Cell: The Building Block of Life

Exploration | Chapter 2 | NCERT Grade 9

1. Where Did Life Begin?

→ Scientific community widely believes **life originated in water**, possibly in small water pools with changing conditions rather than oceans.

→ **Hot springs** are examples of such environments — e.g., Puga Valley (Ladakh) stays near boiling point even in cold climate.

→ These conditions resemble **early Earth ~3.5 billion years ago**.

→ Organisms in hot springs are mostly heat-loving bacteria called **thermophiles** (unicellular).

THERMOPHILES → Heat-loving unicellular bacteria found in extremely hot environments like hot springs.

→ Birbal Sahni Institute of Palaeosciences (Lucknow) found **calcium carbonate** forms rapidly around hot springs — may have protected early organic molecules & helped form the first protective membrane (barrier defining a cell).

What Is a Cell?

CELL → The basic structural & functional unit at which life exists; all living organisms are made up of cells.

→ **Unicellular** organisms (bacteria, yeast) = made of only 1 cell.

→ **Multicellular** organisms (plants, fish, birds, humans) = made of millions of cells working together.

① Similar cells performing similar function → form a tissue

② Different tissues organised → form an organ

③ Several organs work together → form an organ system (e.g. nasal pores + cavity + trachea + lungs = respiratory system)

⚠ **Important for Exam |** Even inside tissues/organs/organ systems, the **cell remains the fundamental unit** of structure & function in all living organisms.

2. 2.1 How to Study Cells?

Limit of Resolution

→ Ability of human eye to see two close objects as separate & distinct = **limit of resolution**.

LIMIT OF RESOLUTION → From 25 cm (near point), two points 0.1 mm apart appear distinct — the human eye's limit of resolution is 0.1 mm.

→ A cell is usually too small to be seen by the unaided eye — so scientists needed magnifying tools.

Microscopes & Magnification

→ A **convex lens** (or combination — objective lens + eyepiece) magnifies an object to make it appear larger.

→ **Robert Hooke** (1665) first observed a cell using a self-designed microscope (~200–300X magnification).

→ Examining a thin slice of **cork**, he saw small box-like compartments and named them **'cells'**.

→ School labs use light microscopes with different objective lenses (10X, 40X) for better magnification & resolution.

ACTIVITY 2.1 → Let us estimate the size of a cell (onion peel).

1. Measure diameter of visible field under microscope in mm, convert to µm (1 mm = 1000 µm).
2. Place onion peel slide; count no. of cells along the diameter in a straight line.
3. Estimate real cell size using the formula below.

FORMULA →

Estimated cell size = Diameter of visible field (µm) ÷ Number of cells along diameter

→ Example: If field diameter = 5000 µm and 25 cells counted along diameter → cell size = 5000/25 = **200 µm**.

→ Total magnification of microscope = magnifying power of **eyepiece** × **objective lens** (e.g., 10X × 10X = 100X).

→ Over the years, microscopes have improved in 3 features: **resolution** (clarity), **contrast** (brightness difference) & **magnification**.

Electron Microscope

→ Uses a beam of **electrons** instead of light — reveals fine cell structure at the **nanometre scale** (1 nm = one-billionth of a metre).

★ SEM image of Colocasia leaf's lower surface clearly shows stomata.

3. 2.2 Structure of a Cell

→ Cells interact with one another & their surroundings at the **cell boundary** — even single-celled organisms exchange material through the cell membrane.

2.2.1 Cell Membrane — The Universal Feature

CELL / PLASMA MEMBRANE → Thin boundary surrounding a cell; protects contents & defines the cell's individuality.

→ It is **selectively permeable** — allows some substances through, blocks others (e.g. O_2/CO_2 exchange in alveoli).

ACTIVITY 2.2 → Let us experiment — cut a potato into 2 equal pieces, weigh them

A. Piece in Beaker A → plain water

B. Piece in Beaker B → 20% salt/sugar solution

→ Leave ~1 hour, then re-weigh & compare.

→ **Beaker A** — potato piece **swells** (weight increases). **Beaker B** — potato piece **shrinks** (weight decreases).

→ Reason: cell membrane lets **water** move in/out but blocks sugar/salt molecules.

OSMOSIS → Movement of water from a dilute (more water) to a concentrated (more solute) solution through a selectively permeable membrane, until concentrations equalise.

DIFFUSION → Net movement of particles from higher to lower concentration — occurs even without a membrane. Osmosis = diffusion of water specifically.

→ In plants, water from soil enters root cells by **osmosis**.

Condition	Meaning	Effect
Isotonic	Outside solute = Inside solute	No net water movement
Hypotonic	Outside solute < Inside solute	Water enters cell (swells)
Hypertonic	Outside solute > Inside solute	Water leaves cell (shrinks)

Fluid-Mosaic Model of Membrane

→ Cell membrane is ~**7–10 nanometres** thick, made of **lipids** (fats) & **proteins**.

① Lipid bilayer — 2 layers of fat molecules; water-attracting heads outward, water-repelling tails inward, with proteins embedded

② Molecules can move sideways, flip & rotate → membrane is **fluid**

③ Proteins act like gatekeepers helping substances pass through

④ Molecules arranged like tiles → called the '**mosaic**' model

4. 2.2.2 Cell Wall — The Outer Covering

→ Plants can't move, so they need a **rigid structure** to withstand wind & rain — hence a **cell wall** outside the cell membrane.

CELL WALL → Rigid but permeable outer covering (in plants, fungi, bacteria) that lets water & minerals pass through; keeps plants firm & upright.

→ Cell wall is made mainly of **cellulose** (a carbohydrate of linked glucose units) — acts as roughage in our diet.

ACTIVITY 2.3 → Compare onion peel / Rhoeo leaf peel cells vs human cheek cells under a microscope.

→ Onion/Rhoeo peel cells are **box-shaped, regularly arranged**; cheek cells are **irregularly arranged** (no cell wall).

→ When put in 20% sugar solution: plant cell **boundary stays same** but inner content shrinks (cell membrane pulls away from wall). Cheek cells **shrink considerably**.

⚠ **Important for Exam |** Rigid cell wall keeps plant cells firm in original shape even after losing water by osmosis — animal cells lack a cell wall & shrink freely.

5. 2.3 The Cell Interior — A Coordinated System

→ Every cell has 3 basic parts: ① selectively permeable plasma membrane, ② semi-fluid cytoplasm, ③ a prominent nucleus.

ORGANELLES → Sub-cellular components in the cytoplasm, most visible only under an electron microscope.

Prokaryotic vs Eukaryotic Cells (Activity 2.4)

→ **Bacterial cell** lacks a well-defined nucleus & membrane-bound organelles → called **prokaryotic** (pro = primitive, karyon = nucleus). Genetic material region = **nucleoid**.

→ **Plant & animal cells** have a well-defined nucleus + membrane-bound organelles → called **eukaryotic** (eu = true).

Feature	Prokaryotic	Eukaryotic
Primitive nucleus	Present	Absent
Cell diameter	1–10 µm	10–100 µm
No. of cells/organism	Usually unicellular	Uni- or multicellular
Membrane-bound organelles	Absent	Present
Membrane-bound nucleus	Absent	Present

★ Cytoskeleton (fine fibre network) in eukaryotic cells gives structural support, shape & enables movement/transport — visible only under electron microscope.

6. 2.3.1 Cell Organelles & Their Jobs

Nucleus — House of Coded Instructions

→ Has a **double-layered nuclear membrane** with pores allowing material transfer between nucleus & cytoplasm.

→ **Nucleolus** = dense round body where ribosomal subunits are made; these exit to cytoplasm to assemble into ribosomes.

CHROMOSOMES → Rod-shaped structures (visible only when cell divides) made of DNA + proteins; carry inherited information from parents.

→ Functional segments of DNA = **genes**. In a non-dividing cell, DNA exists as tangled **chromatin**; it organises into chromosomes when the cell is about to divide.

★ Mature RBCs lack a nucleus (enucleate) — gives more space for haemoglobin to carry oxygen; but they can't repair/divide, so they live only ~120 days.

→ Prokaryotic cells have no well-defined nucleus — DNA is a single circular molecule in a region called the **nucleoid**.

Ribosomes — The Protein Factories

→ Tiny structures, free in cytoplasm or attached to ER — sites of **protein synthesis**.

Endoplasmic Reticulum (ER) — Manufacturing Factory

→ Large network-like organelle continuous with the nuclear envelope; key role in synthesis/transport of proteins, lipids & hormones.

Type	Surface	Function
RER (Rough)	Ribosomes attached → rough	Protein synthesis & secretion (e.g. pancreatic cells)
SER (Smooth)	No ribosomes → smooth	Synthesis & storage of fats & hormones

Golgi Apparatus — Packaging & Shipping

→ Stacks of flattened sac-like structures, linked to ER & cell membrane. Acts like the cell's **post office** — modifies, sorts & packages proteins/lipids into vesicles for transport, secretion or lysosome formation.

★ Golgi apparatus first observed in 1898 by Italian scientist Camillo Golgi in nerve cells of a barn owl.

Lysosomes — The Clean-Up System

LYSOSOMES → Single membrane-bound sacs filled with enzymes that break down unwanted proteins, carbohydrates, fats & damaged parts of the cell.

★ Human sperm cells carry lysosomal enzymes that break down the egg's outer layer, enabling fertilisation.

Mitochondria — The Powerhouse of the Cell

→ Surrounded by **2 membranes**: outer membrane (smooth, porous) & inner membrane folded into finger-like **cristae** (↑ surface area for reactions).

→ Glucose is broken down here in **cellular respiration**, releasing energy stored as **ATP** (Adenosine Triphosphate) — the cell's energy currency.

Plastids — Food Synthesis & Storage in Plants

Plastid	Pigment	Function
Chloroplast	Chlorophyll (green)	Photosynthesis; contains stroma + disc-shaped membranes
Chromoplast	Yellow / orange / red	Bright colour in flowers & fruits → attracts pollinators/seed dispersers
Leucoplast	Colourless	Stores food — starch, oils or proteins (e.g. potato, taro)

→ Mitochondria & plastids both have their **own DNA & ribosomes** → suggests an evolutionary link with single-celled bacteria.

Vacuoles — Storage & Support

→ Mature plant cell has one **large central vacuole** (single selectively permeable membrane) filled with watery **cell sap** — stores water, minerals, sugars, waste.

→ Vacuole keeps the plant cell **firm** by maintaining internal pressure; insufficient water → vacuole shrinks → plant **wilts**.

→ Animal cells sometimes have smaller vacuoles — for temporary material storage.

7. 2.4 How Do Cells Grow & Divide?

→ Cuts heal & hair regrows because **cells grow & divide** to replace old/dead/damaged cells. Growth = cells getting bigger + cells dividing to form new ones.

ACTIVITY 2.5 → Grow onion root tips in water; fix in aceto-alcohol, stain with aceto-carmine, observe under microscope → shows different stages of cell division.

CELL DIVISION → Process by which new cells form from pre-existing cells — enables growth, repair & reproduction.

→ ~Hundreds of billions of cells (≈1% of body's total) are replaced daily. Eukaryotic cells divide in an orderly manner via the **cell cycle**.

Mitosis

MITOSIS → Produces 2 genetically identical daughter cells from 1 parent cell — same DNA & chromosome number as parent.

→ Every human starts as a single fertilised egg — repeated mitosis forms trillions of body cells. Most common type of cell division.

Meiosis

MEIOSIS → Two-step division producing 4 daughter cells (gametes), each with half the chromosome number — creates genetic variation.

→ Occurs only in reproductive organs: **testes** (sperm) & **ovaries** (eggs) in animals; **anthers** (pollen) & **ovaries** (egg cells) in plants.

→ 1st division: chromosome number halves. 2nd division: like mitosis, each daughter splits again → 4 gametes with half DNA. Fertilisation restores original chromosome number.

⚠ **Important for Exam** | Errors in **mitosis** → uncontrolled division → tumours & abnormal chromosome numbers. Errors in **meiosis** → genetic disorders, pregnancy loss or reduced fertility.

8. 2.5 Cell Theory — The Unifying Principle

Scientist	Year	Contribution
Matthias Schleiden	1838	All plants are made up of cells
Theodor Schwann	1839	All animals are made up of cells
Rudolf Virchow	1855	New cells form only from pre-existing cells

CELL THEORY → ① All living organisms are made of one or more cells. ② The cell is the basic unit of structure & function. ③ All cells arise from pre-existing cells.

Do Cells Grow & Reproduce Forever?

→ Cells grow, divide, function & eventually **die** when no longer needed; dead cells are replaced. Every cell has a definite life span.

CONTACT INHIBITION → In many animal cells, division stops once cells touch neighbouring cells.

→ **Cancer cells** lose this control & divide uncontrollably → form **tumours** (benign or malignant, can spread to other body parts).

→ Plant cells (rigid cell wall) don't show contact inhibition & follow a different growth pattern.

★ Programmed Cell Death (PCD) is a controlled process of selective cell destruction — e.g. it removes cells between fingers in the embryo, preventing webbed hands.

★ Totipotency: Gottlieb Haberlandt (1902) showed a mature plant cell can develop into a full plant given the right conditions — foundation of Plant Tissue Culture Technology.

📌 At a Glance — Quick Revision

- ✔ Cell = basic structural & functional unit of all living organisms
- ✔ Prokaryotic: no nucleus/organelles (nucleoid) | Eukaryotic: true nucleus + organelles
- ✔ Cell membrane (all cells) + Cell wall (plants, fungi, bacteria only)
- ✔ Nucleus houses chromosomes (DNA + protein) carrying genetic info
- ✔ Key organelles: Nucleus, ER, Mitochondria, Golgi, Ribosomes, Lysosomes
- ✔ Plant-only organelles: Plastids (chloroplast/chromoplast/leucoplast), large vacuole
- ✔ Mitosis → 2 identical cells | Meiosis → 4 gametes, half chromosomes
- ✔ Normal cells grow in controlled manner & die naturally; cancer cells don't