Exercise

A. Multiple choice — correct answer + short explanation

1. **(b) Mitochondria.**
   Cellular respiration (aerobic) occurs mainly in the mitochondria — glycolysis happens in the cytosol, but the Krebs cycle (matrix) and electron transport / oxidative phosphorylation (inner mitochondrial membrane) take place in mitochondria.
2. **(b) Lipids.**
   The smooth endoplasmic reticulum (SER) is primarily involved in lipid synthesis, detoxification of drugs/poisons (especially in liver cells) and Ca^{2+} storage.
3. **(a) RNA and protein.**
   Ribosomes are made of ribosomal RNA (rRNA) and ribosomal proteins assembled into two subunits.
4. **Primary function of ribosomes: (c) Protein synthesis.**
   Ribosomes translate mRNA into polypeptide chains (proteins). (They do not produce energy or synthesize lipids.)
5. **(c) Golgi apparatus.**
   The Golgi modifies (e.g., glycosylation), sorts and packages proteins and lipids received from the ER, then sends them to their destinations (secretory vesicles, plasma membrane, lysosomes).
6. **(d) Lysosome.**
   Lysosomes contain hydrolytic enzymes that digest macromolecules, worn-out organelles and foreign material — they are the main intracellular waste-breaking organelles.
7. **(a) Cytoskeleton.**
   The cytoskeleton (microfilaments, intermediate filaments, microtubules) maintains cell shape, provides mechanical support and enables movement/transport inside the cell.
8. **(b) Nucleolus.**
   The nucleolus (a dense region inside the nucleus) is where rRNA is transcribed and ribosomal subunits are assembled.
9. **(d) Control of transport of molecules.**
   Nuclear pores regulate and control exchange of molecules (mRNA, ribosomal subunits, proteins) between nucleus and cytoplasm.
10. **(b) Centriole.**
    Centrioles (in animal cells, part of the centrosome) organize the mitotic spindle and help in cell division.
11. **(c) Mitochondria.**
    Mitochondria are the cell's powerhouses — they produce ATP mainly by oxidative phosphorylation.

12. **(d) Mesophyll (mesophyll cells).**
    In leaves, mesophyll cells (especially palisade mesophyll) contain many chloroplasts and perform photosynthesis, producing glucose.
13. **(c) Mitochondria.**
    Mitochondria contain their own DNA and can replicate by binary fission, so they can double their number independently of the nucleus.
14. **(a) Ribosomes.**
    The rough endoplasmic reticulum is "rough" because ribosomes are attached to its cytosolic surface.

B. Short answers (concise but complete)

1. **Main functions of the cell membrane:**
   Acts as a selective barrier controlling entry and exit of ions and molecules; provides structural boundary; contains receptors for signalling; supports cell recognition and adhesion; hosts membrane enzymes and transport proteins. Structurally it is a fluid mosaic of phospholipids, proteins, cholesterol and carbohydrates.
2. **Key role of the Golgi apparatus:**
   Receives proteins and lipids from the ER, modifies them (e.g., glycosylation), sorts and packages them into vesicles for secretion, delivery to the plasma membrane, or formation of lysosomes.
3. **How lysosomes contribute to cell function:**
   They digest extracellular material brought by endocytosis and phagocytosis, break down damaged organelles by autophagy, recycle building blocks (amino acids, sugars), and participate in programmed cell death when needed.
4. **Organelle that detoxifies harmful substances and breaks down lipids:**
   The **smooth endoplasmic reticulum (SER)** is the main organelle for lipid synthesis and detoxification (especially in liver cells). **Peroxisomes** also break down long-chain fatty acids and detoxify reactive oxygen species (e.g., H_2O_2).
5. **What the smooth ER is responsible for:**
   Lipid and steroid synthesis, detoxification of drugs/poisons, storage and regulated release of calcium ions, and some carbohydrate metabolism.
6. **How plant vacuoles differ from animal vacuoles:**
   Plant cells typically have one large central vacuole that stores water, ions, pigments and wastes and maintains turgor pressure; animal cells have smaller, multiple vacuoles (or vesicles) used mainly for storage and transport. Plant vacuoles also help cell growth by enlarging; animal vacuoles rarely do this.
7. **If lysosomal enzymes stop working properly:**
   Undigested materials accumulate inside cells, causing cellular dysfunction and sometimes cell death. This leads to lysosomal storage diseases (e.g., Tay-Sachs, Gaucher), tissue damage—often affecting brain and liver—and impaired recycling of macromolecules.
8. **Why cristae are important for cellular respiration:**
   Cristae (folds of the inner mitochondrial membrane) increase membrane surface

area to house electron transport chain complexes and ATP synthase, allowing more efficient ATP production via oxidative phosphorylation.

9. **How chromatin and chromosomes are related:**
   Chromatin = DNA + histone and non-histone proteins in a relaxed (less condensed) form during interphase. Chromosomes = highly condensed, organized structures of chromatin that form during cell division; each chromosome contains one long DNA molecule.
10. **Which cell sends nerve signals:**
    A **neuron** (nerve cell). Neurons generate and transmit electrical impulses (action potentials) along axons and communicate via chemical synapses using neurotransmitters.
11. **What mesophyll cells do in leaves:**
    They contain many chloroplasts and are the primary site of photosynthesis; palisade mesophyll captures light efficiently while spongy mesophyll facilitates gas exchange.
12. **Definition of a stem cell:**
    An undifferentiated cell that can self-renew (divide to make more stem cells) and differentiate into one or more specialized cell types. Types include totipotent, pluripotent and multipotent.
13. **Chemical compounds that make up:**
    a. **Cell membrane:** Phospholipids (bilayer), cholesterol, membrane proteins, glycolipids and glycoproteins.
    b. **Fungal cell wall:** Mainly **chitin** (poly-N-acetylglucosamine), plus glucans and mannoproteins.
    c. **Plant cell wall:** Cellulose microfibrils (β-1,4 glucose), hemicellulose, pectin; secondary walls may have lignin.
    d. **Bacterial cell wall: Peptidoglycan** (murein) — polysaccharide chains of N-acetylglucosamine and N-acetylmuramic acid crosslinked by short peptides.
    e. **Ribosomes:** Ribosomal RNA (rRNA) and ribosomal proteins.
    f. **Chromosomes:** DNA wrapped around histone proteins (plus non-histone proteins).
14. **Label the parts of the cell diagrams:**
    I don't see the diagrams you mean. Please upload the images if you want precise labels. Meanwhile, common labels for typical **animal-cell** and **plant-cell** diagrams you can use:

- **Common (both):** Plasma membrane, cytoplasm, nucleus, nucleolus, nuclear membrane (envelope), mitochondrion, ribosome, rough ER, smooth ER, Golgi apparatus, lysosome, peroxisome, centrosome (centrioles in animal), cytoskeleton.
- **Plant-specific:** Cell wall, large central vacuole, chloroplast, plasmodesmata.
  If you upload your diagrams I'll label them exactly.

C. Detailed answers (in depth)

1. **Fluid mosaic model of the cell membrane**
   The fluid mosaic model (Singer & Nicolson) describes the plasma membrane as a

two-layered sheet of phospholipids (a bilayer) whose hydrophobic tails face inward and hydrophilic heads face outward. This lipid bilayer is "fluid": phospholipids and many proteins move laterally within the layer. Interspersed are cholesterol molecules (in animal membranes) that modulate fluidity and stability. Membrane proteins form a "mosaic" — integral (span the bilayer) and peripheral (surface-attached) proteins provide transport channels, carriers, receptors, enzymes and anchors for the cytoskeleton. Carbohydrate chains on proteins and lipids (glycoproteins/glycolipids) are on the exterior and are important for recognition and cell communication. Functionally the model explains selective permeability, signal transduction, and dynamic remodeling (endocytosis/exocytosis). Membrane transport includes passive diffusion, facilitated diffusion (channels/carriers), active transport (pumps using ATP), and bulk transport (endocytosis, exocytosis).

2. **Structure and functions of the cell wall**
   In plants the primary cell wall is composed of cellulose microfibrils embedded in a matrix of hemicellulose and pectins; cells also secrete a middle lamella (pectin-rich) between adjacent walls. In cells that become mechanically strong a secondary wall forms beneath the primary wall and may contain lignin. The cell wall gives mechanical support, defines cell shape, resists excessive water uptake (prevents bursting), and provides physical protection against pathogens. It also influences cell growth direction, mediates intercellular communication via plasmodesmata (channels through walls), and acts as a filtration barrier. Fungal walls use chitin and glycoproteins; bacterial walls use peptidoglycan — each wall type is adapted to the organism's needs.
3. **Components of the nucleus**
   The nucleus is bounded by a double membrane — the nuclear envelope — perforated by nuclear pores that regulate transport of RNA and proteins. The inner surface is lined by the nuclear lamina (a fibrous network) that provides mechanical support and organizes chromatin. The nucleoplasm (nuclear matrix) is the viscous fluid containing chromatin (DNA + histones and other proteins). The nucleolus is a dense region where rRNA is transcribed and ribosomal subunits are assembled. During interphase chromatin is less condensed (euchromatin & heterochromatin); during mitosis chromatin condenses into visible chromosomes. The nucleus houses DNA replication, transcription, RNA processing and coordinates cell-cycle events.
4. **Structure and function of lysosome and endoplasmic reticulum**
   Lysosome: A membrane-bound vesicle rich in hydrolytic enzymes (lipases, proteases, nucleases, glycosidases) active at an acidic pH maintained by proton pumps. Lysosomes digest material from endocytosis/phagocytosis, recycle damaged organelles (autophagy), and participate in programmed cell death. Malfunction causes accumulation of substrates (lysosomal storage diseases).
   Endoplasmic reticulum (ER): A continuous network of flattened sacs (cisternae) and tubules connected to the outer nuclear membrane. **Rough ER (RER)** has ribosomes on its cytosolic surface and is the site of synthesis, folding and initial modification (e.g., signal peptide cleavage, N-linked glycosylation) of secretory and membrane proteins; quality control and chaperones operate here. **Smooth ER (SER)** lacks ribosomes and specializes in lipid and steroid synthesis, detoxification, Ca^{2+} storage and some carbohydrate metabolism. The ER is central to the secretory pathway and communicates with the Golgi via transport vesicles.

5. **Formation and function of the Golgi complex**
   The Golgi apparatus is a stack of flattened membrane cisternae with a cis face (receiving side, near the ER) and a trans face (shipping side). Vesicles carrying newly made proteins bud from the ER and fuse with the cis Golgi; as cargo moves through medial to trans cisternae it is further modified (e.g., glycosylation, sulfation), sorted and packaged into transport vesicles targeted to the plasma membrane, secretory granules, endosomes or lysosomes. Two main secretion routes exist: constitutive secretion (continuous) and regulated secretion (stored and released on signal). The Golgi also matures cisternae (cisternal maturation model) and forms lysosomal enzymes and their carriers.
6. **Structure and functions of the chloroplast**
   Chloroplasts are double-membrane organelles containing their own circular DNA and 70S ribosomes. Inside is the stroma (aqueous matrix) and an extensive thylakoid system — flattened sacs arranged in stacks called grana. Thylakoid membranes contain chlorophyll and protein complexes of photosystems I & II, electron carriers and ATP synthase. **Light reactions** occur in thylakoid membranes: photons excite chlorophyll, water is split (O_2 produced), electrons pass along an ETC creating a proton gradient used to make ATP and reduce $NADP^+$ to NADPH. **Calvin cycle (dark reactions)** occurs in the stroma: CO_2 is fixed by Rubisco using ATP and NADPH to produce triose phosphates that are converted to glucose and other carbohydrates. Chloroplasts also participate in fatty acid and amino acid synthesis and can convert to other plastid types (amyloplasts, chromoplasts).
7. **How turgor pressure develops in a plant cell**
   Plant cells maintain a high internal solute concentration (especially in the vacuole), creating an osmotic gradient that draws water into the cell by osmosis. The large central vacuole fills and presses the protoplast against the rigid cell wall; because the cell wall resists further expansion, an internal pressure (turgor pressure) builds. Turgor keeps non-woody plant tissues firm, drives cell expansion during growth, and is essential for stomatal opening and mechanical support. If water is lost (drought) turgor falls and the cell plasmolyzes, causing wilting.
8. **Four differences between plant and animal cells** (choose any four; here are clear examples)
   - **Cell wall:** Present in plant cells (cellulose), absent in animal cells.
   - **Chloroplasts:** Present in plant cells for photosynthesis; absent in most animal cells.
   - **Vacuole:** Large central vacuole in plant cells; small or many temporary vacuoles in animal cells.
   - **Centrioles:** Usually present in animal centrosomes and involved in mitosis; often absent or non-centriole microtubule organizing centers in higher plant cells.
     (Other differences: storage compounds—starch in plants vs glycogen in animals; mode of cytokinesis—cell plate in plants vs cleavage furrow in animals.)
9. **Division of labour in multicellular organisms**
   Division of labour means different cells/tissues/organs perform specialized tasks rather than every cell performing all functions. Specialization increases efficiency and allows complex functions. For example: (1) **Red blood cells** transport O_2 (have

haemoglobin, no nucleus), (2) **Neurons** transmit electrical signals rapidly to coordinate responses, (3) **Pancreatic beta cells** produce and secrete insulin to regulate blood glucose. Coordination occurs via signalling systems (nervous impulses and hormones). Interdependence means if one specialized tissue fails, others are affected.

10. **Cell specialization (note)**
    Specialization (differentiation) is the process by which unspecialized cells (often stem cells) develop specific structures and functions by expressing particular sets of genes. Differentiation involves changes in size, shape, metabolic activity and organelle content to suit a role (e.g., muscle cells develop many mitochondria; secretory cells develop extensive RER and Golgi). Epigenetic modifications and transcription factor networks control specialization. Specialized cells form tissues and organs whose integrated function maintains the organism.

D. Inquisitive (deeper conceptual) questions

1. **Impact of mitochondrial dysfunction or absence on other organelles**
   Mitochondria supply most of the cell's ATP; without adequate mitochondrial function many energy-dependent processes fail. Active transport (ion pumps, vesicular trafficking, ER protein folding), operation of the Golgi and lysosomal proton pumps (vacuolar ATPases), and cytoskeletal motor proteins (kinesin, dynein, myosin) all need ATP — so secretion, endocytosis, protein maturation and organelle maintenance degrade. Mitochondrial failure also raises reactive oxygen species (ROS), damaging lipids, proteins and DNA and causing oxidative stress that impairs ER function (ER stress, unfolded protein response), damages membranes and may trigger apoptosis via cytochrome c release. Calcium homeostasis is disrupted (mitochondria buffer Ca^{2+}), affecting ER signalling and enzyme activities. In short: loss of mitochondria causes energy shortage, oxidative damage, disrupted signalling and eventually widespread organelle and cellular dysfunction.
2. **If coordination between ribosomes and the nucleus fails — consequences and importance**
   The nucleus encodes genetic information and produces mRNA (and rRNA), while ribosomes translate mRNA into proteins. Failure of coordination — for example faulty mRNA export, defective ribosome biogenesis, or mismatched timing of transcription/translation — leads to incorrect protein levels, missing essential proteins, accumulation of untranslated mRNAs, and formation of incomplete or misfolded proteins. This can cause ER stress (from misfolded secretory proteins), impair assembly of multi-subunit complexes (so enzymes and structural proteins malfunction), interrupt cell-cycle control, and ultimately cause disease (ribosomopathies, neurodegeneration). Proper coordination is essential to ensure that proteins are synthesized at the right time, in the right place and in correct amounts for cell survival and function.
