

Cell Biology — 50 Short Questions

End-Semester Revision • 2 marks each • Model answers

Unit I — Cell, Plasma Membrane and Transport

1. State the cell theory. Who proposed it?

The cell theory was proposed by **M.J. Schleiden (1838)** and **T. Schwann (1839)**, and extended by **R. Virchow (1855)**. It states: (i) all living organisms are made of one or more cells; (ii) the cell is the basic structural and functional unit of life; (iii) all cells arise from pre-existing cells (*omnis cellula e cellula*).

2. Give two differences between prokaryotic and eukaryotic cells.

Feature	Prokaryotic	Eukaryotic
Nucleus	No true nucleus; nucleoid, no nuclear envelope	True nucleus bounded by double nuclear envelope
Organelles	No membrane-bound organelles	Mitochondria, ER, Golgi, etc. present
Ribosomes	70S	80S in cytoplasm (70S in organelles)

3. What are mycoplasma (PPLO)? Why are they important?

Mycoplasma (pleuropneumonia-like organisms) are the **smallest known free-living cells** (about 0.1–0.3 μm), discovered in cattle pleuropneumonia. They **lack a cell wall**, so they are pleomorphic and resistant to penicillin. They are important as the model of a minimal cell and as pathogens (e.g. *Mycoplasma pneumoniae* causes atypical pneumonia).

4. State the fluid mosaic model. Who proposed it?

Proposed by **S.J. Singer and G.L. Nicolson (1972)**. The membrane is a **fluid phospholipid bilayer** in which globular proteins are embedded or attached like a mosaic. Both lipids and proteins can move laterally, which gives the membrane fluidity. The membrane is also asymmetric, with carbohydrates only on the outer surface.

5. Distinguish between integral and peripheral membrane proteins.

Integral (intrinsic) proteins are embedded partly or fully across the bilayer (transmembrane). They are amphipathic and can be removed only with detergents, e.g. glycophorin and bacteriorhodopsin. **Peripheral (extrinsic) proteins** are loosely bound to the membrane surface by ionic or hydrogen bonds. They are removed by mild salt or pH change, e.g. spectrin and cytochrome c.

6. What is a lipid raft?

Lipid rafts are small (10–200 nm), thicker, less fluid **microdomains** of the plasma membrane rich in **cholesterol and sphingolipids**. They concentrate specific proteins, such as GPI-anchored proteins and signalling receptors. They serve as platforms for cell signalling, membrane trafficking and viral entry.

7. Define glycocalyx and give one function.

The glycocalyx (cell coat) is the **carbohydrate-rich layer** on the outer surface of the plasma membrane. It is formed by the oligosaccharide chains of glycoproteins and glycolipids. **Functions:** cell–cell recognition (e.g. ABO blood group antigens), adhesion, and protection of the cell surface (e.g. intestinal epithelium).

8. Differentiate passive transport from active transport.

Passive transport moves solutes **down** their concentration gradient without using metabolic energy, by simple or facilitated diffusion (e.g. GLUT transporters, ion channels). **Active transport** moves solutes **against** the gradient using energy from ATP or an ion gradient, and always requires a carrier (e.g. the Na^+/K^+ pump).

9. What is the Na^+/K^+ ATPase pump? Give its stoichiometry.

It is a P-type ATPase in the plasma membrane of animal cells. It maintains a high K^+ and low Na^+ concentration inside the cell. For every **1 ATP hydrolysed it pumps 3 Na^+ out and 2 K^+ in**, so it is electrogenic. It maintains the resting membrane potential and cell volume, and it drives secondary active transport.

10. Define uniport, symport and antiport, with one example of each.

Uniport: one solute is moved in one direction, e.g. GLUT1 (glucose). **Symport:** two solutes are moved in the **same** direction, e.g. the Na^+ -glucose symporter (SGLT1) of intestinal cells. **Antiport:** two solutes are moved in **opposite** directions, e.g. the $\text{Na}^+/\text{Ca}^{2+}$ exchanger or the $\text{Cl}^-/\text{HCO}_3^-$ exchanger of RBCs.

11. What is receptor-mediated endocytosis? Give one example.

It is the selective uptake of specific macromolecules (ligands) that bind to cell-surface receptors clustered in **clathrin-coated pits**. The pits pinch off with the help of dynamin to form coated vesicles. **Example:** uptake of LDL-cholesterol via the LDL receptor (Brown and Goldstein). Other examples are transferrin-iron and insulin uptake.

12. Name two types of cell junctions and state the function of each.

Tight junctions (zonula occludens): seal adjacent epithelial cells and prevent leakage of solutes between them; formed by claudins and occludins. **Gap junctions:** channels made of connexons (6 connexins each) that allow ions and small molecules to pass directly between cells, e.g. electrical coupling in cardiac muscle. (Desmosomes, which provide mechanical adhesion, may also be cited.)

Unit II — Cell Organelles

13. What is the difference between RER and SER?

Feature	RER	SER
Ribosomes	Studded with ribosomes	Lack ribosomes
Form	Mostly flattened cisternae	Mostly tubules and vesicles
Function	Synthesis of secretory and membrane proteins	Lipid and steroid synthesis, detoxification, Ca^{2+} storage

14. Define signal peptide and state its role.

A signal peptide is a short sequence of **15–30 mostly hydrophobic amino acids**, usually at the N-terminus of a newly made protein. It directs the protein to the ER (or another organelle). It is recognised by SRP, targets the ribosome to the ER membrane, and is then cleaved by **signal peptidase** (Blobel's signal hypothesis, Nobel Prize 1999).

15. What is the role of SRP (signal recognition particle)?

SRP is a **ribonucleoprotein** (7S RNA + 6 proteins). It binds the signal peptide as it emerges from the ribosome and **temporarily arrests translation**. It then carries the ribosome to the **SRP receptor** on the ER membrane. After docking, SRP is released (by GTP hydrolysis) and translation resumes into the ER lumen through the translocon (Sec61).

16. Distinguish between the cis and trans faces of the Golgi complex.

The **cis (forming) face** is convex, faces the ER/nucleus, receives vesicles from the ER, and has thinner, ER-like membranes. The **trans (maturing) face** is concave, faces the plasma membrane, and releases secretory vesicles. Its membranes are thicker and plasma-membrane-like, and it is rich in thiamine pyrophosphatase.

17. What are dictyosomes?

Dictyosomes are the individual **Golgi stacks of plant cells**. Each is a stack of 4–8 flattened cisternae with associated vesicles, and they are scattered through the cytoplasm (up to hundreds per cell). They secrete cell-wall matrix polysaccharides (pectin, hemicellulose) and form the **cell plate** during cytokinesis.

18. What is the role of mannose-6-phosphate in lysosome formation?

In the cis-Golgi, lysosomal hydrolases are tagged with **mannose-6-phosphate (M6P)** by GlcNAc-phosphotransferase. In the trans-Golgi network, **M6P receptors** recognise the tag and package these enzymes into clathrin-coated vesicles, which fuse with endosomes to form lysosomes. M6P is therefore the **sorting signal** for lysosomal enzymes.

19. Why are lysosomes called "suicide bags"?

Lysosomes contain about 50 powerful **acid hydrolases** (proteases, nucleases, lipases, acid phosphatase). If the lysosomal membrane ruptures, these enzymes are released and digest the cell itself (**autolysis**). This happens in dead cells and in tissue regression, e.g. resorption of the tadpole tail. The term was coined by Christian de Duve.

20. Differentiate primary from secondary lysosomes.

Primary lysosomes are newly formed from the Golgi. They contain inactive or unused hydrolases and have not yet taken part in digestion. **Secondary lysosomes** (digestive vacuoles) form when a primary lysosome fuses with a phagosome (heterophagosome) or an autophagosome, and they actively digest material. Undigested remains form **residual bodies**.

21. What is I-cell disease?

I-cell disease (inclusion-cell disease, mucopolysaccharidosis II) is an autosomal recessive lysosomal storage disorder. It is caused by deficiency of **GlcNAc-phosphotransferase**, so lysosomal enzymes are not tagged with M6P. The enzymes are then **secreted out of the cell** instead of reaching lysosomes, and cells fill with undigested inclusions. It causes skeletal defects and mental retardation.

22. What are peroxisomes? Name their marker enzyme.

Peroxisomes (microbodies) are small (0.2–1 μm), single-membrane organelles, discovered by de Duve. They contain oxidases that produce H_2O_2 and the enzyme **catalase** (the **marker enzyme**), which breaks H_2O_2 into H_2O and O_2 . They carry out β -oxidation of very-long-chain fatty acids and photorespiration in plants.

23. What are glyoxysomes and where are they found?

Glyoxysomes are specialised peroxisomes found in the **endosperm or cotyledons of germinating fatty (oil) seeds** such as castor and groundnut. They contain enzymes of the **glyoxylate cycle** (isocitrate lyase and malate synthase), which convert stored fats into carbohydrates (via succinate) for the growing seedling.

24. What are F_0 – F_1 particles (oxysomes)?

Oxysomes are tennis-racket-shaped particles on the matrix side of the **inner mitochondrial membrane** (cristae). They are **ATP synthase** complexes. The F_0 part is embedded in the membrane and forms a proton channel. The F_1 head ($\alpha_3\beta_3\gamma\delta\epsilon$) projects into the matrix and synthesises ATP by rotary catalysis as H^+ flows through F_0 .

25. Why are mitochondria and chloroplasts called semi-autonomous organelles?

They possess their own **circular DNA**, **70S ribosomes** and **protein-synthesising machinery**, and they divide by fission. They can therefore make some of their own proteins. However, most of their proteins are coded by **nuclear genes** and imported from the cytoplasm, so they are only partly (semi-) autonomous.

26. State the endosymbiotic theory, with two supporting evidences.

Proposed by **Lynn Margulis (1967)**, the theory states that mitochondria and chloroplasts evolved from free-living **aerobic bacteria** and **cyanobacteria**, respectively, that were engulfed by an ancestral eukaryotic cell. **Evidence:** (i) they have circular naked DNA and 70S ribosomes like bacteria; (ii) they have a double membrane and divide by binary fission (other evidence: their inner membrane contains cardiolipin).

27. Distinguish between the 70S and 80S ribosome.

Feature	70S	80S
Occurrence	Prokaryotes, mitochondria, chloroplasts	Eukaryotic cytoplasm and RER
Subunits	50S + 30S	60S + 40S
rRNA	23S, 5S (large); 16S (small)	28S, 5.8S, 5S (large); 18S (small)

28. What are polysomes?

A polysome (polyribosome) is a group of **several ribosomes attached to a single mRNA** molecule, each translating it simultaneously. They are joined like beads on a string. Polysomes allow rapid synthesis of many copies of a protein from one mRNA, e.g. haemoglobin synthesis in reticulocytes.

Unit III — Cytoskeleton and Cell Motility

29. Name the three components of the cytoskeleton and give their diameters.

(i) **Microfilaments** (actin filaments), about **7 nm**. (ii) **Intermediate filaments** (keratin, vimentin, lamins), about **10 nm**. (iii) **Microtubules** (tubulin), about **25 nm**, hollow tubes with 13 protofilaments.

30. What is treadmilling in actin filaments?

Treadmilling is a steady state in which **G-actin monomers are added at the plus (barbed) end** at the same rate as they are **lost from the minus (pointed) end**. The filament therefore keeps a constant length while its subunits flux through it from plus to minus end. This is important in cell crawling, e.g. at the lamellipodia.

31. What is dynamic instability of microtubules?

Dynamic instability is the random switching of microtubule plus ends between phases of **slow growth** and **rapid shrinkage**. A **GTP-cap** of GTP-tubulin at the end stabilises growth. When the cap is lost (GTP is hydrolysed to GDP), the microtubule rapidly depolymerises (**catastrophe**); regaining the cap is called **rescue**. It allows spindle microtubules to search for and capture kinetochores.

32. Describe the 9+2 arrangement of the axoneme.

The axoneme is the core of cilia and flagella. It has **9 peripheral doublet microtubules** (A and B tubules) arranged around **2 central singlet microtubules**, which are enclosed in a central sheath. Each A tubule bears inner and outer **dynein arms** and a radial spoke. Adjacent doublets are linked by nexin. Dynein-driven sliding of the doublets produces bending.

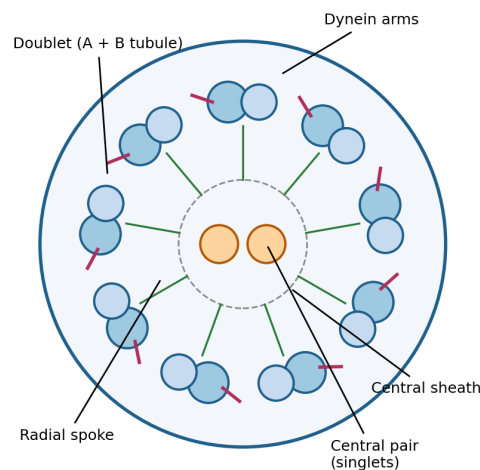


Fig. 1. Transverse section of the axoneme (9+2).

33. Differentiate between kinesin and dynein.

Both are ATP-driven microtubule motor proteins. **Kinesin** moves towards the **plus (+) end** of microtubules, i.e. anterograde transport away from the cell centre (e.g. carrying vesicles down an axon). **Dynein** moves towards the **minus (-) end**, i.e. retrograde transport towards the centrosome; axonemal dynein also drives ciliary beating.

34. What is the MTOC? Give one example.

The microtubule-organising centre (MTOC) is the site where microtubules are **nucleated and anchored** by their minus ends. Nucleation involves the γ -tubulin ring complex. **Examples:** the centrosome (with a pair of centrioles) in animal cells, basal bodies of cilia, and spindle pole bodies in yeast.

35. Give two differences between a centriole and a basal body.

(i) The **centriole** lies in the centrosome near the nucleus and organises the mitotic spindle, whereas the **basal body** lies below the plasma membrane at the base of a cilium or flagellum and organises the axoneme. (ii) Centrioles occur in pairs at right angles, while each basal body is single and has rootlets. Both show the 9+0 triplet structure, and a centriole can become a basal body.

Unit IV — Nucleus and Chromosomes

36. What is the nuclear pore complex? Give its function.

The nuclear pore complex (NPC) is a large (~120 MDa) **octagonally symmetrical** protein structure made of about 30 kinds of nucleoporins. It spans both membranes of the nuclear envelope. It regulates **two-way transport** between nucleus and cytoplasm. Small molecules diffuse through freely, while proteins with an NLS are imported and RNAs and ribosomal subunits are exported, with the help of importins/exportins and Ran-GTP.

37. Differentiate euchromatin from heterochromatin.

Euchromatin is lightly stained and loosely coiled during interphase. It is **transcriptionally active**, gene-rich and replicates early. **Heterochromatin** is darkly stained and highly condensed. It is **transcriptionally inactive**, late-replicating and found near centromeres and telomeres. It is either constitutive (e.g. satellite DNA) or facultative (e.g. the Barr body).

38. What is a nucleosome? Give its composition.

The nucleosome is the **basic repeating unit of chromatin**, described by Kornberg (1974) and seen as the 'beads-on-a-string' 11 nm fibre. It consists of a **histone octamer** (2 each of H2A, H2B, H3 and H4) around which **~146 bp of DNA** is wrapped in about 1.65 left-handed turns. Linker DNA joins adjacent nucleosomes, and histone **H1** seals the DNA at the entry and exit points.

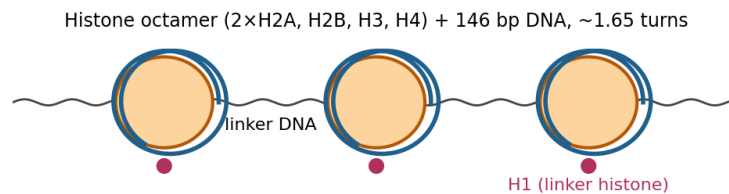


Fig. 2. Nucleosomes: the 'beads-on-a-string' structure.

39. What are lampbrush chromosomes and where are they found?

Lampbrush chromosomes are very large, **diplotene-stage bivalents** of meiosis I found in **primary oocytes** of vertebrates (especially amphibians such as salamanders) and some insects. They were first seen by Flemming and named by Rückert. Their chromatin forms paired lateral loops that are **sites of active transcription** (for yolk and mRNA synthesis), giving the appearance of a lamp-chimney brush.

40. What are polytene chromosomes? What are Balbiani rings?

Polytene chromosomes are giant chromosomes found in the salivary glands of dipteran larvae (e.g. *Drosophila*, *Chironomus*). They form by **repeated DNA replication without cell division** (endoreduplication), producing about 1000 parallel chromatids with somatic pairing and dark bands. **Balbani rings** are very large **puffs**, i.e. regions of intense transcription, first described in *Chironomus*.

41. What is a telomere? Give the role of telomerase.

Telomeres are the **protective ends of linear chromosomes**, made of tandem repeats (TTAGGG in humans) and bound proteins (shelterin). They prevent end-to-end fusion and degradation. **Telomerase** is a ribonucleoprotein reverse transcriptase that uses its own RNA template to **add telomeric repeats**, which solves the end-replication problem. It is active in germ cells, stem cells and most cancer cells.

42. Define nucleolar organiser region (NOR).

The NOR is the region of certain chromosomes (satellite chromosomes, at the secondary constriction) that contains **tandemly repeated genes for 18S, 5.8S and 28S rRNA**. The nucleolus forms around the NOR after cell division. In humans, NORs are on the short arms of acrocentric chromosomes 13, 14, 15, 21 and 22.

Unit V — Cell Cycle, Division and Cell Death

43. Name the phases of the cell cycle and state what happens in the S phase.

The cell cycle has **interphase** (G_1 , S, G_2) and the **M phase** (mitosis + cytokinesis); non-dividing cells enter G_0 . In the **S (synthesis) phase**, **DNA is replicated** (the DNA content doubles from 2C to 4C, while the chromosome number stays the same), histones are synthesised, and the centrosome is duplicated.

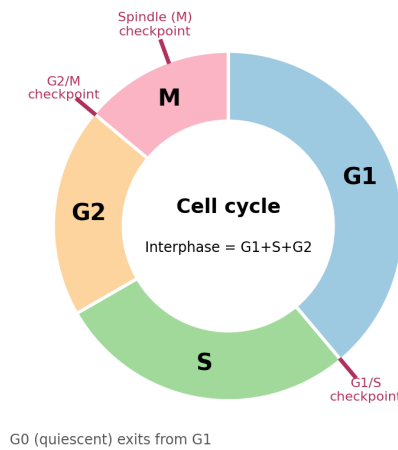


Fig. 3. Phases of the cell cycle and major checkpoints.

44. What are cyclins and CDKs?

Cyclin-dependent kinases (CDKs) are serine/threonine protein kinases that drive the cell cycle. They are active only when bound to **cyclins**, regulatory proteins whose levels rise and fall cyclically; cyclins are destroyed by ubiquitin-mediated proteolysis. For example, cyclin B–CDK1 (MPF, maturation/M-phase promoting factor) triggers entry into mitosis. Hartwell, Hunt and Nurse received the Nobel Prize for this work (2001).

45. What are cell cycle checkpoints? Name any two.

Checkpoints are **control mechanisms** that halt the cycle until the previous step is correctly completed or DNA damage is repaired. (i) **G₁/S checkpoint** (restriction point) checks cell size, nutrients and DNA damage (via p53 and Rb). (ii) **G₂/M checkpoint** checks that DNA replication is complete and undamaged. The **spindle (metaphase) checkpoint** checks that all kinetochores are attached.

46. Differentiate between mitosis and meiosis, giving two points.

Feature	Mitosis	Meiosis
Chromosome number	Maintained ($2n \rightarrow 2n$); equational	Halved ($2n \rightarrow n$); reductional
Divisions / products	One division; 2 identical daughter cells	Two divisions; 4 genetically different cells
Pairing / crossing over	Absent	Synapsis and crossing over in prophase I
Occurrence	Somatic cells	Germ cells (gonads)

47. What is the synaptonemal complex?

The synaptonemal complex is a **tripartite, ladder-like protein structure** formed between homologous chromosomes during **zygotene** of prophase I. It consists of two lateral elements and a central element joined by transverse filaments. It holds the homologues in close alignment (synapsis) and allows **crossing over** during pachytene. It dissolves in diplotene.

48. Define crossing over and chiasma.

Crossing over is the reciprocal exchange of segments between **non-sister chromatids of homologous chromosomes** during pachytene of meiosis I. It is mediated by recombinase enzymes and produces genetic recombination. A **chiasma** (plural: chiasmata) is the visible X-shaped point of contact where crossing over has occurred, seen in diplotene/diakinesis.

49. Differentiate between apoptosis and necrosis.

Feature	Apoptosis	Necrosis
Nature	Programmed, physiological, energy (ATP)-dependent	Accidental, pathological
Morphology	Cell shrinkage, chromatin condensation, DNA laddering, apoptotic bodies	Cell swelling, membrane rupture, leakage of contents
Inflammation	None (removed by phagocytes)	Causes inflammation

50. What is a proto-oncogene? Give one example.

A proto-oncogene is a **normal cellular gene** that promotes cell growth and division, coding for growth factors, receptors, signal transducers or transcription factors. When mutated or overexpressed, it becomes an **oncogene** that causes uncontrolled proliferation (a gain-of-function change, dominant). **Examples:** *ras* (point mutation), *myc* (translocation in Burkitt's lymphoma), *erbB/HER2* (amplification in breast cancer).