The Simple AP® Biology Unit 4 Cheat Sheet

4.1 Cell Communication

Why Cells Signal

Signals coordinate growth, metabolism, immunity and homeostasis across the body.
Ligand = signaling molecule. Binds a matching **receptor** on or in the target cell.
Target cell: only cells with the receptor respond.
Same signal, diff. cells: can trigger different responses (epinephrine: heart vs liver).

Signal Distance

Type	Range	Example
Direct	Touching	Gap junctions
Paracrine	Nearby	Growth factors
Synaptic	Nearby	Nerve signals
Endocrine	Far (blood)	Hormones

Gap junctions (animals) / **plasmodesmata** (plants): channels linking neighbor cells.
Cell-cell recognition: surface molecules touch → e.g., immune cells activate T cells.
Hormones travel in the blood to distant targets (insulin, epinephrine, growth hormone).

Single Cells Signal Too

Quorum sensing: bacteria sense crowd size by signal level → act together (biofilms).
Yeast use mating signals between cells → shows that signaling evolved very early.

⚠ No receptor → no response, even if the signal is there in high amounts all around it.

✓ Touching → direct; nearby → paracrine/synaptic; blood → endocrine.

4.2 Intro to Signal Transduction

Three Stages

1) Reception: the ligand binds the receptor → the receptor changes its 3D shape.
2) Transduction: relay molecules pass the signal along, often in a chain of steps.
3) Response: genes turned on, enzymes activated, or the cell divides or dies.

Receptor Types

Receptor	Where	Ligand
GPCR	Membrane	Epinephrine
Receptor TK	Membrane	Insulin
Ion channel	Membrane	Neurotrans.
Intracell.	Inside	Steroids

Polar/large ligands (proteins) can't cross the membrane → bind **membrane receptors**.
Nonpolar ligands (steroids like estrogen) cross → bind **receptors inside** → often turn genes on.
GPCR: the receptor activates a G protein → which then activates an enzyme inside the cell.
Ligand-gated channel: opens → ions rush in → a very fast response (nerves, muscle).
Receptor tyrosine kinase: pairs up, adds phosphates → starts many pathways at once.
Specific: the receptor's shape matches its ligand, just like an enzyme + its substrate.

⚠ The ligand usually stays outside the cell. The receptor passes the message on.

✓ Hydrophobic ligand → receptor inside; hydrophilic → on the membrane.

4.3 Signal Transduction Pathways

Phosphorylation Cascades

Kinase: adds a phosphate → turns the next protein on. Chain of kinases = **cascade**.
Phosphatase: removes the phosphate → turns the protein off → resets the pathway.
Amplification: each step activates many more → 1 ligand makes a huge response.

Second Messengers

Second messenger: small molecule that spreads the signal inside the cell (**cAMP**, **Ca^{2+}**).
cAMP: made from ATP by adenylyl cyclase → it activates protein kinase A (PKA).
Ca^{2+}: released from the ER into the cytosol → triggers muscle contraction & secretion.

Example: Epinephrine

Step	What happens
Reception	Binds GPCR
Relay	G protein on
2nd messenger	ATP → cAMP
Response	Glycogen → glucose

Responses: fast (enzyme turned on/off) or slower (new proteins made from genes).
Turning off: ligand leaves, phosphatases act, cAMP broken down → ready for next signal.

⚠ Kinases ADD phosphates; phosphatases REMOVE them. You need both.

✓ FRQ: name each step in order and what molecule activates the next one in line.

4.4 Changes in Signal Transduction

What Can Go Wrong

Any step can fail: the ligand, the receptor, a relay protein or the response protein at the end.
Stuck off → no response, even with signal.
Stuck on → response with NO signal.
Mutation in a receptor or relay protein can cause either problem (stuck on or off).

Classic Examples

Change	Effect
Ras stuck on	Nonstop growth
Cholera toxin	G protein stuck on
Insulin resist.	Type 2 diabetes
Beta-blockers	Block epinephrine

Cholera: toxin keeps cAMP high → water pours into the gut → severe diarrhea & dehydration.
Drugs: some mimic ligands; others block receptors or enzymes (e.g., beta-blockers, statins).

Reasoning Pattern

Block after the receptor → no response, even if the ligand still binds to its receptor.
More ligand only helps if the problem is too little ligand, not a broken receptor or relay.
Common ancestry: many organisms share the same pathway parts (e.g., kinases).

⚠ A stuck-ON protein causes a response even when there's NO signal present at all.

✓ Find the broken step → stuck on or off → the effect on every step downstream of it.

4.5 Feedback

Negative Feedback

Negative feedback: response reverses the change → back to set point (**homeostasis**).
Glucose high → pancreas releases **insulin** → cells take up glucose → blood glucose drops.
Glucose low → pancreas releases **glucagon** → liver releases glucose → glucose rises.
Too hot → sweat → the body cools. **Too cold** → shiver → the body warms back up to 37 °C.
Loop parts: stimulus → sensor → control center → effector → response that reverses it.

Positive Feedback

Positive feedback: the response boosts the change → builds up to an endpoint (birth).

Example	Loop
Childbirth	Oxytocin → more contractions
Blood clotting	Platelets call more
Fruit ripening	Ethylene → more

When Feedback Fails

Diabetes: type 1 = no insulin made; type 2 = cells ignore insulin → glucose stays high.
Plants: guard cells close stomata when water is low → saves water (ABA signal).
Hyperthyroidism: thyroid hormone stays high → metabolism stays too fast (feedback fails).

⚠ "Positive" doesn't mean good. It means the change keeps getting bigger & bigger.

✓ Values swing up & down around a set point → negative feedback is at work there.

4.6 Cell Cycle

Interphase

Phase	What happens
G_1	Cell grows
S	DNA copied
G_2	Grows, preps
G_0	Resting (neurons)
M	Mitosis + split

After S: each chromosome = 2 **sister chromatids** joined at the centromere (X shape).
DNA amount doubles in S, then halves when the cell divides. Chromosome # stays the same.

Mitosis: PMAT

Prophase: chromosomes condense; the spindle forms; nuclear envelope breaks down.
Metaphase: chromosomes line up in the middle.
Anaphase: sister chromatids pulled apart.
Telophase: two new nuclei form.
Cytokinesis: the cell splits in 2 (animals pinch in; plants build a **cell plate** → new wall).

Why Mitosis

Result: 2 identical diploid cells → used for growth, repair & asexual reproduction of the body.
G_0 cells (mature nerve, muscle) stop dividing.
Prokaryotes divide by binary fission instead.

⚠ DNA is copied in S phase, not during mitosis.

✓ More cells seen in a phase = more time spent in that phase of the cell cycle overall.

4.7 Regulation of the Cell Cycle

Checkpoints

G_1: big enough? DNA OK? growth signal present? If no → the cell enters **G_0** (resting).
G_2: DNA copied correctly? If no → pause to repair.
M: all chromosomes attached to the spindle? If no → the cell waits before anaphase starts.
Why it matters: skipped checkpoints → wrong chromosome # or damaged DNA.

Cyclins & CDKs

CDK: a kinase enzyme that works only when it's bound to its partner protein, a **cyclin**.
Cyclin levels rise and fall → CDK turns on and off → drives each phase of the cycle in order.
Growth factors (e.g., PDGF) signal a cell to pass the G_1 checkpoint & divide again.

Cancer & Apoptosis

Gene	Job	Cancer if
Oncogene	Gas pedal	Stuck on
Tumor supp.	Brake (p53)	Lost

p53: spots DNA damage → stops the cycle for repair, or triggers cell death (apoptosis).
Apoptosis: programmed cell death; removes damaged or unneeded cells (finger webbing).
Cancer cells ignore checkpoints & signals → divide nonstop → form tumors that can spread.

⚠ Cancer usually needs several mutations (oncogene on + brakes off), not just one.

✓ Graph: cyclin rises through interphase, peaks at M, then drops sharply as it's broken down.

Unit 4 Exam Strategy & Connections

Signal Pathway FRQ

Template: ligand binds receptor → shape change → relay → response in the cell (4 steps).
Use names: "cAMP activates kinase A" beats "the signal is passed on" every time.
Block: steps before it still work; steps after don't.

Graph Skills

DNA per cell: flat (G_1) → rises (S) → high (G_2, M) → halves at division, then the cycle repeats.
Insulin peaks after glucose peaks → feedback lag.
Phase timing: % of cells in a phase × total cycle time = the time spent in that phase.
Experiments: control = no ligand or drug; change 1 factor; measure the response (e.g., cAMP).

	Mitosis	Binary fission
Who	Eukaryotes	Prokaryotes
Chromosomes	Many, linear	1, circular
Spindle	Yes	No

Links

Unit 2: membrane receptors. **Unit 5**: meiosis. **Unit 6**: gene regulation by transcription factors.
Unit 3: kinases use ATP. **Unit 7**: shared pathways → evidence of common ancestry.

⚠ Mitosis keeps the chromosome # the same; meiosis cuts it in half (2n → n).

✓ Every answer: name the molecule + the step + the effect on the cell. All 3, every time.