nucleoplasm (nuclear matrix) — The dense fluid filling the interior of the nucleus. It contains chromatin and nucleoli.

4. Chromatin — Loosely extended nucleoprotein fibres made of DNA, histone proteins, non-histone proteins, and RNA. During cell division, chromatin condenses into distinct chromosomes.

5. Nucleolus — One or more spherical, non-membrane-bound structures present in the nucleoplasm. Site of active ribosomal RNA (rRNA) synthesis. Larger and more numerous in cells actively carrying out protein synthesis.

Labelled diagram of Nucleus:
Key labels: Nuclear membrane (envelope), Nuclear pore, Nucleoplasm,

Nucleolus, Chromatin (nucleoprotein fibres).

(ii) CENTROSOME

The centrosome is an organelle found in animal cells (absent in most plant cells). It lies near the nucleus.

Structure:
- A centrosome contains two cylindrical structures called centrioles, surrounded by amorphous pericentriolar material.
- The two centrioles lie perpendicular to each other.
- Each centriole has a cartwheel-like organisation:
  - Made up of nine evenly spaced peripheral fibrils of tubulin protein.
  - Each peripheral fibril is a triplet (three microtubules fused together).
  - Adjacent triplets are linked to each other.
  - The central part of the proximal region is proteinaceous and called the hub.
  - The hub is connected to the peripheral triplets by radial spokes made of protein.

Functions of centrioles:
- Form the basal bodies of cilia and flagella.
- Give rise to spindle fibres that form the spindle apparatus during cell division in animal cells.

Labelled diagram of Centrosome:
Key labels: Two centrioles (arranged perpendicular to each other), Peripheral fibrils (triplets of tubulin), Hub (central proteinaceous region), Radial spokes, Pericentriolar material.

Answer: (i) Nucleus: bounded by double-membrane nuclear envelope with nuclear pores; contains nucleoplasm, chromatin (DNA+histones+RNA), and nucleolus (rRNA synthesis site). (ii) Centrosome: contains two perpendicular centrioles, each a cartwheel of 9 peripheral tubulin triplets connected by radial spokes to a central hub, surrounded by pericentriolar material; forms basal bodies of cilia/flagella and spindle fibres during cell division.

Q14 What is a centromere? How does the position of centromere form the basis of classification of chromosomes. Support your answer with a diagram showing the position of centromere on different types of chromosomes.

SOLUTION

Centromere:

The centromere is the primary constriction present on every chromosome. It is the region where two chromatids of a chromosome are held together. Disc-shaped protein structures called kinetochores are present on the sides of the centromere; kinetochores serve as attachment sites for spindle fibres during cell division.

Classification of chromosomes based on centromere position:

Chromosomes are classified into four types depending on where the centromere is located:

1. Metacentric — Centromere is at the middle of the chromosome, forming two arms of equal length.
   Shape: V-shaped during anaphase.

2. Sub-metacentric — Centromere is slightly away from the middle, resulting in one shorter arm (p-arm) and one longer arm (q-arm).
   Shape: L-shaped during anaphase.

3. Acrocentric — Centromere is situated close to one end of the chromosome, forming one extremely short arm and one very long arm.
   Shape: J-shaped during anaphase.

4. Telocentric — Centromere is at the terminal end (tip) of the chromosome.
   Shape: I-shaped (rod-shaped) during anaphase.

Note: Some chromosomes also have a secondary constriction at a constant location, giving the appearance of a small fragment called the satellite.

Labelled diagram — Types of chromosomes based on centromere position:
The diagram shows four chromosomes in metaphase (X-shaped, two chromatids visible):
- Metacentric: centromere at centre; two equal arms on each side.
- Sub-metacentric: centromere shifted slightly from centre; one short arm (p) and one long arm (q).
- Acrocentric: centromere very close to one end; one very short arm and one very long arm; may show satellite on short arm and secondary constriction.
- Telocentric: centromere at the very tip; only one visible arm.

Key labels on diagram: Short arm, Long arm, Centromere, Satellite, Secondary constriction.

Answer: The centromere is the primary constriction of a chromosome where the two chromatids are held together; kinetochores are present on its sides for spindle fibre attachment. Based on centromere position, chromosomes are: metacentric (centromere at middle, equal arms), sub-metacentric (centromere off-centre, one short + one long arm), acrocentric (centromere near one end, one very short + one very long arm), and telocentric (centromere at terminal end, only one arm visible).