Cell Biology

Unit 1 · Lesson 1 · Cell theory and cell types

The notes for Lesson 1 of Unit 1: chapters 1.1 to 1.3 of the unit book, with their figures, worked examples, exam traps and quizzes, in one file. The full unit book, with every chapter, the exam question bank and the glossary, is linked at the end.

Lesson 1 of 2 | 3 chapters | Chapters 1.1 to 1.3

About these notes

These are the notes for **Lesson 1 · Cell theory and cell types** of the University free n easy video lessons on Cell Biology Unit 1, Foundations: Cell Theory and Cell Types. They are chapters 1.1 to 1.3 of the unit book, unchanged, so a page here is the same page in the full book.

1.1 Development of the cell theory

The cell theory says three things: every living organism is made of one or more cells; the cell is the smallest unit that is alive; and every cell comes from an earlier cell by division. It took almost two hundred years to establish, from Robert Hooke's cork in 1665 to Rudolf Virchow's principle in 1855, because it had to wait for good microscopes. It is the base of biology and medicine: a disease is a disorder of cells, an antibiotic attacks bacterial cells, and biotechnology grows and engineers cells.

You need: only school biology.

Seeing cells: Hooke and Leeuwenhoek

In 1665 the English scientist Robert Hooke published *Micrographia*, a book of drawings made through his compound microscope. A thin slice of cork showed rows of tiny empty boxes, and he called them "cells", from the Latin *cella*, a small room. Hooke was looking at dead tissue: he saw the walls left behind by cork cells, with nothing living inside.

In the 1670s Antonie van Leeuwenhoek, a cloth merchant in Delft in the Netherlands, made single-lens microscopes that magnified a few hundred times. With them he saw and described living single cells: protists in pond water, bacteria scraped from his teeth, sperm cells and blood

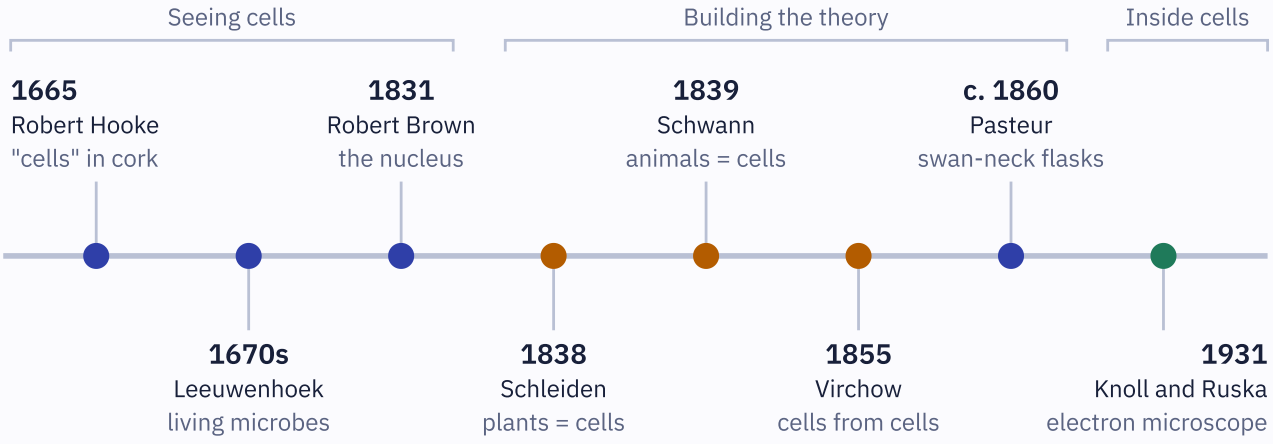
cells. He called the tiny moving ones "animalcules" and reported them in letters to the Royal Society of London; textbooks credit him with the first description of a living cell.

Lenses improved slowly after that. In 1831 the Scottish botanist Robert Brown noticed a round body in orchid cells and named it the nucleus.

Building the theory: Schleiden, Schwann and Virchow

In 1838 the German botanist Matthias Schleiden concluded that all plant tissues are made of cells. In 1839 the zoologist Theodor Schwann showed the same for animal tissues. Schwann noted that animal cells have a thin outer layer, today called the plasma membrane, and that plant cells have a cell wall outside it. He proposed that cells are the basic units of all living things: the Schleiden–Schwann cell theory.

Their theory had a gap. They could not say where new cells come from, and both believed new cells could form out of a structureless fluid, rather like crystals growing in a solution. In the early 1850s Robert Remak watched cells divide in developing embryos, and in 1855 the German doctor Rudolf Virchow stated the principle *omnis cellula e cellula*: every cell comes from a pre-existing cell. Virchow built cellular pathology on it, the idea that disease starts in cells. Around 1860 Louis Pasteur's swan-neck flask experiments showed that microbes do not arise from broth by themselves; they come only from other microbes.



Gaps between dates are not drawn to scale.

Figure 1.1.1 How the cell theory was built. Blue dots are advances in seeing cells; the three orange dots are the classical theory (Schleiden for plants, Schwann for animals, Virchow for the origin of cells); the green dot opened the inside of the cell. Notice the wait of more than 150 years between Leeuwenhoek and Schleiden: the idea needed better microscopes first.

The modern cell theory

The electron microscope, built by Max Knoll and Ernst Ruska in 1931, revealed the organelles inside cells, and molecular biology showed that the hereditary material is DNA. The theory as taught today keeps the three classical statements and adds three more:

1. All living organisms are made of one or more cells.
2. The cell is the basic unit of structure and function in living things.
3. All cells arise from pre-existing cells by division.
4. Cells carry hereditary information as DNA, which passes to daughter cells at division.
5. All cells have broadly the same chemical composition (Chapter 1.4).
6. The chemical reactions of life (metabolism) take place inside cells.

Exceptions and limits

Examiners often ask for "exceptions to the cell theory". Give each one with its reason:

- **Viruses** are not cells: they have no metabolism of their own and multiply only inside a host cell, so they sit outside the theory rather than disproving it.
- **Syncytia and coenocytes** have many nuclei in one continuous cytoplasm, not split into cells: a skeletal muscle fibre (made by many cells fusing), the hyphae of the bread mould *Rhizopus*, and the alga *Vaucheria*.
- **Cells without a nucleus**: mature mammalian red blood cells and the sieve tube elements of phloem lose their nucleus. They still live and work but cannot divide.
- **Mitochondria and chloroplasts** have their own DNA and ribosomes and divide by splitting, like cells inside cells (Chapter 1.2).
- **The first cell**: "every cell from a cell" cannot explain how the first cell arose, more than 3.5 billion years ago.

WORKED EXAMPLE

Question. The unaided eye can just separate two points about 0.1 mm (100 µm) apart at reading distance. (a) What is the smallest magnification at which a red blood cell 7.5 µm across can be seen as an object? (b) A bacterium 2 µm long? (c) If Leeuwenhoek's lens magnified 250 times, could he see bacteria? Could he see a ribosome about 25 nm across? (6 marks)

Idea. An object becomes visible when its magnified image is at least as large as the smallest detail the eye can resolve: magnification × object size ≥ 100 µm. So the minimum magnification is M = 100 µm ÷ object size.

1. Red blood cell: M = 100 µm ÷ 7.5 µm ≈ 13. About 13 times shows it as a dot; more is needed to see its shape.
2. Bacterium: M = 100 µm ÷ 2 µm = 50 times.
3. Leeuwenhoek and bacteria: image = 2 µm × 250 = 500 µm = 0.5 mm, five times the eye's limit. He could see bacteria as tiny moving specks, which is what he reported.
4. Ribosome: 25 nm = 0.025 µm, so image = 0.025 µm × 250 = 6.25 µm, far below 100 µm. More magnification would not help: a light microscope cannot separate details closer than about 0.2 µm, because of the wavelength of light (Unit 6). Ribosomes had to wait for the electron microscope.

Answer. (a) About 13 times. (b) 50 times. (c) Yes for bacteria (image 0.5 mm); no for ribosomes (image about 6 µm, and below the resolution limit of any light microscope).

EXAM TRAPS

- Hooke named cells but saw only dead cork walls; Leeuwenhoek is credited with first seeing and describing living cells. "Hooke discovered living cells" loses the mark.
- Two Roberts: Robert Hooke (1665, cells) and Robert Brown (1831, nucleus). Do not swap them.
- Schleiden worked on plants (1838) and Schwann on animals (1839). *Omnis cellula e cellula* is Virchow's (1855), and it corrected them: they thought cells could form from non-living fluid.
- For "exceptions", name viruses first and say why they fall outside the theory. A bare list without reasons earns half marks.

CHECK YOURSELF

– REMEMBER **State the three statements of the classical cell theory.** 3 marks

All organisms are made of one or more cells; the cell is the basic unit of structure and function; all cells arise from pre-existing cells.

– UNDERSTAND **Why was Virchow's statement needed to complete the theory of Schleiden and Schwann?** 2 marks

Schleiden and Schwann could not explain where new cells come from and believed in "free cell formation" from fluid. Virchow, building on Remak's observations, showed that cells arise only by division of existing cells, which explains growth, repair and inheritance.

– UNDERSTAND **A mature human red blood cell has no nucleus. Is it still a cell?** 2 marks

Yes. It is bounded by a plasma membrane, carries out metabolism (it breaks down glucose and carries oxygen) and arose by division of nucleated cells in the bone marrow. It only lacks the ability to divide.

– APPLY ***Mycoplasma* cells are about 0.3 µm across. What minimum magnification shows one to the eye, and can a light microscope show its shape?** 3 marks

M = 100 µm ÷ 0.3 µm ≈ 330 times. The cell is only just above the light microscope's limit of about 0.2 µm, so it appears as a dot; its shape needs an electron microscope.

– APPLY **Broth boiled in a swan-neck flask stays clear for months, but turns cloudy within days once the neck is broken. Explain using the cell theory.** 3 marks

Boiling kills the microbes already present. The curved neck traps dust that carries microbes, so no new cells arrive and none appear. Breaking the neck lets microbe-laden dust in, and the microbes multiply. New cells came only from existing cells, as the third statement says.

– ANALYZE **"A skeletal muscle fibre disproves the cell theory." Argue for and against.** 4 marks

For: one fibre has hundreds of nuclei in one cytoplasm with no cell boundaries, so it is not a single cell in the usual sense. **Against:** it forms when many myoblast cells fuse, each made by division, and it is built of cellular material and runs cellular metabolism. It is best called a syncytium, a modified cellular unit, so it refines the theory rather than disproving it.

BEYOND THE SYLLABUS

Not for the exam. The cell theory is now studied one cell at a time. Single-cell RNA sequencing reads the active genes of thousands of individual cells in one experiment, and the Human Cell Atlas project uses it to catalogue every human cell type. Organoids, tiny organ-like clusters grown from stem cells, show how cells build tissues. Other groups assemble "synthetic cells" from lipids and purified molecules to find the least a system needs to count as alive. Search: single-cell RNA-seq, Human Cell Atlas, organoids, bottom-up synthetic cell.

1.2 Prokaryotic and eukaryotic cell organization

All cells on Earth follow one of two plans. A prokaryotic cell (bacteria and archaea) has no nucleus: its DNA lies in the cytoplasm in a region called the nucleoid, and it has no membrane-bound organelles. A eukaryotic cell (protists, fungi, plants and animals) keeps its DNA inside a nucleus wrapped in a double membrane and divides its interior into membrane-bound compartments. The names are Greek: *karyon* is a kernel (the nucleus), *pro* means before and *eu* means true. The plan also decides which host a biotechnologist picks: *E. coli* for fast, cheap production, yeast or animal cells when a protein needs eukaryotic processing.

You need: Chapter 1.1.

The prokaryotic plan

A typical bacterium such as *Escherichia coli* is a rod about 2 µm long and 1 µm wide (1 µm is a thousandth of a millimetre). From the outside in (Figure 1.2.1A):

- **Capsule** (in many species): a sticky polysaccharide coat that helps the cell cling to surfaces and resist white blood cells.
- **Cell wall**: in bacteria a mesh of peptidoglycan that stops the cell bursting; thick in Gram-positive bacteria, thin and covered by an outer membrane in Gram-negative ones. Archaea have walls without peptidoglycan; *Mycoplasma* has no wall.
- **Plasma membrane**: the cell's working membrane, controlling what enters and leaves. Respiration, and light capture in photosynthetic bacteria, happen on it or on its infoldings.
- **Cytoplasm** with **70S ribosomes** (one 30S and one 50S subunit) and storage granules such as glycogen.

- **Nucleoid**: usually one circular chromosome, folded and supercoiled with proteins but with no membrane around it. Many cells also carry **plasmids**, small extra DNA circles that often carry antibiotic-resistance genes and serve as cloning vectors.
- **Flagella**, rotating propellers of the protein flagellin, and **pili**, thin hairs for attachment and for passing DNA in conjugation.

Because the DNA is not walled off, ribosomes start translating an mRNA while it is still being transcribed: transcription and translation are coupled. A prokaryote divides by binary fission, copying its chromosome and splitting in two, without mitosis.

Archaea look like bacteria and are prokaryotes, but in 1977 Carl Woese showed from ribosomal RNA (16S rRNA) sequences that they are a separate group. Their membrane lipids have ether bonds instead of ester bonds, and their machinery for reading DNA resembles that of eukaryotes. In 1990 Woese proposed three domains of life: Bacteria, Archaea and Eukarya.

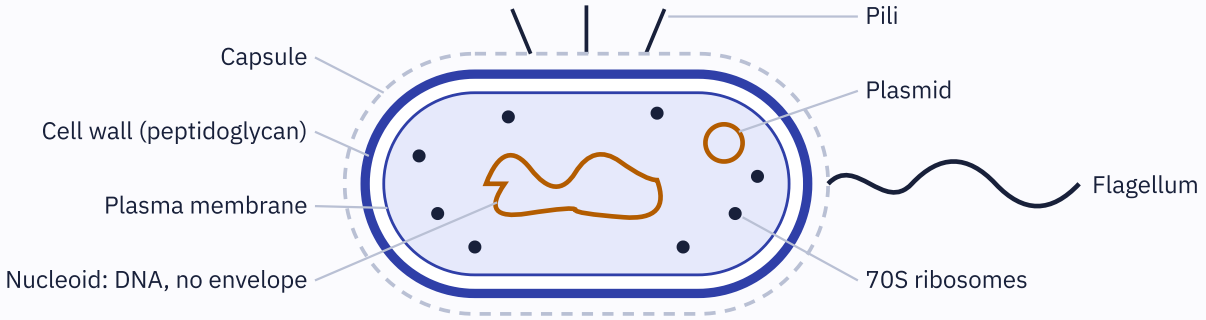
The eukaryotic plan

A eukaryotic cell is usually 10 to 100 µm across (Figure 1.2.1B). It has:

- A **nucleus** bounded by a double membrane, the nuclear envelope, with pores. The DNA is split into several linear chromosomes wound on histone proteins (chromatin); the nucleolus makes ribosome subunits.
- An **endomembrane system** (endoplasmic reticulum, Golgi apparatus, lysosomes, endosomes, vesicles), plus **mitochondria**, **peroxisomes** and, in plants and algae, **chloroplasts** (Chapter 1.5).
- **80S ribosomes** (40S plus 60S) in the cytosol and on the rough ER.
- A **cytoskeleton** of microtubules, actin filaments and intermediate filaments, with motor proteins that move cargo (Unit 3).
- Division by **mitosis**, and by **meiosis** for sex cells (Unit 4). Transcription in the nucleus is separated from translation in the cytoplasm, so RNA is processed (capped, spliced, tailed) before it leaves.
- Cilia and flagella, where present, of microtubules in a 9 + 2 pattern, bent by the motor protein dynein: they beat like whips instead of rotating.

Mitochondria and chloroplasts are thought to descend from bacteria that an ancestral cell engulfed and kept: the endosymbiotic theory, championed by Lynn Margulis from 1967. Both have two membranes, their own circular DNA and bacteria-like ribosomes, and both divide by fission.

A. Prokaryotic cell (a bacterium), about 1–5 µm long



B. Eukaryotic cell (animal), about 10–30 µm across

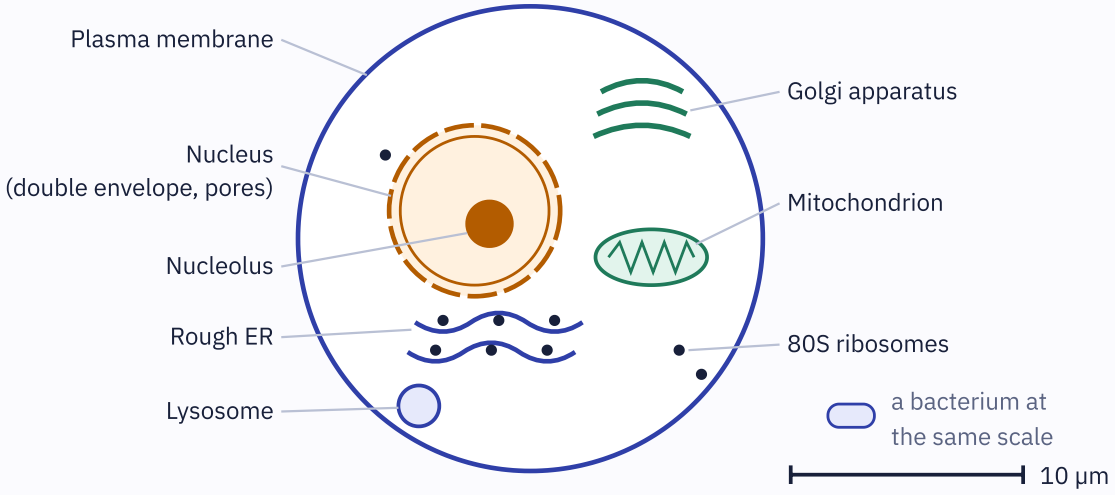


Figure 1.2.1 The two cell plans. (A) A bacterium, enlarged: its DNA (orange) lies in the cytoplasm as a nucleoid, with no membrane around it, beside a plasmid. (B) An animal cell: the DNA is closed inside a double-membraned nucleus and the interior is divided into organelles. The small rod at bottom right is a bacterium at the same scale as cell B; a eukaryotic cell is often a thousand times larger in volume.

Side by side

FEATURE	PROKARYOTIC CELL	EUKARYOTIC CELL
Typical size	1–5 µm	10–100 µm
Nucleus	none; DNA in a nucleoid	true nucleus with a double envelope
Chromosomes	usually one, circular; plasmids common	several, linear, wound on histones
Membrane-bound organelles	absent	present

FEATURE	PROKARYOTIC CELL	EUKARYOTIC CELL
Ribosomes	70S (30S + 50S)	80S (40S + 60S) in the cytosol; smaller, bacteria-like ones in mitochondria and chloroplasts
Cell wall	peptidoglycan in bacteria	cellulose (plants), chitin (fungi), none (animals)
Respiration	on the plasma membrane	in mitochondria
Division	binary fission	mitosis and meiosis
Gene expression	transcription and translation coupled; introns rare	separated by the nuclear envelope; introns common
Flagellum	rotates; made of flagellin	bends like a whip; 9 + 2 microtubules

WORKED EXAMPLE

Question. Treat a coccus (round bacterium) as a sphere 1 μm in diameter and an animal cell as a sphere 20 μm in diameter. (a) Find the surface area, volume and surface-area-to-volume ratio (SA/V) of each. (b) The time for a molecule to diffuse a distance x is roughly $t \approx x^2/(2D)$, where D is its diffusion coefficient. How many times longer does a molecule take to diffuse from the membrane to the centre of the animal cell? (c) What does this mean for how the cells are organized? (8 marks)

Formulas. For a sphere of radius r: $SA = 4\pi r^2$ and $V = (4/3)\pi r^3$, so $SA/V = 3/r$.

1. Bacterium, r = 0.5 μm: $SA = 4\pi(0.5)^2 = 3.14\ \mu m^2$; $V = (4/3)\pi(0.5)^3 = 0.524\ \mu m^3$; $SA/V = 3 \div 0.5 = 6.0\ \mu m^{-1}$.
2. Animal cell, r = 10 μm: $SA = 4\pi(10)^2 = 1257\ \mu m^2$; $V = (4/3)\pi(10)^3 = 4189\ \mu m^3$; $SA/V = 3 \div 10 = 0.30\ \mu m^{-1}$.
3. Compare: the animal cell has 8000 times the volume but only 400 times the surface, so each μm^3 of it has 20 times less membrane serving it.
4. Diffusion: D is the same for the same molecule, so t grows with x^2. Ratio = $(10\ \mu m \div 0.5\ \mu m)^2 = 20^2 = 400$.
5. Meaning: a large cell cannot rely on its outer membrane and on diffusion alone. Eukaryotes add internal membranes (ER, mitochondrial cristae) to multiply membrane area, compartments that keep each job in one place, and motor proteins that carry cargo along the cytoskeleton.

Answer. SA/V is $6.0\ \mu m^{-1}$ for the bacterium and $0.30\ \mu m^{-1}$ for the animal cell, 20 times less; diffusion to the centre takes about 400 times longer. Hence the compartments and active transport of eukaryotic cells.

EXAM TRAPS

- Prokaryotes do organize their DNA: the nucleoid is folded and packed with proteins. What they lack is a nuclear envelope.
- Svedberg units do not add up: 30S + 50S gives 70S, and 40S + 60S gives 80S. S measures how fast a particle sinks in a centrifuge, which depends on shape as well as mass.
- "Eukaryotes have 80S ribosomes" is true of the cytosol only; their mitochondria and chloroplasts have smaller, bacteria-like ribosomes.
- Older books draw mesosomes, membrane infoldings said to carry out respiration. Electron microscopists now regard them as artefacts of chemical fixation; say so if your book shows them.

CHECK YOURSELF

– REMEMBER **Name the subunits of a 70S and of an 80S ribosome.** 2 marks

70S = 30S + 50S (prokaryotes); 80S = 40S + 60S (eukaryotic cytosol).

– UNDERSTAND **Why can transcription and translation be coupled in *E. coli* but not in yeast?** 2 marks

In *E. coli* the DNA and ribosomes share one compartment, so ribosomes bind the mRNA while it is still being made. In yeast, transcription happens inside the nucleus and the mRNA is processed and exported before cytoplasmic ribosomes can reach it.

– UNDERSTAND **Give four pieces of evidence that mitochondria descend from bacteria.** 4 marks

Two membranes; their own circular DNA; bacteria-like ribosomes; division by fission (the cell never builds them from scratch).

– APPLY **A coccus is 2 μm across and a yeast cell 6 μm across. Treating both as spheres, find SA/V for each and the ratio.** 3 marks

Coccus: r = 1 μm, SA/V = 3 μm^{-1}. Yeast: r = 3 μm, SA/V = 1 μm^{-1}. The coccus has 3 times more surface per unit volume.

– APPLY **A eukaryotic cell is 15 times wider than a bacterium. How many times longer does diffusion across it take?** 2 marks

t grows with x^2, so $15^2 = 225$ times longer.

– ANALYZE **Human insulin is made commercially in *E. coli*, but erythropoietin (EPO), a glycoprotein, is made in Chinese hamster ovary (CHO) cells. Explain the choice.** 4 marks

EPO needs sugar chains added in the ER and Golgi to work as a drug; without them it is cleared from the blood too quickly. *E. coli* has no ER or Golgi and cannot add them, so a mammalian host is used. Insulin needs no sugar chains, so the cheaper, faster prokaryotic host is enough.

BEYOND THE SYLLABUS

Not for the exam. The two-plan picture is being refined. Asgard archaea, found by DNA sequencing of sea-floor sediments from 2015 onwards, carry genes once thought to exist only in eukaryotes and are the closest known prokaryotic relatives of eukaryotes. The bacterium *Thiomargarita magnifica*, described in 2022, is about a centimetre long and keeps its DNA in membrane sacs. Bacteria also have cytoskeletal proteins related to tubulin (FtsZ) and actin (MreB). Search: Asgard archaea, eukaryogenesis, *Thiomargarita magnifica*, bacterial cytoskeleton.

1.3 Plant cells versus animal cells

Plant and animal cells are both eukaryotic and share almost every organelle. Their differences follow from lifestyle. A plant stays in one place, makes its own food from light and holds itself up with water pressure, so its cells have a rigid wall, chloroplasts and a large water-filled vacuole. An animal moves, eats and changes shape, so its cells have no wall and keep centrioles and lysosomes. The others fold it into eukaryotic organization or take it as known from Class 11.

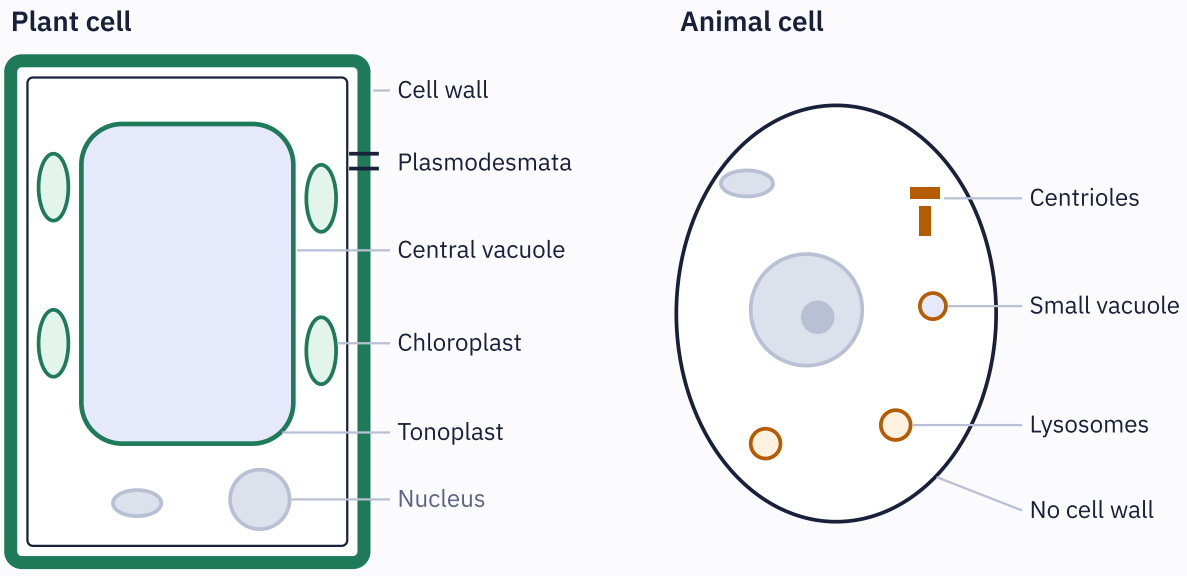
What both have

Nucleus, plasma membrane, mitochondria, endoplasmic reticulum, Golgi apparatus (in plants, many separate stacks called dictyosomes), ribosomes, peroxisomes and a cytoskeleton. A plant cell has mitochondria as well as chloroplasts: chloroplasts make sugar, mitochondria burn it, day and night.

The differences examiners ask for

FEATURE	PLANT CELL	ANIMAL CELL
Cell wall	present: cellulose, with pectin in the middle lamella between cells	absent; an extracellular matrix instead (Unit 5)
Plastids	chloroplasts (photosynthesis), chromoplasts (colour), leucoplasts (storage, such as starch in amyloplasts)	none
Vacuole	one large central vacuole bounded by the tonoplast, up to 90% of the cell volume	small and temporary, if any
Centrioles	absent in flowering plants and conifers	a pair in the centrosome
Lysosomes	few; the vacuole does most of the digesting	present
Stored carbohydrate	starch	glycogen
Cytokinesis	a cell plate grows outward from the middle	a furrow pinches in from outside (Unit 4)
Links between cells	plasmodesmata through the walls	gap junctions, tight junctions, desmosomes (Unit 5)
Shape	fixed, often box-like	variable, often rounded

Turgor ties the plant features together. The vacuole holds a concentrated solution, water enters it by osmosis (Unit 2), and the swelling vacuole presses the cytoplasm against the wall. The wall pushes back, so the cell becomes firm, or turgid, instead of bursting. An animal cell in pure water has nothing to push back, so it swells and can burst, as red blood cells do.



Green: only in plant cells. Orange: only in animal cells. Grey: in both.
Both also have mitochondria, ER, Golgi, ribosomes and peroxisomes.

Figure 1.3.1 A plant cell and an animal cell with their unique parts coloured. In the plant cell the central vacuole fills most of the space and pushes the cytoplasm, chloroplasts and nucleus into a thin layer against the wall; the animal cell has no wall, so its shape can change.

WORKED EXAMPLE

Question. A plant cell is a cube 50 µm on each side. Its central vacuole, also cube-shaped and centred, fills 90% of the cell volume. Ignoring the wall, how thick is the layer of cytoplasm around the vacuole? (3 marks)

1. Cell volume = 50^3 = 125 000 µm³.
2. Vacuole volume = 0.90 × 125 000 = 112 500 µm³, so the vacuole's side s = $\sqrt[3]{112\,500}$ = 48.3 µm.
3. The cytoplasm lies in equal layers on both sides: thickness = (50 − 48.3) ÷ 2 ≈ 0.86 µm.

Answer. Under 1 µm. The cytoplasm is a thin film against the wall, which suits light capture and exchange with neighbours, and the vacuole, mostly water, is a cheap way to build a big cell.

EXAM TRAPS

- Plant cells have mitochondria too. "Plants have chloroplasts instead of mitochondria" is wrong.
- Not every plant cell has chloroplasts: root and storage cells have leucoplasts instead.
- "No centrioles" holds for flowering plants and conifers; mosses, ferns and cycads make swimming sperm with basal bodies.
- A fungal cell also has a wall (of chitin, not cellulose) and stores glycogen, so "has a wall" alone does not make a cell a plant cell.

CHECK YOURSELF

– REMEMBER **Name the three kinds of plastid and the job of each.** 3 marks

Chloroplasts: photosynthesis. Chromoplasts: pigments that colour fruits and flowers. Leucoplasts: storage of starch, oils or proteins.

– UNDERSTAND **Why does a red blood cell burst in distilled water while a leaf cell only becomes firm?** 2 marks

Water enters both by osmosis. The leaf cell's wall resists the swelling and the cell becomes turgid; the red blood cell has no wall, so it swells until its membrane breaks.

– APPLY **Repeat the worked example for a 40 µm cube whose vacuole fills 80% of the volume.** 3 marks

Cell 64 000 µm³; vacuole 51 200 µm³; side $\sqrt[3]{51\,200} = 37.1$ µm; layer = $(40 - 37.1) \div 2 \approx 1.4$ µm.

– ANALYZE **Cell X has a wall, a large vacuole, starch grains and no chloroplasts. Cell Y has a chitin wall and glycogen granules. Identify each.** 3 marks

X is a non-green plant cell, such as a potato tuber or root cell (starch in amyloplasts). Y is a fungal cell: chitin walls and glycogen stores mark fungi.

– UNDERSTAND **Why does a plant cell divide with a cell plate instead of a furrow?** 2 marks

The rigid wall cannot pinch inward, so the new wall is built from the middle outward by vesicles from the Golgi that fuse into a cell plate.

BEYOND THE SYLLABUS

Not for the exam. Plant cells grown in steel bioreactors work as factories. Taliglucerase alfa, an enzyme for Gaucher disease made in carrot cells, became in 2012 the first drug from plant cell culture approved by the US FDA, and the anticancer drug paclitaxel is also produced by plant cell culture. Search: plant cell culture, molecular farming.

Key terms of this lesson

TERM	MEANING OR FORMULA	CHAPTER
Cell theory	all organisms are made of cells; the cell is the basic unit of life; cells arise only from cells	1.1
Omnis cellula e cellula	"every cell from a cell": Virchow, 1855	1.1
Minimum magnification	M ≈ 100 µm (the eye's limit) ÷ object size; no light microscope resolves details closer than about 0.2 µm	1.1
Prokaryote, eukaryote	no nucleus, DNA in a nucleoid; DNA inside a nucleus with a double envelope	1.2
Ribosome types	70S = 30S + 50S (prokaryotes); 80S = 40S + 60S (eukaryotic cytosol)	1.2
Surface-to-volume ratio	for a sphere, SA/V = 3/r	1.2
Diffusion time	$t \approx x^2/(2D)$: twice the distance takes four times as long	1.2
Turgor	pressure of the swollen vacuole pressing the cytoplasm against the cell wall	1.3

Glossary (terms used in this lesson)

Archaea Prokaryotes that form a domain of their own, separate from bacteria, with ether-linked membrane lipids and no peptidoglycan.

Binary fission	Division of a prokaryotic cell into two after copying its chromosome, without mitosis.
Capsule	Sticky polysaccharide coat outside the wall of many bacteria.
Cell theory	All organisms are made of cells, the cell is the basic unit of life, and cells arise only from cells.
Centriole	Small cylinder of microtubules; a pair forms the centrosome of animal cells.
Compartment	A membrane-enclosed space in a cell with its own set of proteins and conditions.
Cytoplasm	Everything between the plasma membrane and the nucleus, organelles included.
Cytosol	The fluid part of the cytoplasm, outside all organelles.
Endomembrane system	ER, Golgi, endosomes, lysosomes and vesicles, which exchange material by vesicles.
Endosymbiotic theory	Mitochondria and chloroplasts descend from bacteria engulfed by an ancestral cell.
Eukaryote	Organism whose cells keep their DNA in a nucleus and have membrane-bound organelles.
Nucleoid	Region of a prokaryotic cell holding its DNA, with no membrane around it.
Nucleolus	Dense region inside the nucleus where ribosome subunits are made.
Organelle	A structure in a cell with a specific job, such as a mitochondrion or a ribosome.
Peptidoglycan	Mesh of sugar chains cross-linked by short peptides that forms the bacterial cell wall.
Plasmid	Small circular DNA molecule that copies itself apart from the chromosome.
Plasmodesmata	Channels through plant cell walls that join the cytoplasm of neighbouring cells.
Plastid	Double-membrane plant organelle: chloroplast, chromoplast or leucoplast.
Prokaryote	Organism (bacterium or archaeon) whose cells have no nucleus and no membrane-bound organelles.
Resolution	The smallest distance at which two points can still be seen as separate.
Tonoplast	Membrane around the central vacuole of a plant cell.

The full unit book

Every chapter of Unit 1, the unit summary, the exam question bank with model answers and the full glossary: Cell Biology · Unit 1 · Foundations: Cell Theory and Cell Types (one file, works offline).

Sources and further reading

Textbooks

- Alberts B. et al. *Molecular Biology of the Cell*, 7th edition, W. W. Norton (2022): the chapters on cells and genomes, cell chemistry, and intracellular compartments and protein sorting (from memory; check).
- Lodish H. et al. *Molecular Cell Biology*, W. H. Freeman: the opening chapters on cells and their molecules (from memory; check).
- Cooper G. M. *The Cell: A Molecular Approach*, Oxford University Press: the chapters on the origin and composition of cells (from memory; check).
- Karp G. *Cell and Molecular Biology: Concepts and Experiments*, Wiley: the introductory chapter on cells (from memory; check).
- NCERT *Biology*, Class XI, chapter "Cell: The Unit of Life", for a school-level recap of cell theory and cell types (from memory; check).

Open web resources used for numbers in this book

- BioNumbers 105911, internal membrane area of a hepatocyte, about 100 000 μm², 50 times the plasma membrane (source given there: Alberts et al.): bionumbers.hms.harvard.edu/bionumber.aspx?id=105911
- BioNumbers 110374, relative amounts of membrane types; the ER membrane is about 25 times (liver) and 12 times (pancreatic exocrine cell) the plasma-membrane area: bionumbers.hms.harvard.edu/bionumber.aspx?id=110374
- BioNumbers 110373, membrane-enclosed compartments occupy nearly half the volume of a cell: bionumbers.hms.harvard.edu/bionumber.aspx?id=110373
- University of Hamburg course page, "Molecular composition of a bacterial cell" (data for Figure 1.4.1): www-archiv.fdm.uni-hamburg.de/b-online/library/biology107/bi107vc/fa99/terry/table2.html
- Thermo Fisher Scientific, "Macromolecular components of *E. coli* and HeLa cells" (masses used in the Chapter 1.4 worked example and questions): thermofisher.cn, Ambion technical reference

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