Unit 1 · Cell Biology

STUDY NOTES

Key terms

Prokaryotic cell: no nucleus, no membrane-bound organelles (bacteria, cyanobacteria, archaea).

Eukaryotic cell: true nucleus, membrane-bound organelles (protists, fungi, plants, animals).

Nucleoid: region of a prokaryote's DNA; no membrane round it.

Plasmid: small extra ring of DNA; can carry antibiotic resistance.

Peptidoglycan (murein): bacterial wall; sugars cross-linked by amino acid chains.

Organelle: "little organ", a part with its own job.

Fully permeable: lets water and dissolved substances pass freely (wall).

Selectively permeable: lets some through, stops others (membrane).

Turgid: swollen firm against the wall.

Semi-autonomous: own DNA and 70S ribosomes, but needs proteins from the nucleus.

Autolysis: a damaged cell digested by its own lysosomes.

Autophagy: worn-out parts digested and recycled.

Formulas

$\text{total magnification} = \text{eyepiece} \times \text{objective}$	10× and 40× → 400× **Use:** light microscope
$\text{real size} = \dfrac{\text{image size}}{\text{magnification}}$	both in one unit **Use:** sizes in pictures
$\dfrac{\text{surface area}}{\text{volume}} = \dfrac{6a^2}{a^3} = \dfrac{6}{a}$	a side of a cube **Use:** why cells are small

- 1 mm = 1,000 μm; 1 μm = 1,000 nm
- light microscope: at most about 1,000× (best about 1,500×); can't separate points under about 0.2 μm → no ribosomes (about 25 nm), no inside of a mitochondrion
- electron microscope: detail well under 1 nm
- 1 μm cube: 6 μm^2 per μm^3; 10 μm cube: 0.6 → cell too big starves in its middle
- eukaryotes' answer: folded inner membranes + active transport along tracks

1.1 Prokaryotic and eukaryotic

Every cell:

- membrane
- cytoplasm
- DNA
- ribosomes

Prokaryotic	Eukaryotic
no true nucleus; nucleoid	double nuclear envelope
usually one circular chromosome; no histones (bacteria); often plasmids	several linear chromosomes, on histones
no membrane-bound organelles	mitochondria, ER, Golgi, lysosomes, vacuoles; plastids in plants
70S ribosomes	80S in cytoplasm (70S in mitochondria, chloroplasts)
wall: peptidoglycan	cellulose (plants), chitin (fungi), none (animals)
respiration on the membrane	mostly in mitochondria
mostly 1–5 μm	mostly 10–100 μm
binary fission, no spindle	mitosis or meiosis, spindle

A bacterium, outside in (*E. coli*, about 2 μm × 0.8 μm):

- **capsule or slime layer**
  - stops drying
  - sticks to surfaces (plaque)
  - harder for white cells to swallow
- **wall**: shape, stops bursting; penicillin stops it being built → harms bacteria, not our cells
- **membrane**: traffic; the enzymes that release energy with oxygen
- **ribosomes**: tens of thousands, 70S
- **nucleoid**: *E. coli*'s DNA about 1.5 mm stretched, over 700 × the cell
- **plasmids**: pass between bacteria → antibiotic resistance spreads
- **pili, fimbriae**: cling; a long pilus joins two bacteria to pass a plasmid
- **flagellum**: hollow protein tube turned by a rotary motor (a sperm's beats, built of microtubules)
- **mesosome**: old books' fold of the membrane (respiration, division); now known to be an **artifact** of preparing cells

Endosymbiotic theory (Lynn Margulis, 1967): mitochondria and chloroplasts were once free-living bacteria. Evidence:

- bacteria-sized; two membranes
- own circular DNA, 70S ribosomes

- divide by splitting; a cell can't make one from scratch
- DNA like purple bacteria (mitochondria), cyanobacteria (chloroplasts)

1.2 The organelles

Cell wall (plants, fungi, most bacteria; not animals)

- cellulose fibrils in hemicellulose and pectin
- **middle lamella**: pectate, glues cells
- **primary wall**: thin, stretchy
- **secondary wall**: thick, often **lignin**
- **plasmodesmata**: channels joining neighbors' cytoplasm

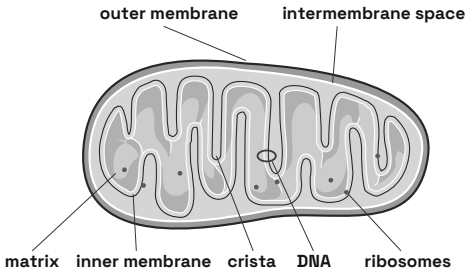
- shape
- strength
- protection
- no bursting (turgor)
- fully permeable

Cell membrane: about 8 nm; **fluid mosaic model** (Singer and Nicolson, 1972)

- phospholipid bilayer: heads to water, tails inward
- integral proteins cross it (channels, carriers); peripheral on one face
- cholesterol among the tails (animals); sugar chains outside only, as name tags
- fluid: lipids and proteins move sideways
- jobs
  - encloses
  - selectively permeable
  - endocytosis (phagocytosis), exocytosis
  - recognition
  - receptors

Mitochondria: 0.5–1 μm wide, 1–10 μm long

- smooth outer membrane
- inner folded into **cristae** with **F_1 particles** (ATP synthase)
- intermembrane space
- **matrix**
  - enzymes
  - circular DNA
  - 70S ribosomes
- aerobic respiration, most ATP: "powerhouse"
- many in
  - muscle
  - liver
  - kidney
  - nerve cells
  - sperm tail
- DNA from the mother only



A mitochondrion cut lengthwise.

Plastids (plants, algae): two membranes, own DNA, 70S ribosomes

Kind	Pigment	Job
chloroplast	chlorophyll, green	photosynthesis
chromoplast	carotenoids: yellow, orange, red	color, attracts pollinators and seed carriers
leucoplast	none	stores: **amyloplast** starch, **elaioplast** oil, **aleuroplast** protein

- one kind can become another: green tomato ripens red; potato in light turns green
- **chloroplast**
  - about 5 μm long
  - double envelope
  - **stroma** (enzymes, starch, DNA, 70S)
  - **thylakoids** stacked into **grana**, joined by **stroma lamellae**
- light trapped, water split, oxygen out in **thylakoids**; sugar made in **stroma**

Nucleus: usually 5–10 μm; Robert Brown, 1831

- **envelope**: two membranes, outer joined to the ER; **pores** control traffic
- **nucleoplasm**
- **chromatin** on histones: euchromatin (light, genes read), heterochromatin (dark, mostly off)
- coils into chromosomes at division
- **nucleolus**: no membrane; makes ribosome parts

- holds DNA
- controls the cell
- makes RNA
- starts division

- Hämmerling's *Acetabularia* grafts (1930s): the cap follows the base's nucleus

Golgi body (Camillo Golgi, 1898; **dictyosomes** in plants)

- stack of 4–8 **cisternae**; **cis** face receives from ER, **trans** face ships
- modifies
- sorts

- packs
- secretes
- makes lysosomes
- cell plate and wall materials in plants
- acrosome of a sperm

Centrosome (Boveri, 1888): two **centrioles** at right angles

- centriole: 0.25 × 0.5 μm; **nine triplets**, empty middle: **9 + 0**
- forms the spindle
- organizes microtubules
- basal bodies of cilia and flagella (those **9 + 2**)
- none in most flowering plants and conifers

Lysosome (de Duve; named 1955; Nobel 1974)

- single membrane
- about 50 digestive enzymes
- pH about 4.5–5
- made by Golgi
- primary (unused), secondary (digesting)
- digestion inside the cell
- recycling
- removes whole tissues (tadpole's tail)
- autolysis: "**suicide bags**"

Vacuole: single membrane (**tonoplast**), **cell sap**

- 80–90% of a mature plant cell
- small or none in animals
- contractile and food vacuoles in *Amoeba*, *Paramecium*
- turgor
- stores food, water, salts
- stores wastes (tannins, calcium oxalate)
- anthocyanins (red, purple, blue)
- lysosomes' work in plants

Ribosome: about 20–30 nm, **no membrane**; Palade, 1955

- two subunits of rRNA and protein
- free or bound
- polysome
- **80S = 60S + 40S**; **70S = 50S + 30S** (S: sinking speed, depends on shape, so numbers don't add)
- makes proteins; streptomycin, tetracycline jam 70S → side effects via our mitochondria

ER: membranes joined to the nucleus (Porter, Claude, Fullam, 1945)

- **rough**
  - cisternae with ribosomes
  - proteins to export or for membranes and lysosomes
  - plenty in pancreas
- **smooth**
  - tubules
  - lipids, steroid hormones
  - detoxifies in liver
  - stores calcium in muscle
- channels
- compartments
- surface
- new membrane
- support

A protein's way out: nucleus (mRNA) → ribosome on rough ER → vesicle → Golgi cis to trans → vesicle → membrane (exocytosis); ATP from mitochondria (Palade's radioactive amino acids, 1967).

1.3 Organelles in life processes

Process	Parts at work
Respiration	cytoplasm: glycolysis; matrix: Krebs cycle; cristae: most ATP; membrane: gases
Photosynthesis	thylakoids: light, oxygen; stroma: glucose; wall and membrane: gases; vacuole: turgor
Excretion	lysosomes, smooth ER, Golgi vesicles, vacuoles, membrane
Reproduction	nucleus; centrosome (animals); mitochondria: ATP; ribosomes; membrane pinches (animals) or Golgi's cell plate (plants)

- glucose + oxygen → carbon dioxide + water + energy (ATP): every living cell, day and night
- carbon dioxide + water → glucose + oxygen (light, chlorophyll)
- too little oxygen: glycolysis only → lactic acid (muscle), alcohol + carbon dioxide (yeast)
- prokaryote: binary fission

COMMON MISTAKES

✗ prokaryotes have no ribosomes
✓ they do: 70S; only membrane-bound parts are missing.

✗ wall decides what enters
✓ wall fully permeable; the membrane decides.

✗ centriole is 9 + 2
✓ centriole 9 + 0; cilium 9 + 2.

✗ chlorophyll in the stroma
✓ in thylakoids; sugar in the stroma.

✗ plants respire only at night
✓ every living cell, day and night.

✗ red petal color in chromoplasts
✓ anthocyanins in the vacuole; carotenoids in chromoplasts.

✗ changing mm to μm: divide
✓ × 1,000; real size = image ÷ magnification.