AP Biology Unit 2

The Cell

One-page sprint review
Free at Sophriva

EXAM WEIGHT	MCQs	FRQ APPEARANCE	SPRINT TIME
10–13%	6–8	Very Frequent	~2 hours

Inside this pack

- **Quick Glance at every Unit topic with priority + format**
- **Topic-by-topic key traps, must-know rules, and exam frames**
- **Worked example questions on the highest-yield topics**

AP Biology Unit 2 — The Cell

Sprint Review • Exam in 3 Days

Exam Weight	~MCQs	FRQ Appearance	Sprint Time
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Quick Glance — All Topics at a Glance

Topic	Priority	Exam Format	Key Trap
2.1 Cell Structure	★★★	MCQ, FRQ	Prokaryotes DO have ribosomes (70S); nucleolus is INSIDE nucleus
2.2 Cell Size / SA:V	★★★	MCQ, Calc	Larger cell = LOWER SA:V = LESS efficient (not more)
2.3 Plasma Membrane	★★★	MCQ, FRQ	Cholesterol is a BUFFER — increases fluidity in cold, decreases in heat
2.4 Permeability	★★	MCQ	Water crosses slowly (via aquaporins); ions CANNOT cross without channels
2.5–2.6 Passive Transport	★★★	MCQ, FRQ	Facilitated diffusion uses proteins but needs NO ATP — still passive!
2.7 Tonicity / Osmosis	★★★	MCQ, Calc, Data	Plant cells: hypo → turgid (NOT lysis); animal cells: hypo → lysis
2.8 Active Transport	★★★	MCQ, FRQ	Na+/K+ pump: 3 Na+ OUT, 2 K+ IN — net charge moves out → electrochemical gradient
2.9–2.10 Compartments + Endosymbiosis	★★★	MCQ, FRQ	Must cite 3+ pieces of evidence for endosymbiosis; mitochondria in ALL eukaryotes

2.1 Cell Structure & Function

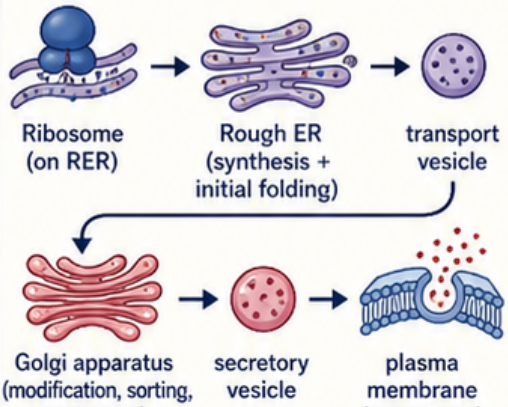
Prokaryotes, eukaryotes, organelles, and the secretory pathway

Prokaryote vs. Eukaryote — Must-Know Comparison

Feature	Prokaryote	Eukaryote
Nucleus	None — DNA in nucleoid region (no membrane)	Membrane-bound nucleus (double membrane)
DNA shape	Single circular chromosome + plasmids	Multiple linear chromosomes + histones
Membrane-bound organelles	None	ER, Golgi, mitochondria, etc.
Ribosomes	70S (smaller) — ALL cells have ribosomes!	80S cytoplasm; 70S in mitochondria/chloroplasts
Cell wall	Peptidoglycan (bacteria)	Cellulose (plant); chitin (fungi); none (animal)
Size	1–10 μm	10–100 μm
Examples	Bacteria, Archaea	Animals, Plants, Fungi, Protists

Secretory Pathway — High Frequency

Protein Secretion Route



- Ribosome (on RER) → Rough ER (synthesis + initial folding) → transport vesicle → Golgi apparatus (modification, sorting, packaging) → secretory vesicle → plasma membrane (exocytosis)
- Golgi is the "post office" — receives, modifies, and ships proteins
- Lysosomes bud from Golgi → contain hydrolytic enzymes for intracellular digestion

Energy Organelles
Mitochondria & Chloroplasts

- **Mitochondria:** double membrane; inner membrane highly folded (cristae = increased surface area for ATP synthesis); site of cellular respiration; matrix contains enzymes for Krebs cycle

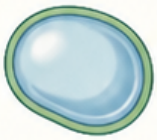
- **Chloroplasts:** double membrane + thylakoid membranes stacked into grana; site of photosynthesis; stroma = liquid between thylakoids

- Both have 70S ribosomes + circular DNA → endosymbiotic evidence (2.10)

Quick Reference
Other Key Organelles

- **Nucleus:** site of transcription; nuclear pores control traffic; nucleolus = rRNA synthesis (inside nucleus, NOT separate organelle)

- **Smooth ER:** lipid synthesis, detoxification (liver), calcium storage (muscle)



- **Vacuole:** central vacuole in plant cells → turgor pressure; contractile vacuole in protists (osmoregulation)

- **Cytoskeleton:** microfilaments (actin, cell shape/movement), microtubules (cilia/flagella, spindle fibers), intermediate filaments (structural)

Exam Sniper

- Classic FRQ: trace a secreted protein from synthesis to exit → Ribosome on RER → RER lumen → transport vesicle → Golgi → secretory vesicle → exocytosis
- A drug inhibits Golgi function → secretion of modified proteins is most affected
- Evidence for mitochondrial prokaryotic ancestry → double membrane, 70S ribosomes, circular DNA, binary fission
- Cells producing lots of lipids have abundant smooth ER

Trap Alert

- Prokaryotes DO have ribosomes — 70S, not 80S
- The nucleolus is NOT a separate organelle — it is inside the nucleus
- Archaea are prokaryotes but are more closely related to eukaryotes than to bacteria

2.2 Cell Size & Surface Area:Volume Ratio

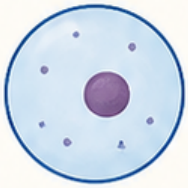
Why cells stay small and how to calculate SA:V

The Core Idea

Why SA:V Matters

- Surface area (membrane) = interface for exchanging nutrients, O_2, CO_2, waste
- Volume = metabolic demands of the interior
- As cell grows, volume increases faster than surface area
- Large cell = low SA:V = insufficient exchange = cell division triggered
- Small cells are **MORE** efficient at exchange

Small cell
High SA:V
Efficient

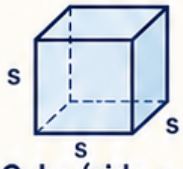


Large cell
Low SA:V
Inefficient

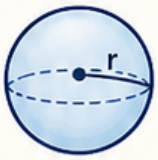
Formulas — Memorize

SA:V Calculations

- Cube (side = s): SA = $6s^2$; V = s^3; SA:V = $6/s$
- Sphere (radius = r): SA = $4\pi r^2$; V = $4/3\ \pi r^3$
- **Rule:** Double the radius → SA ×4, V ×8 → SA:V halves
- Always show units; SA:V has units of 1/length (e.g., μm^{-1})



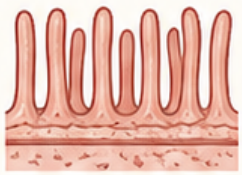
Cube (side = s)
$SA = 6s^2$
$V = s^3$
$SA:V = 6/s$



Sphere (radius = r)
$SA = 4\pi r^2$
$V = \frac{4}{3}\ \pi r^3$

Biological Applications

High SA:V Adaptations



Microvilli in intestine → increased SA for nutrient absorption

Alveoli in lungs → small spheres, high SA for gas exchange

Cristae in mitochondria → increased inner membrane SA for ATP synthesis

Root hair cells → elongated projections increase SA for water/ion uptake

Red blood cells → flattened biconcave disc → maximizes SA relative to V

Exam Sniper

- Given two cells, calculate both SA:V values → smaller cell has higher SA:V and exchanges materials more efficiently
- Agar cube diffusion labs: smaller cubes equilibrate faster because of higher SA:V
- Cells divide because volume grows faster than surface area, so SA:V falls below what is needed for the interior

Calculation MCQ

Two cuboidal cells are compared: Cell A has sides of 1 μm and Cell B has sides of 3 μm. Which cell is more efficient at exchanging materials with its environment, and what is the SA:V ratio for each?

(A) Cell B is more efficient; Cell A SA:V = 2, Cell B SA:V = 6
(B) Cell A is more efficient; Cell A SA:V = 6, Cell B SA:V = 2
(C) Both are equally efficient; SA:V = 1 for both
(D) Cell B is more efficient; larger cells have more surface area

Answer: (B) — Cell A: SA = 6, V = 1, SA:V = 6.
Cell B: SA = 54, V = 27, SA:V = 2.
The smaller cell has proportionally more membrane per unit volume, so exchange is more efficient.

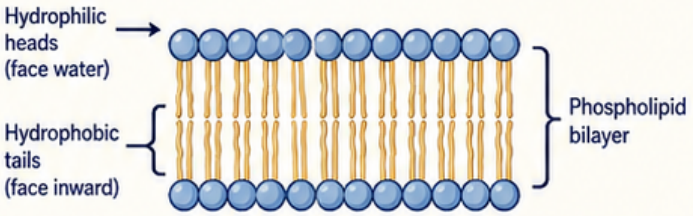
2.3–2.4 Plasma Membrane & Permeability

Fluid mosaic model, membrane proteins, and what can cross

Model Name

Fluid Mosaic Model

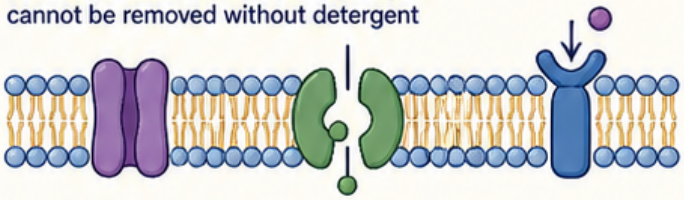
- "Fluid": phospholipids and proteins can move laterally within each layer — not rigid
- 'Mosaic': proteins of many types embedded throughout
- Proposed by Singer & Nicolson, 1972
- Selectively permeable: controls what enters/exits
- Phospholipid bilayer: hydrophilic heads face water; hydrophobic tails face inward



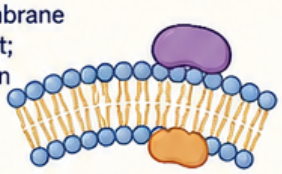
Components

Membrane Proteins

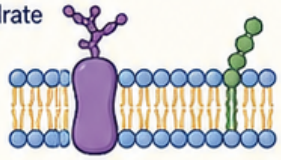
- **Integral proteins:** span the bilayer; channel proteins, carrier proteins, receptor proteins — cannot be removed without detergent



- **Peripheral proteins:** attached to membrane surface; signaling and structural support; removable by changing salt concentration



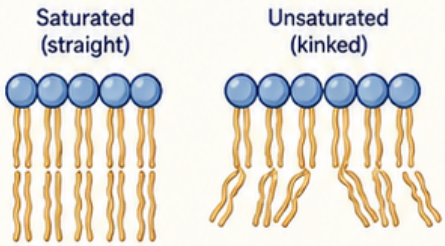
- **Glycoproteins/glycolipids:** carbohydrate chains on OUTER face only; cell-cell recognition, immune response, cell adhesion



Fluidity Control — High Exam Yield

Factors Affecting Fluidity

- **Higher temperature** → higher kinetic energy → higher fluidity
- **More unsaturated fatty acids** (kinked tails) → cannot pack tightly → higher fluidity
- **Cholesterol = fluidity buffer:** at high temp restrains movement → lowers fluidity; at low temp prevents freezing → raises fluidity
- **Shorter fatty acid chains** → less van der Waals force → higher fluidity
- **Cold-water organisms:** more unsaturated lipids to keep membranes fluid



Membrane Permeability

Molecule Type	Example	Crosses Freely?	Why?
Small nonpolar	O_2, CO_2, N_2, steroids	Yes — simple diffusion	Dissolve in hydrophobic core; small enough to pass
Small uncharged polar	H_2O, urea, ethanol	Slowly (aquaporins speed up water)	Small helps, but polarity slows crossing
Ions (any charge)	Na^+, K^+, Cl^-, Ca^{2+}	No — need ion channels	Hydration shells too large to enter hydrophobic core
Large polar molecules	Glucose, amino acids	No — need carrier proteins	Too large and polar to diffuse through lipid layer
Macromolecules	Proteins, RNA, polysaccharides	No — need vesicle transport	Far too large; require endo/exocytosis

Exam Sniper

- Fish moved from warm to cold water — increase unsaturated fatty acids to maintain membrane fluidity
- At body temperature, cholesterol stabilizes the membrane by reducing fluidity
- Glycoproteins are on the outer face because they were glycosylated in the ER/Golgi lumen and remain facing outward after vesicle fusion
- Glucose cannot cross by simple diffusion because it is both large and polar
- Aquaporins show that water can cross slowly without them, but much faster with them

Trap Alert

- Cholesterol does NOT simply increase or decrease fluidity — it is a buffer, and the answer depends on temperature
- Glycoproteins are on the outer face only
- Phospholipids move laterally easily, but flip-flop between leaflets is rare

2.5–2.6 Passive Transport

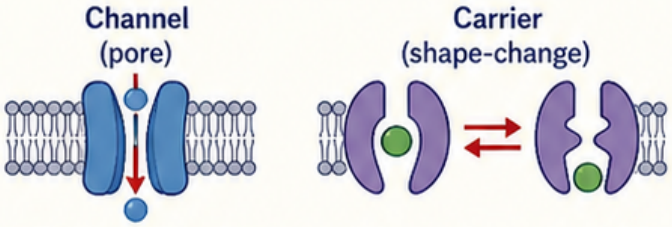
Simple diffusion, osmosis, and facilitated diffusion

All Passive Transport = No ATP, Down Gradient

Type	What Moves	Protein Required?	ATP Required?	Direction
Simple Diffusion 	Small nonpolar gases (O_2, CO_2), steroids	No	No	High → Low concentration
Osmosis 	Water (H_2O)	Via aquaporins (speeds up)	No	Low solute → High solute (High Ψ → Low Ψ)
Facilitated Diffusion 	Ions, glucose, amino acids	Yes (channel or carrier)	No	High → Low concentration

Facilitated Diffusion — Key Details

Channel vs. Carrier Proteins



- **Channel proteins:** form a pore; allow ions to flow through; can be gated by voltage, ligand, or mechanical signals
- **Carrier proteins:** bind a specific molecule, change shape, release it on the other side; slower; shows saturation
- Both are specific, require no ATP, and move substances down the gradient
- **Saturation:** when all carriers are occupied, rate maxes out — unlike simple diffusion

Diffusion Rate Factors

What Affects Diffusion Speed

- Higher concentration gradient → higher diffusion rate
- Higher temperature → higher kinetic energy → higher rate
- Higher surface area → higher rate
- Shorter distance → higher rate (Fick's Law: rate ∝ SA × ΔC / distance)
- More fluid membrane → faster diffusion
- Smaller molecule size → faster crossing

Exam Sniper

- Carrier protein + no ATP + down gradient = facilitated diffusion
- A rate curve that plateaus suggests carrier-mediated transport (saturation), not simple diffusion
- Alveoli are efficient for gas exchange because they have high surface area, short diffusion distance, and thin membranes

Trap Alert

- Uses a protein does NOT automatically mean active transport
- Facilitated diffusion requires NO ATP
- Simple diffusion has no maximum rate; carrier-mediated transport does

Question:
Glucose enters a cell using a carrier protein, and no ATP is used. What type of transport is this?

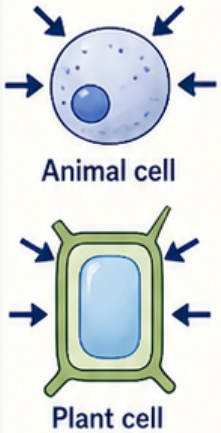
Answer:
Facilitated diffusion — because glucose moves through a carrier protein down its concentration gradient with no ATP required.

2.7 Tonicity, Osmosis & Water Potential

The highest-frequency calculation and reasoning topic

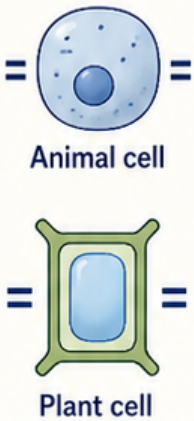
Osmosis = diffusion of water across a selectively permeable membrane, from low solute → high solute (equivalently: from high water potential → low water potential).

Hypotonic



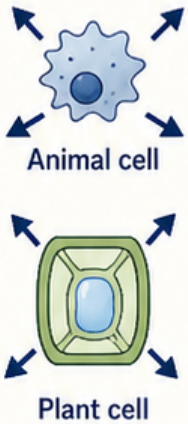
- Water moves **INTO** cell
- Animal cell → swells → **LYSES**
- Plant cell → **TURGID** (normal healthy state)
- RBC in distilled water → lysis

Isotonic



- No **NET** water movement
- Animal cell → **normal**
- Plant cell → **flaccid**
- 0.9% NaCl is isotonic to human blood

Hypertonic



- Water moves **OUT** of cell
- Animal cell → **crenates** (shrivels)
- Plant cell → **plasmolysis** (membrane pulls away from wall)
- Examples: saltwater fish, salted meat preservation

Ψ_S Calculation

Solute Potential Formula

$$\Psi_S = -iCRT$$

- i = ionization constant (1 for glucose/sucrose; 2 for NaCl; 3 for $CaCl_2$)
- C = molar concentration (mol/L)
- R = 0.0831 L·bar/mol·K
- T = temperature in Kelvin (°C + 273)
- Result is always negative — solutes lower Ψ

Plant Cell Water Potential

Turgor Pressure in Plants

- Ψ_P = 0 in open systems (like a beaker); positive in turgid plant cells
- At equilibrium: Ψ of cell = Ψ of solution
- Turgor pressure prevents wilting; drives stomatal opening/closing
- Guard cells: gain water → become turgid → stoma opens
- Wilted plant: low turgor pressure → $\Psi_P \approx 0$ → gains water when watered

Exam Sniper

- Given concentrations and temperature, calculate Ψ_S and determine water movement
- If a plant cell is −4 bar and the solution is −2 bar, water moves from −2 to −4 → into the cell
- In mass-vs-sucrose graphs, the isotonic point is where mass change is zero
- Plant cells in hypotonic solution become turgid, NOT lysed

Trap Alert

- Water moves from low solute to high solute
- More negative Ψ = lower Ψ; water moves there
- Isotonic means no NET movement, not no movement at all
- Plant cells in hypotonic solution become turgid, not lysed

A student places red blood cells and plant cells into three solutions: distilled water, 0.9% NaCl, and 3% NaCl. In which solution would the plant cell become turgid AND the red blood cell lyse?

(A) 3% NaCl
(B) Distilled water
(C) 0.9% NaCl
(D) Both 3% NaCl and distilled water

Answer:
(B) — Distilled water is hypotonic to both cells. Water enters both; the plant cell becomes turgid because its wall prevents lysis, while the red blood cell bursts.

2.8 Active Transport, Bulk Transport & Co-transport

Against the gradient, ATP, pumps, vesicles, and indirect transport

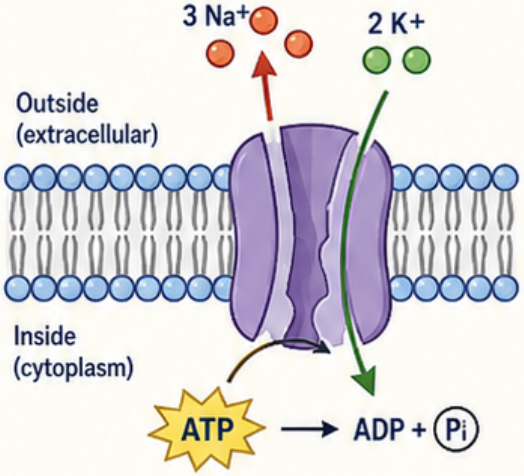
Definition

Active Transport

- Moves substances against concentration gradient (low → high)
- Requires ATP
- Uses pump proteins
- Maintains gradients needed for nerve impulses, nutrient uptake, and pH regulation

Most-Tested Pump

Na^+/K^+-ATPase Pump

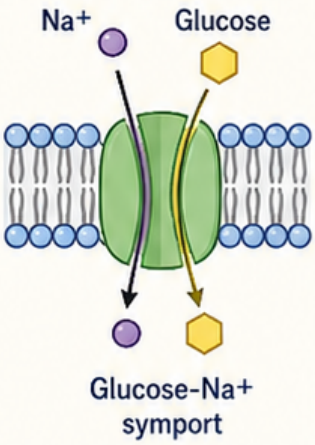


- Pumps 3 Na^+ *OUT* and 2 K^+ IN per ATP hydrolyzed
- Both move against their gradients
- Net positive charge moves out → inside becomes more negative → resting membrane potential (~−70 mV)
- Critical for nerve impulses, muscle contraction, and secondary active transport
- Memory: NaKe 3-2 rule

Indirect Active Transport

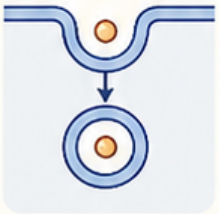
Co-transport (Secondary Active)

- Uses an existing ion gradient (usually Na^+) to drive another molecule
- Example: glucose-Na^+ symport in intestinal epithelium
- The Na^+ gradient was created by the Na^+/K^+ pump, so ATP is used indirectly
- Symport = same direction; Antiport = opposite directions

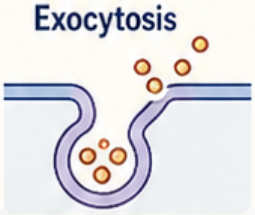


Bulk Transport

Endo & Exocytosis



- Endocytosis: cell engulfs material using membrane vesicles; requires ATP
- Phagocytosis = solids; pinocytosis = fluids/small molecules; receptor-mediated endocytosis = specific ligands



- Exocytosis: vesicles fuse with plasma membrane and release contents outside
- Both require ATP and involve membrane fusion

Exam Sniper

- Blocking ATP production most directly affects active transport, co-transport indirectly, and endocytosis/exocytosis; passive transport continues
- The Na^+/K^+ pump creates resting membrane potential by exporting 3 Na^+ and importing 2 K^+
- Intestinal glucose uptake via Na^+/glucose co-transporter is secondary active transport
- Vesicle required = endocytosis or exocytosis

Trap Alert

- Na^+/K^+ pump = 3 Na^+ OUT, 2 K^+ IN — never reverse it
- Co-transport is not passive transport; it uses an ion gradient created by ATP
- Phagocytosis and pinocytosis are both types of endocytosis

2.9–2.10 Compartmentalization & Endosymbiotic Theory

Why membrane compartments matter and how mitochondria/chloroplasts evolved

Why Compartmentalize?

Advantages of Membrane Compartments

- Allows simultaneously incompatible reactions to occur
- Concentrates reactants → higher reaction efficiency
- Creates H+ gradients for ATP synthesis in mitochondria and chloroplasts
- Isolates digestive enzymes in lysosomes to prevent self-digestion
- Nucleus separates transcription from translation, allowing post-transcriptional processing

FRQ Must-Know

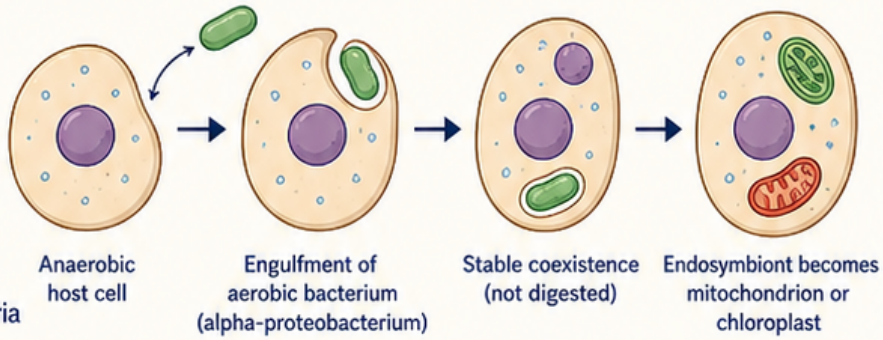
Endosymbiotic Theory — Evidence

- ★ Double membrane
- ★ 70S ribosomes
- ★ Circular DNA
- ★ Reproduce by binary fission
- ★ Size similar to bacteria
- ★ Antibiotic sensitivity: some prokaryote-targeting antibiotics also affect mitochondria

Theory Details

Who Was Engulfed?

- Proposed by Lynn Margulis
- Mitochondria descended from aerobic alpha-proteobacteria; found in ALL eukaryotes
- Chloroplasts descended from cyanobacteria; found only in photosynthetic eukaryotes
- Host cell was an anaerobic archaean-like cell that phagocytosed but did not digest these bacteria
- Over time, most bacterial genes transferred to the host nucleus



Exam Sniper

- To support endosymbiosis, list multiple independent pieces of evidence: 70S ribosomes, circular DNA, double membrane, binary fission
- An antibiotic that targets 70S ribosomes may also affect mitochondria and chloroplasts
- Compartmentalization helps cells run incompatible reactions and create specialized microenvironments
- Plant cells have chloroplasts, central vacuoles, and cell walls; animals do not

Common Confusions

- Mitochondria are in ALL eukaryotes, not just plants
- Chloroplasts are only in photosynthetic eukaryotes
- The evidence must show prokaryotic ancestry, not just organelle function

Sprint Practice — Mixed Questions

Cross-topic AP-style reasoning

1 MCQ Cross-Topic: Transport

A researcher treats intestinal epithelial cells with ouabain, a drug that specifically inhibits the Na+/K+-ATPase pump. Which of the following would be the MOST DIRECT effect on glucose absorption in these cells?

(A) Glucose diffusion would increase because the concentration gradient would steepen

(B) Glucose uptake via the Na+/glucose co-transporter would decrease because the Na+ gradient would dissipate

(C) Glucose would be exported from the cell by exocytosis instead

(D) Passive diffusion of glucose would compensate for the blocked pump

Answer:

(B) — The Na+/glucose co-transporter depends on the Na+ gradient maintained by the Na+/K+ pump. Block the pump → Na+ builds up inside → the gradient collapses → co-transport decreases → glucose absorption falls.

2 Data Analysis MCQ: Tonicity

A student places identical pieces of potato tissue (each 5 grams) into sucrose solutions of different concentrations and records mass after 2 hours. Results: 0.0 M → 5.6 g; 0.2 M → 5.2 g; 0.4 M → 4.9 g; 0.6 M → 4.8 g; 0.8 M → 4.5 g. What is the approximate solute concentration of the potato cells?

(A) 0.0 M

(B) 0.8 M

(C) Approximately 0.3–0.4 M

(D) 0.6 M

Answer:

(C) — The isotonic point is where mass change is closest to zero. The sample gains mass at 0.2 M and loses a little at 0.4 M, so the internal concentration is about 0.3–0.4 M.

3 FRQ-Style Endosymbiosis

A scientist discovers a new eukaryotic organism with organelles resembling mitochondria. She claims these organelles evolved via endosymbiosis. Describe THREE independent pieces of evidence she could present to support this claim.

(A) 80S ribosomes, double membranes, and ATP production

(B) 70S ribosomes, circular DNA without histones, and reproduction by binary fission

(C) A single membrane, ATP synthase, and maternal inheritance

(D) Presence in all eukaryotes, oxygen use, and cristae

Answer:

(B) — The strongest evidence is 70S ribosomes, circular DNA without histones, and binary fission. These are prokaryotic features and support endosymbiotic ancestry.

Tip: For Unit 2 questions, always identify the gradient, the transport mechanism, and whether ATP is used.

Final Review — Exam Traps + Checklist

Use this page the night before and the morning of the exam

1. Unit 2 High-Frequency Exam Traps

- Facilitated diffusion uses proteins but NO ATP
- Plant cells in hypotonic solution become TURGID, not lysed
- Water moves from low solute to high solute; from high Ψ to low Ψ
- Larger cells have LOWER SA:V and are LESS efficient
- Prokaryotes DO have ribosomes — 70S
- Cholesterol is a fluidity BUFFER — answer depends on temperature
- Na+/K+ pump = 3 Na+ OUT, 2 K+ IN
- The nucleolus is inside the nucleus

2. Pre-Exam 10-Minute Checklist

A. Cell Structure (2.1)

- ☐ Prokaryotes: no nucleus, circular DNA, 70S ribosomes, peptidoglycan wall
- ☐ Secretory pathway: ribosome on RER → RER → vesicle → Golgi → vesicle → plasma membrane/lysosome
- ☐ Nucleolus is inside the nucleus
- ☐ Smooth ER = lipids/detox; Rough ER = proteins

B. Cell Size & Membrane (2.2–2.4)

- ☐ SA:V for cube = 6/s; larger cell = lower SA:V
- ☐ Can calculate SA:V for cube and sphere
- ☐ Fluid mosaic model = fluid + mosaic
- ☐ Cholesterol reduces fluidity in heat, prevents rigidity in cold
- ☐ Glycoproteins are on the outer face only
- ☐ More unsaturated fatty acids = more fluid membrane

C. Transport (2.5–2.8)

- ☐ Simple diffusion: small nonpolar molecules
- ☐ Facilitated diffusion: ions + glucose + amino acids; no ATP
- ☐ Osmosis: water from low solute to high solute
- ☐ Tonicity outcomes: plant turgid/flaccid/plasmolyzed; animal lyse/normal/crenate
- ☐ Water potential: Ψ = Ψs + Ψp; pure water Ψ = 0
- ☐ Na+/K+ pump = 3 out / 2 in
- ☐ Co-transport uses Na+ gradient; no direct ATP

D. Compartmentalization & Endosymbiosis (2.9–2.10)

- ☐ Compartments allow incompatible reactions and create proton gradients
- ☐ Endosymbiotic evidence: 70S ribosomes, circular DNA, double membrane, binary fission
- ☐ Mitochondria in all eukaryotes; chloroplasts only in photosynthetic eukaryotes

3. Final Sprint Strategy for Unit 2

- **Biggest point-earners:** tonicity outcomes, water potential calculations, SA:V calculations, Na+/K+ pump, endosymbiosis evidence
- **FRQ danger zone:** always state direction of movement, mechanism, ATP use, and protein involved if any
- **Data questions:** isotonic point = where mass does not change
- **Connections forward:** membrane fluidity → Unit 1; chloroplasts/mitochondria → Unit 3; Na+ gradients → Unit 4; endosymbiosis → Unit 7

If you can explain every checked item out loud, you're ready.

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