The Ultimate AP® Biology Unit 2 Cheat Sheet

2.1 Subcellular Components

Ribosomes: In Every Cell

Ribosome = rRNA + protein; 2 subunits (large + small). NOT membrane-bound → found in prokaryotes AND eukaryotes.
Job: translate mRNA → protein. Universal in all cells → strong evidence of the common ancestry of all life.
Free (cytosol) → proteins used in cytosol. **Bound** (on rough ER) → proteins for secretion, membranes, lysosomes.

Organelle Quick Map

Organelle	Structure	Function
Rough ER	Ribosome-studded	Makes/folds prot.
Smooth ER	No ribosomes	Lipids, detox
Golgi	Flat cisternae	Modify, sort, ship
Mitochondria	Double memb.	Cell resp. → ATP
Chloroplast	Double + thylak.	Photosynthesis
Lysosome	Acidic, enzymes	Digest, recycle
Vacuole	Memb. sac	Store H_2O, ions
Nucleus	Double env.	Holds DNA

Key Details

Smooth ER: also stores Ca^{2+} (muscle cells); detoxifies drugs & alcohol (liver cells → lots of smooth ER).
Golgi: cis face receives ER vesicles → enzymes add/trim sugars (glycosylation) → trans face ships vesicles out.
Lysosome: hydrolytic enzymes, pH ~5. Digests food, old organelles (autophagy); drives apoptosis. Animal cells mainly.
Central vacuole (plants): stores H_2O, ions, pigments, waste; full vacuole → turgor pressure → plant stays upright.
Plant only: chloroplasts, cell wall, central vacuole. **Animal only**: centrioles, (most) lysosomes, no wall.

⚠ Plants have mitochondria too. They photosynthesize AND do cellular respiration, day and night, in every cell.

✓ Ribosomes in a prokaryote? Yes. Membrane-bound organelles? No. Know the difference.

2.2 Cell Structure & Function

Endomembrane System

Members: nuclear envelope, ER, Golgi, lysosomes, vacuoles, vesicles, plasma memb. Linked by vesicles. NOT mito/chloro.
Secretion path: DNA → mRNA → rough ER ribosome → protein enters ER lumen → transport vesicle → Golgi (modify) → vesicle → plasma memb. → exocytosis.
Rough ER lumen: folds new proteins, adds sugars, and keeps them separate from the cytosol until shipped.

Mitochondria: Folded for ATP

Double membrane: smooth outer + folded **inner membrane (cristae)**. Folds → ↑ surface area → more ETC proteins + ATP synthase → more ATP per mitochondrion.
Matrix = inner space: Krebs cycle enzymes, own DNA, own ribosomes. **Intermembrane space** builds H^+ gradient.

Chloroplasts: Stacked for Light

Thylakoids stacked in **grana** → ↑ surface area for light rxns (chlorophyll, ETC, ATP synthase). **Stroma** = fluid around them → Calvin cycle builds sugar from CO_2.

Space	Mito	Chloro
Folded memb.	Cristae (ETC)	Thylakoids (ETC)
Fluid	Matrix (Krebs)	Stroma (Calvin)
H^+ piles up in	Intermemb. sp.	Thylakoid space

Cells With a Job

Pancreas / plasma cells (secrete protein) → lots of rough ER + Golgi. **Muscle / sperm** → lots of mitochondria. **Liver** → lots of smooth ER for drug & alcohol detox.
Nucleus: double envelope w/ **nuclear pores** → mRNA out, proteins in. **Nucleolus** builds ribosome subunits.
Cytoskeleton: microtubules, actin → cell shape + tracks for organelles & vesicles (motor proteins).

⚠ Proteins made on FREE ribosomes stay in the cytosol. Secreted proteins MUST start on rough ER.

✓ FRQ formula: structure (folding, ↑ SA) → more enzymes/membrane → more function.

2.3 Cell Size: Surface Area to Volume

Why Cells Stay Small

Surface area (plasma memb.) controls how fast cell trades nutrients, O_2, waste. **Volume** sets how much it needs.
As size ↑: volume grows faster than SA (r^3 vs r^2) → **SA:V ↓** → exchange is too slow to supply the cell.
High SA:V = efficient exchange per unit volume. Small cells win → this limits the max size of a single cell.

Apply the Formula Sheet

Cube: SA = $6s^2$, V = s^3. **Sphere**: SA = $4\pi r^2$, V = $4/3\pi r^3$.
Cylinder: SA = $2\pi rh + 2\pi r^2$, V = $\pi r^2 h$.

Cube side	SA	V	SA:V
1 μm	6	1	6 : 1
2 μm	24	8	3 : 1
3 μm	54	27	2 : 1
6 μm	216	216	1 : 1

Pattern: for a cube, SA:V = 6/s. Double side → SA:V halves.
Divide SA by V; report as a ratio or a decimal. Keep units: $\mu m^2/\mu m^3 = \mu m^{-1}$ (per micrometer), not μm.

How Life Beats the Limit

Folds & projections: microvilli (gut), root hairs, alveoli, cristae → ↑ SA w/o ↑ V much at all. Same trick everywhere.
Shape: flat or long cells (RBCs, neurons) → more SA per volume than a sphere of the same size.
Divide: cells split before SA:V gets too low. **Compartments** → small local volumes inside one cell, too.
Whole organisms: small animals have high SA:V → lose heat faster → higher metabolic rate per gram.
Exam twist: same V, flatter/longer shape → higher SA:V → faster diffusion to the center (agar-cube lab).

⚠ Bigger cell = MORE total SA but LOWER SA:V. Answer w/ the ratio, not the total surface area of the cell.

✓ Grid-in: compute SA, then V, then divide SA by V. Round only at the very end of the work, not midway.

2.4–2.5 Plasma Membranes & Permeability

Fluid Mosaic Model

Phospholipid bilayer: hydrophilic phosphate heads face H_2O (inside & out); hydrophobic fatty acid tails face in.
Fluid: lipids & proteins drift sideways in the layer. **Mosaic**: proteins scattered through the bilayer.

Part	Role
Integral protein	Spans bilayer; channels
Peripheral protein	Surface; signals, anchor
Cholesterol	Buffers fluidity vs temp
Glycoprotein/lipid	Cell ID, recognition

Integral proteins: hydrophobic AAs sit in tail region, hydrophilic AAs stick out into H_2O → amphipathic.
Cholesterol: high temp → restrains movement; low temp → blocks tight packing. **Unsaturated tails** → kinks → more fluid.

Selective Permeability

Crosses freely: small nonpolar (O_2, CO_2, N_2), lipids/steroids. Small amounts of H_2O slip through slowly.
Needs a protein: ions (Na^+, K^+, Cl^-, H^+) b/c charge; large polar molecules (glucose); lots of H_2O (aquaporins).
Why: the hydrophobic core repels charged & polar particles. Size matters too: big = slow or blocked.

Cell Walls

Cell wall outside memb.: plants (cellulose), fungi (chitin), prokaryotes (peptidoglycan). Gives shape, blocks bursting.
Wall ≠ barrier: fully permeable to H_2O & small solutes. The membrane inside it does the selecting.
Amphipathic lipids self-assemble into bilayers in H_2O → no energy is needed to form a membrane.
Membrane protein jobs: transport, enzymes, signal receptors, cell-cell joining, anchoring cytoskeleton.

⚠ Ions are tiny but charged → still can't cross the bilayer w/o a protein. Charge beats size every time.

✓ Predict Qs: small + nonpolar = crosses on its own. Charged, or big + polar = needs a transport protein.

2.6–2.7 Membrane Transport

Passive vs Active

Passive transport: high → low conc. (down the gradient). No ATP. Runs until equilibrium (net movement stops, but molecules keep moving both ways at equal rates).
Active transport: low → high conc. (against the gradient). Needs energy (ATP) + a specific carrier protein.

Type	Gradient	Protein?	ATP?
Simple diff.	Down	No	No
Facilitated	Down	Yes	No
Osmosis	Down (H_2O)	Aquapor.	No
Active	Up	Pump	Yes
Bulk	Either	Vesicle	Yes

2.7 Facilitated Diffusion

Channel proteins: hydrophilic tunnel, very fast; some **gated** (open on signal, voltage). **Aquaporins** = H_2O channels.
Carrier proteins: bind solute → change shape → release other side (e.g., GLUT glucose transporter).
Saturation: rate levels off when all carriers are busy. Simple diffusion rate keeps rising w/ conc. instead.

Pumps & Gradients

Na^+/K^+ pump: 3 Na^+ out, 2 K^+ in per ATP → inside more negative → **membrane potential** (neurons, muscle).
Electrochemical gradient = conc. gradient + charge difference across the membrane. Stored energy.
Cotransport: pump builds gradient (e.g., H^+, Na^+) → ion flows back down → drags glucose/sucrose uphill. Indirect ATP use.
Rate of diffusion ↑ w/ a steeper gradient, higher temp, more SA, and a smaller/nonpolar molecule size.

⚠ Facilitated diffusion uses a protein but NO ATP. A protein alone does not mean active transport.

✓ Graph Qs: rate plateaus as [solute] ↑ → the carriers are saturated (facilitated, not simple diffusion).

2.8 Tonicity & Osmoregulation

Osmosis & Tonicity

Osmosis: H_2O moves across a membrane from low solute → high solute (high Ψ → low Ψ), passively.
Tonicity = solute conc. of a soln vs the cell (only solutes that can't cross the memb. count toward it).

Soln is…	H_2O moves	Animal	Plant
Hypertonic	Out	Shrivels	Plasmolyzed
Hypotonic	In	Lyses	Turgid (ideal)
Isotonic	No net	Normal	Flaccid

Water Potential (Ψ)

Ψ = Ψp + Ψs. Water flows from high Ψ → low Ψ. Pure H_2O in an open container: Ψ = 0 bar (the max).
Ψs = −iCRT. i = ionization constant (sucrose 1, NaCl 2); C = molar conc.; R = 0.0831 L·bar/mol·K; T = °C + 273.
Adding solute → Ψs more negative → Ψ ↓. **Pressure** (turgor) → Ψp ↑ (positive) → Ψ ↑. Sum them.
Worked: 0.1 M NaCl at 27 °C → Ψs = −(2)(0.1)(0.0831)(300) ≈ **−4.99 bar** (i = 2, T = 300 K, open beaker).
Compare cells: the lower (more negative) Ψ side gains H_2O. Equal Ψ → no net flow either way across.

Osmoregulation

Contractile vacuole: freshwater protists pump out extra H_2O (hypotonic environment) → uses ATP to do it.
Plant cell wall resists bursting → turgor. **Kidneys** & **gills** balance solutes & water in animal bodies.
Plasmolysis: membrane pulls away from the wall in a hypertonic soln → wilting; often fatal to the cell.
Turgor = positive Ψp in plant cells. **Wilting** = Ψp drops to ~0.

⚠ "Hyper/hypo" describe the SOLUTION vs the cell. Water moves TOWARD the hypertonic side.

✓ Lab data: graph % mass change vs molarity; the x-intercept (0% change) = the isotonic point of the tissue.

2.9–2.10 Bulk Transport & Compartments

2.9 Endocytosis & Exocytosis

Exocytosis: vesicle fuses w/ the plasma memb. → contents out (hormones, neurotransmitters, enzymes). Adds membrane area to the cell surface each time it happens.
Endocytosis: memb. folds in → vesicle brings large stuff in. Removes memb. from surface. Both need ATP.

Endocytosis	Takes in	Example
Phagocytosis	Large particles	WBC eats bacteria
Pinocytosis	Fluid + solutes	Nonspecific gulp
Receptor-med.	Bound ligand	LDL cholesterol

Receptor-mediated: ligand binds receptor → coated pit → vesicle. Specific; concentrates rare molecules.
Fate: the food vacuole fuses w/ a lysosome → its hydrolytic enzymes digest the vacuole's contents.

2.10 Why Compartments?

Membranes split the cell into regions w/ their own pH, enzymes, conc. → incompatible rxns run at once (e.g., digestion in lysosomes, synthesis in cytosol).
Localizes enzymes → ↑ efficiency. **Builds gradients** (H^+ in mito, chloro) → ATP synthase makes ATP from them.
Internal membranes → ↑ SA for membrane-bound rxns (ETC in mito, protein folding in the rough ER).
Prokaryotes: no organelles, but plasma memb. folds (infoldings) host ETC and photosynthesis.
Example: lysosome pH ~5 vs cytosol ~7.2 → its enzymes work inside, but go idle if they leak out (self-protection).
Eukaryote advantage: compartments let cells grow larger & specialize (secretory, muscle, nerve cells).
Nuclear envelope: separates transcription (nucleus) from translation (cytosol) → extra gene control.

⚠ Bulk transport moves macromolecules in vesicles. It never passes through a channel protein.

✓ FRQ: name the compartment + the condition it keeps (low pH, H^+ gradient) + why that helps the cell.

2.11 Origins & Unit 2 Exam Strategy

Endosymbiont Theory

Claim: an ancestral host engulfed an aerobic prokaryote (→ **mitochondria**) and, later, a photosynthetic prokaryote (→ **chloroplasts**) that lived on inside it as partners.
Evidence: double membrane; own circular DNA; own 70S-type ribosomes; divide by binary fission; inner memb. like bacteria; DNA similar to modern bacteria.
Order: mitochondria first (in nearly all eukaryotes); chloroplasts later (only plants & algae have them).

Prokaryote vs Eukaryote

Feature	Prokaryote	Eukaryote
Nucleus	No (nucleoid)	Yes
Memb. organelles	No	Yes
Ribosomes	Yes (smaller)	Yes
DNA	Circular	Linear chrom.
Size	~1–5 μm	~10–100 μm

Shared by all: plasma memb., cytoplasm, ribosomes, DNA → common ancestry of all cells on Earth.

FRQ & MCQ Moves

Predict: "If organelle X fails…" → name the lost function → effect on cell (no ATP → active transport stops).
Calculate: SA:V and Ψ show up as grid-ins. Show the setup; units matter (bar, μm^{-1}) for full credit on FRQs.
Links: Unit 1 phospholipids → Unit 3 ETC in mito/chloro → Unit 4 receptors in the plasma membrane.
Claim-evidence: endosymbiosis FRQs want 2 pieces of evidence, each tied to a bacterium trait.
Experiment design: IV = solute conc. or cell size; DV = mass change or diffusion depth; keep T constant.

⚠ Mito and chloro are NOT part of the endomembrane system. They came from endosymbiosis.

✓ The formula sheet gives SA, V & Ψ equations. Know when to use each one & the units it gives.