📄 1 – Cell: Discovery, Definition & General Features 🔬

🔹 Discovery of Cell

- **1665 – Robert Hooke**: observed dead cork cells → coined term **“cell”**.
- **1674 – Anton van Leeuwenhoek**: first observed **living cells** (bacteria, protozoa, sperm).
- **1838 – Schleiden**: all plants made of cells.
- **1839 – Schwann**: all animals made of cells → together proposed **Cell Theory**.
- **1855 – Virchow**: “Omnis cellula e cellula” (cells arise from pre-existing cells).

🔹 Definition

- **Cell** = basic **structural, functional, and hereditary unit** of life.
- Smallest unit capable of independent life.

🔹 General Features of Cells

- **Cell membrane**: outer limiting boundary.
- **Cytoplasm**: fluid matrix with organelles & inclusions.
- **Nucleus** (in eukaryotes): controls heredity & metabolism.
- **Metabolism**: biochemical reactions occur inside cells.
- **Reproduction**: mitosis, meiosis, binary fission (prokaryotes).
- **Growth & response**: cells grow, divide, and respond to environment.

🔹 Types of Cells

1. **Prokaryotic cells**
    - Primitive, no nucleus or membrane-bound organelles.
    - Examples: Bacteria, Cyanobacteria, Mycoplasma.
2. **Eukaryotic cells**
    - True nucleus, membrane-bound organelles.
    - Examples: Plants, Animals, Fungi, Protists.

🔹 Mnemonics 💡

- **Cell Discoverers → "Hook-Lewis-Schwa-Virchow"**
    - Hooke → named cell
    - Leeuwenhoek → saw living cells
    - Schleiden → plants
    - Schwann → animals
    - Virchow → continuity of cells

◈ **Exam Capsule** 🎯

- Cell = **basic unit of structure, function, heredity**.
- Discovered by **Hooke (1665)**, living cell by **Leeuwenhoek**.
- **Cell theory** → Schleiden & Schwann (1838–39).
- **Virchow (1855)** → cells arise from pre-existing cells.
- Two cell types: **Prokaryotic & Eukaryotic**.

📄 2 – Prokaryotic Cells (Structure, Features & Examples) ▯

◈ **General Features**

- **Prokaryote** = organisms without a true nucleus.
- DNA is **circular, naked**, lies in **nucleoid** (not enclosed by membrane).
- No membrane-bound organelles.
- Reproduce mainly by **binary fission**.
- Cell size: **0.1–5 µm** (much smaller than eukaryotes).

◈ **Cell Structure**

1. **Cell Envelope**
    - **Capsule/slime layer** (glycocalyx) → protection.
    - **Cell wall** → peptidoglycan (murein), maintains shape.
    - **Plasma membrane** → selectively permeable, mesosomes may form.
2. **Cytoplasm**

- Contains **ribosomes (70S)**.
- Inclusion bodies → glycogen, phosphate granules, gas vacuoles.

3. **Nucleoid**
   - Single, circular, double-stranded DNA molecule.
   - No histone proteins (except in Archaea).
4. **Plasmids**
   - Extra-chromosomal DNA, self-replicating.
   - Provide antibiotic resistance, toxin production, etc.
5. **Cell Appendages**
   - **Flagella** → motility.
   - **Pili & fimbriae** → conjugation (sex pili), attachment (fimbriae).

🔹 **Examples of Prokaryotes**

- **Eubacteria** → *Escherichia coli, Bacillus, Streptococcus*.
- **Cyanobacteria** (blue-green algae) → *Nostoc, Anabaena*.
- **Archaebacteria** → *Halobacterium, Methanogens*.
- **Mycoplasma (PPLO)** → smallest, no cell wall.

🔹 **Mnemonics** 💡

- **Prokaryote = "No Pro-Nucleus" → No membrane-bound nucleus or organelles**.

🔹 **Exam Capsule** 🎯

- **Prokaryotes** lack true nucleus & organelles.
- Genetic material → **naked circular DNA in nucleoid**.
- **Ribosomes = 70S**.
- Reproduction by **binary fission**.
- Examples: **bacteria, cyanobacteria, archaea, mycoplasma**.

📄 3 – Bacterial Cell Structure ▯

🔹 **1. Capsule / Glycocalyx**

- Outermost covering (slime layer or capsule).
- Polysaccharide/protein composition.
- Functions → protection from desiccation, phagocytosis, antibiotics; helps adhesion.

◈ 2. Cell Wall

- Made of **peptidoglycan (murein)** → NAG (N-acetylglucosamine) + NAM (N-acetylmuramic acid) cross-linked with peptides.
- Provides rigidity & shape.

Gram Positive (+):

- Thick peptidoglycan (90%).
- Teichoic acids present.
- Stains **purple/violet**.

Gram Negative (–):

- Thin peptidoglycan (10%).
- Outer membrane with **lipopolysaccharides (LPS)**.
- Periplasmic space present.
- Stains **pink/red**.

◈ 3. Plasma Membrane

- Selectively permeable bilayer.
- Functions → transport, respiration, photosynthesis, biosynthesis.
- Contains **mesosomes** = infoldings of plasma membrane, function in:
    - DNA replication.
    - Cell wall formation.
    - Respiration & secretion.

◈ 4. Cytoplasm

- Contains enzymes, metabolites, ribosomes (70S).
- Inclusion bodies (starch, glycogen, volutin, gas vacuoles).

◈ 5. Special Structures

- **Endospores**: resistant structures (e.g., *Bacillus*, *Clostridium*).

- **Plasmids**: extra-chromosomal DNA.

🔹 **Mnemonics** 💡

- **Gram + vs Gram – → "+ Purple Thick, – Pink Thin"**

🔹 **Exam Capsule** 🎯

- **Capsule** → protection, adhesion.
- **Cell wall** → peptidoglycan; Gram + (thick, teichoic acid) vs Gram – (thin, LPS).
- **Plasma membrane** → selective transport, mesosomes.
- **Endospores** → survival structures.
- **Plasmids** → carry antibiotic resistance genes.

📄 4 – Bacterial Appendages (Flagella, Pili, Fimbriae) 🚩

🔹 **1. Flagella (Locomotory Organelles)**

- Long, thread-like structures for **motility**.
- Made of **flagellin protein**.
- Structure:
  - **Filament** → long, helical.
  - **Hook** → connects filament to basal body.
  - **Basal body** → anchors flagellum to cell wall & membrane.

Types (based on arrangement):

1. **Monotrichous** → single flagellum (e.g., *Vibrio cholerae*).
2. **Lophotrichous** → tuft at one end.
3. **Amphitrichous** → one or tuft at both ends.
4. **Peritrichous** → all over surface (e.g., *E. coli*).

🔹 **2. Pili**

- Short, hair-like protein appendages.
- Hollow tubes made of **pilin protein**.

- **Sex pili** → mediate **conjugation** (transfer of plasmid DNA).

🔹 **3. Fimbriae**

- Thin, bristle-like appendages.
- Numerous, shorter than pili.
- Function → **attachment** to surfaces (host tissues, substrates).
- Important in **pathogenic bacteria** for colonization.

🔹 **Mnemonics** 💡

- **Flagella = Movement, Pili = Mating, Fimbriae = Fixing**

🔹 **Exam Capsule** 🎯

- **Flagella** → locomotion, types (mono-, lopho-, amphi-, peritrichous).
- **Pili** → hollow, longer, few in number, role in **conjugation**.
- **Fimbriae** → numerous, short, role in **attachment/adhesion**.

📄 5 – Eukaryotic Cells (Features & Plant vs Animal Cells) 🦕🐾

🔹 **General Features**

- **Have true nucleus enclosed by nuclear membrane.**
- **DNA organized with histone proteins into chromosomes.**
- **Possess membrane-bound organelles (mitochondria, ER, Golgi, lysosomes, plastids).**
- **Larger size: 10–100 µm.**
- **Ribosomes = 80S (except 70S in organelles like mitochondria, chloroplasts).**
- **Cell division by mitosis and meiosis.**

🔹 **Comparison: Plant vs Animal Cells**

Feature	Plant Cell	Animal Cell
Cell wall	Present (cellulose)	Absent
Plastids	Present (chloroplasts, etc.)	Absent
Vacuole	Large central vacuole	Small, temporary vacuoles
Centrosome	Usually absent (except lower plants)	Present with centrioles
Lysosomes	Rare, replaced by lytic vacuoles	Common
Shape	Fixed, rigid (rectangular)	Flexible, round/irregular
Reserve food	Starch	Glycogen

◈ Mnemonics

- Unique to Plants → “3P”: Plastids, Primary cell wall, Permanent vacuole.
- Unique to Animals → “CL”: Centrioles, many Lysosomes.

◈ Exam Capsule

- Eukaryotes → true nucleus + organelles, DNA with histones, 80S ribosomes.
- Plant cells → cell wall, plastids, big vacuole, no centrioles.
- Animal cells → no cell wall/plastids, centrioles present, many lysosomes.
- Both → nucleus, mitochondria, ER, Golgi, ribosomes, plasma membrane.

8 – Cytoplasm

◈ Definition

- Cytoplasm = Protoplasm – Nucleus.
- Semi-fluid matrix between plasma membrane & nucleus.
- Site of most metabolic activities.

◈ Components

1. Cytosol (Matrix)

- Colloidal fluid → 90% water + proteins, carbohydrates, lipids, ions.
- Acts as medium for biochemical reactions.

2. **Cell Organelles (membrane-bound and non-membrane-bound).**
- **Membrane-bound: mitochondria, plastids, ER, Golgi, lysosomes, peroxisomes.**
- **Non-membrane-bound: ribosomes, cytoskeleton.**
3. **Inclusion Bodies (non-living storage materials).**
- **Starch grains (plants).**
- **Glycogen granules (animals, fungi).**
- **Oil droplets, crystals, pigments.**
- **Gas vacuoles (prokaryotes).**

🔹 Cytoplasmic Streaming (Cyclosis)

- **Continuous movement of cytoplasm.**
- **Helps distribution of organelles, nutrients, metabolites.**
- **Seen in Hydrilla leaf cells, Tradescantia hairs.**

🔹 Functions

- **Medium for enzymatic reactions.**
- **Provides structural support.**
- **Stores metabolites (inclusions).**
- **Allows intracellular transport (via cyclosis).**

🔹 Mnemonics 💡

- **Inclusions → "SGOP"**
  - **Starch**
  - **Glycogen**
  - **Oil droplets**
  - **Pigments**

🔹 Exam Capsule 🎯

- **Cytoplasm = protoplasm minus nucleus.**
- **Composed of cytosol, organelles, inclusions.**
- **Inclusions = non-living reserves (starch, glycogen, oils, pigments).**
- **Cytoplasmic streaming → distributes materials.**

- **Acts as site of metabolism, transport, storage.**

9 – Cytoskeleton

Definition

- **Network of protein filaments in the cytoplasm.**
- **Provides shape, mechanical support, motility, intracellular transport.**
- **Present in eukaryotic cells (not in prokaryotes).**

Components

1. **Microtubules**

- **Hollow tubes made of tubulin proteins.**
- **Diameter: ~25 nm.**
- **Functions:**
  - **Form cilia, flagella, spindle fibers.**
  - **Organelle positioning & vesicle transport.**
  - **Basis of mitotic spindle.**

2. **Microfilaments**

- **Thin filaments of actin proteins.**
- **Diameter: ~7 nm.**
- **Functions:**
  - **Muscle contraction (with myosin).**
  - **Amoeboid movement, endocytosis, exocytosis.**
  - **Cytoplasmic streaming.**

3. **Intermediate Filaments**

- **Protein filaments (keratin, vimentin, lamin).**
- **Diameter: ~10 nm.**
- **Functions:**
  - **Provide tensile strength.**
  - **Support nuclear envelope (lamins).**
  - **Cell junction stability.**

Functions of Cytoskeleton

- **Maintains cell shape & structure.**
- **Facilitates movement (cilia, flagella, amoeboid).**
- **Helps in cell division (spindle fibers).**
- **Provides tracks for transport of vesicles & organelles.**

🔹 Mnemonics 💡

- **Cytoskeleton Components → "MT-MF-IF"**
  - **MicroTubules → transport, spindle.**
  - **MicroFilaments → movement, contraction.**
  - **Intermediate Filaments → strength, stability.**

🔹 Exam Capsule 🎯

- **Cytoskeleton = network of MT, MF, IF.**
- **Microtubules = tubulin, hollow tubes, transport, spindle.**
- **Microfilaments = actin, contraction, motility, streaming.**
- **Intermediate filaments = keratin, strength, nuclear lamina.**
- **Functions: shape, motility, division, transport.**

📄 10 – Cell Organelles ▯

🔹 1. Centrosome

- **Found in animal cells (absent in higher plants).**
- **Contains two centrioles at right angles, surrounded by pericentriolar material.**
- **Functions:**
  - **Organizes spindle fibers during cell division.**
  - **Forms basal bodies of cilia & flagella.**

🔹 2. Cilia & Flagella

- **Hair-like appendages for movement.**
- **Structure: 9 + 2 arrangement of microtubules.**
  - **9 peripheral doublets + 2 central singlets.**

- Surrounded by plasma membrane.

- **Cilia → short, numerous, rhythmic beating.**
- **Flagella → long, fewer, whip-like movement.**
- **Functions: locomotion (protozoa, sperm), movement of fluids (trachea, oviduct).**

🔹 3. Endoplasmic Reticulum (ER)

- **Network of membrane-bound tubules & sacs (cisternae).**
- **Continuous with nuclear envelope.**

Types:

1. **Rough ER (RER)**
   - **Ribosomes attached.**
   - **Functions: protein synthesis, glycosylation, membrane formation.**
2. **Smooth ER (SER)**
   - **No ribosomes.**
   - **Functions: lipid metabolism, detoxification, steroid hormone synthesis, Ca^{2+} storage (muscle SR).**

🔹 Mnemonics 💡

- **Centrosome → "Cell's Compass" (guides spindle).**
- **Cilia vs Flagella → "C = Countless, F = Few".**
- **ER → "R = Ribosomes (proteins), S = Steroids (lipids)".**

🔹 Exam Capsule 🎯

- **Centrosome = centriole pair; spindle organizer.**
- **Cilia/Flagella = 9+2 microtubule arrangement; cilia short & many, flagella long & few.**
- **RER = protein synthesis.**
- **SER = lipid/steroid metabolism, detoxification, Ca^{2+} storage.**

🔹 1. Golgi Apparatus (Dictyosome)

- **Discovered by Camillo Golgi (1898).**
- **Stack of cisternae (flattened sacs) + vesicles.**

- **Cis face = receiving side (from ER).**
- **Trans face = shipping side (towards plasma membrane).**
- **Functions:**
    - **Protein modification, packaging, glycosylation.**
    - **Formation of lysosomes & secretory vesicles.**
    - **Cell wall material (pectin, hemicellulose) in plants.**

🔹 2. Lysosomes

- **Membrane-bound vesicles with hydrolytic enzymes.**
- **Enzymes active at acidic pH (pH ~5).**
- **Functions:**
    - **Intracellular digestion.**
    - **Autophagy (self-digestion).**
    - **Autolysis ("suicidal bags").**
- **Abundant in animal cells; less common in higher plants.**

🔹 3. Vacuoles

- **Membrane (tonoplast)-bound sac filled with cell sap.**
- **Functions:**
    - **Maintains turgor pressure.**
    - **Storage (sugars, proteins, pigments, ions, secondary metabolites).**
    - **In protozoa: contractile vacuole (osmoregulation), food vacuole (digestion).**

🔹 4. Microbodies

- **Single membrane-bound, enzyme-rich.**
- **Types:**
    - **Peroxisomes → contain catalase; β-oxidation of fatty acids, photorespiration.**
    - **Glyoxysomes → in germinating seeds; convert fats → sugars (glyoxylate cycle).**

🔹 Mnemonics 💡

- **Golgi → "Post Office" (packages proteins).**
- **Lysosomes → "Suicidal Bags".**
- **Vacuole → "Water Tank".**
- **Microbodies → "PG" → Peroxisome, Glyoxysome.**

🔷 Exam Capsule 🎯

- **Golgi = modifies, sorts, packages proteins & lipids.**
- **Lysosomes = acidic vesicles, hydrolytic enzymes, autophagy.**
- **Vacuoles = turgor, storage, osmoregulation.**
- **Peroxisomes = detox, photorespiration; Glyoxysomes = fat → sugar conversion in seeds.**

🔷 1. Ribosomes

- **Protein factories of the cell.**
- **Non-membranous, composed of rRNA + proteins.**
- **Types:**
  - **70S (Prokaryotes, mitochondria, chloroplasts).**
  - **80S (Eukaryotic cytoplasm).**
- **Functions: protein synthesis (translation).**

🔷 2. Mitochondria (Powerhouse of the Cell)

- **Double-membrane organelle.**
- **Outer membrane → smooth.**
- **Inner membrane → folded into cristae (increase surface area).**
- **Matrix → enzymes for Kreb's cycle, DNA, ribosomes.**
- **Functions:**
  - **ATP production (oxidative phosphorylation, ETC).**
  - **Apoptosis regulation.**
  - **Semi-autonomous → has its own DNA & ribosomes.**

🔷 3. Plastids (Plant-Specific)

- **Double-membrane organelles with DNA & 70S ribosomes.**

- **Types:**
    1. **Chloroplasts → photosynthesis, contain chlorophyll a & b.**
        - **Structure: double membrane, stroma (DNA, ribosomes, enzymes), thylakoid membranes stacked into grana.**
    2. **Chromoplasts → red, orange, yellow pigments (carotenoids, xanthophylls).**
        - **Example: tomato, carrot petals.**
    3. **Leucoplasts → colorless; storage of food.**
        - **Amyloplasts → starch.**
        - **Elaioplasts → oil.**
        - **Aleuroplasts → protein.**

◈ Mnemonics 💡

- **Ribosome Types → "PMS" → Prokaryote, Mitochondria, Stroma → 70S.**
- **Plastids → "CCL"**
    - **Chloroplast → photosynthesis.**
    - **Chromoplast → color.**
    - **Leucoplast → storage.**

◈ Exam Capsule 🎯

- **Ribosomes = protein synthesis; 70S (prokaryotes, organelles), 80S (eukaryotes).**
- **Mitochondria = powerhouse, cristae + matrix, ATP, semi-autonomous.**
- **Plastids = unique to plants; chloroplasts (photosynthesis), chromoplasts (pigments), leucoplasts (storage).**

📄 11 – Nucleus ▫️🏛️

◈ Definition

- **The control center of eukaryotic cells.**
- **Discovered by Robert Brown (1831).**
- **Contains genetic material (DNA) → regulates cell functions & heredity.**

◈ Structure

1. **Nuclear Envelope**

- **Double membrane.**
- **Outer membrane continuous with ER.**
- **Nuclear pores allow exchange (RNA, proteins).**

2. **Nucleoplasm (Nuclear Sap)**

- **Fluid matrix containing nucleotides, enzymes, ions.**

3. **Chromatin**

- **DNA + histone proteins.**
- **Types:**
  - **Euchromatin → lightly stained, active.**
  - **Heterochromatin → darkly stained, inactive.**
- **Condenses to form chromosomes during division.**

4. **Nucleolus**

- **Non-membrane structure inside nucleus.**
- **Rich in rRNA & proteins.**
- **Site of ribosome biogenesis.**

◈ Functions

- **Stores and expresses genetic information.**
- **Regulates metabolism, growth, cell cycle.**
- **Forms ribosomal subunits (nucleolus).**
- **Coordinates protein synthesis by directing RNA synthesis.**

◈ Mnemonics 💡

- **Nucleus Parts → "NECN"**
  - **Nuclear envelope**
  - **Euchromatin/heterochromatin**
  - **Chromosomes**
  - **Nucleolus**

◈ Exam Capsule 🎯

- **Robert Brown (1831) discovered nucleus.**

- **Enclosed by double membrane with pores.**
- **Contains chromatin (DNA + histones).**
- **Euchromatin = active, heterochromatin = inactive.**
- **Nucleolus = ribosome factory.**

📄 14 – Cell Theory & Modern Modifications 📜🔬

🔹 Classical Cell Theory

Proposed by Schleiden (1838) & Schwann (1839)

1. **All living organisms are composed of one or more cells.**
2. **Cell is the basic structural and functional unit of life.**

🔹 Contribution of Virchow (1855)

- **Added the concept: "Omnis cellula e cellula" = every cell arises from pre-existing cell.**
- **Established continuity of life through cells.**

🔹 Modern Cell Theory (Modifications)

1. **All living organisms are made of cells and their products.**
2. **Cell is the basic unit of structure, function, and heredity.**
3. **All cells arise from pre-existing cells (Virchow's principle).**
4. **Cell contains hereditary information (DNA/RNA) passed to daughter cells.**
5. **Cell metabolism (biochemical reactions) occurs within cells.**
6. **Activities of an organism depend on the activities of its cells.**
7. **Energy flow (metabolism & biochemistry) occurs within cells.**
8. **Modern addition: viruses are acellular but depend on host cells.**

🔹 Exceptions / Special Cases

- **Viruses → acellular, lack protoplasm.**
- **Red blood cells (mammals) → lack nucleus when mature.**
- **Multinucleate cells (e.g., fungi, skeletal muscles).**

◈ Mnemonics 💡

- **Modern Cell Theory → “SHARE”**
  - **Structure**
  - **Heredity**
  - **Arise from pre-existing cells**
  - **Reactions (metabolism)**
  - **Energy flow inside cells**

◈ Exam Capsule 🎯

- **Schleiden & Schwann (1838–39) → Cell theory (basic unit of life).**
- **Virchow (1855) → cells come from pre-existing cells.**
- **Modern theory includes → heredity, metabolism, energy flow.**
- **Exceptions: viruses, RBCs, multinucleate cells.**