SI-03: Q4
Disruption Cascade Template

From Disruption -> Molecular Effect -> System Effect -> Justification

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Q4 often asks students to analyze a biological change, disruption, mutation, or environmental condition and predict or explain its effect. It's worth 4 points and rewards a complete causal chain — from a molecular event to a system-level outcome, with mechanism justifying the chain. Most students lose points by stopping too early ("the cell will be affected") or jumping too far ahead ("the organism dies") without showing the steps in between.

Q4 | 4 pts | Conceptual Analysis | Skills 5 & 6 | Cross-unit

1. Common Q4 Stem Patterns

Common Q4 stem patterns:

- Predict the effect of [disruption] on [system]. Justify your prediction.
- Explain how [mutation/loss/inhibitor] would alter [process].
- Describe the consequences of [environmental change] on [biological process].

What graders look for:

- A clear causal chain — not a single sentence.
- Use of the correct biological mechanism, not just a re-statement of the disruption.
- Evidence-based justification (the why).

Bottom line: Q4 is not about saying something changes; it is about showing a complete mechanism from disruption to consequence.

so you can earn all 4 points deliberately.

7. The Q4 Self-Check + Practice Question

Use this 1-minute scan before moving on

The Q4 Self-Check (1 minute before moving on)

- [ ] Did I name the specific component that was disrupted? (L1)
- [ ] Did I describe the molecular or cellular failure? (L2)
- [ ] Did I scale up to a system-level consequence? (L3)
- [ ] Did I provide biological justification? (L4)
- [ ] Did I avoid the words *affected* or *changed* without specifying how?
- [ ] Did I use the right direction (increase / decrease / no change) and the right magnitude?

If any are missing, add one sentence —
Q4 is forgiving of length but unforgiving of missing levels.

Q4-Style FRQ (4 pts)

A geneticist studies a mutation in the gene encoding a voltage-gated potassium channel in cardiac muscle cells. The mutation reduces K^+ conductance through the channel by approximately 80%.

(a) Predict and explain the effect of this mutation on the duration of the cardiac action potential. [2 pts]

(b) Predict and justify the effect on heart rhythm at the tissue level. [2 pts]

Try answering the stem yourself before checking Page 8.

Page focus: self-check fast, then apply the cascade to a real FRQ.

8. Model Answer + One-Page Cheat Card

Finish with the worked example and the memory summary

Model Answer

(a) [2 pts]

L1–L2: With reduced K^+ conductance, the outward K^+ current that normally repolarizes the cardiac action potential is decreased.

L3: The cell membrane stays depolarized for longer, so the duration of the action potential is increased.

[1 pt: identifies decreased K^+ outflow → impaired repolarization; 1 pt: predicts longer action potential duration]

(b) [2 pts]

L3: Prolonged action potentials at the cellular level translate to a longer refractory period and irregular timing of contractions across the cardiac tissue, increasing the risk of arrhythmia (e.g., long QT phenotype).

L4: Coordinated heart rhythm depends on synchronized depolarization and repolarization across cardiac cells; disruption of repolarization timing breaks that synchrony.

[1 pt: predicts arrhythmia or rhythm irregularity; 1 pt: justifies via dependence of rhythm on synchronized electrical activity]

One-Page Cheat Card

The cascade in one sentence: Disruption → molecular effect → system effect → justification.

★ **8 scenarios you should be able to walk through cold:**

Molecular	Cellular	Organismal	Ecological
Enzyme active site	Receptor mutation	Insulin resistance	Apex predator removal
Membrane channel	p53 loss	Mitochondrial defect	(use trophic cascade logic)
Transcription factor	(cell cycle checkpoint)	(metabolic dysfunction)	—

Time budget for Q4:
8–10 minutes.
4 sentences minimum, one per level.

Show the chain, not just the outcome.

End of SI-03 content — review complete.

4. High-Frequency Disruption Scenarios (1–4)

Practice turning common AP Biology disruptions into full L1–L4 chains

1 Scenario 1 – Enzyme Active Site Mutation

L1 Disruption	A point mutation changes one amino acid in the active site of an enzyme
L2 Molecular	Substrate cannot bind in the correct orientation; the enzyme-substrate complex doesn't form
L3 System	Reaction rate decreases or stops; the metabolic pathway downstream is interrupted
L4 Justification	Enzyme specificity depends on shape complementarity at the active site; structure determines function

2 Scenario 2 – Membrane Protein Loss (e.g., aquaporin)

L1 Disruption	The aquaporin gene is knocked out, so no aquaporins are produced
L2 Molecular	Water cannot cross the membrane efficiently via facilitated diffusion through channels
L3 System	The cell cannot rapidly equilibrate water; in hypotonic environments it may swell or lyse, in hypertonic it shrinks
L4 Justification	The phospholipid bilayer is hydrophobic and limits water passage; aquaporins are required for high-throughput water transport

3 Scenario 3 – Receptor Mutation (Signal Transduction)

L1 Disruption	The ligand-binding domain of a membrane receptor is mutated
L2 Molecular	Ligand cannot bind the receptor; no conformational change occurs to activate downstream G-protein or kinase
L3 System	Downstream signaling cascade is not triggered; the target gene or response is not activated
L4 Justification	Signal transduction requires ligand-receptor binding to initiate the cascade; without binding, no signal propagates

4 Scenario 4 – p53 Loss-of-Function (Cell Cycle Checkpoint)

L1 Disruption	The *TP53* gene is mutated, producing nonfunctional p53 protein
L2 Molecular	The DNA damage response cannot effectively activate p53-mediated cell cycle arrest, DNA repair, or apoptosis
L3 System	Cells with damaged DNA continue to divide; mutations accumulate; risk of tumor formation increases
L4 Justification	p53 acts as a tumor suppressor by halting the cell cycle for repair or initiating apoptosis when damage is severe

Page focus: memorize these four chains cold.

5. High-Frequency Disruption Scenarios (5–8)

More common chains: gene regulation, metabolism, ecology, and homeostasis

5 Scenario 5 — Transcription Factor DNA-Binding Mutation

L1 Disruption	The DNA-binding domain of a transcription factor is mutated
L2 Molecular	TF cannot bind the enhancer; RNA polymerase II is not recruited to the promoter
L3 System	Target gene is not transcribed; mRNA and protein levels drop; phenotype associated with that gene is absent
L4 Justification	Eukaryotic transcription depends on TF binding to enhancers to recruit the transcription machinery

6 Scenario 6 — Mitochondrial ETC Component Mutation

L1 Disruption	A mutation inactivates a protein in the electron transport chain (e.g., complex I)
L2 Molecular	Electrons cannot flow through the chain; the proton gradient across the inner membrane is reduced
L3 System	ATP synthesis by oxidative phosphorylation drops sharply; cells must rely on fermentation, producing far less ATP per glucose
L4 Justification	Oxidative phosphorylation produces most of the ATP in aerobic respiration; mitochondrial dysfunction forces cells to rely on the much smaller ATP yield of glycolysis and fermentation

7 Scenario 7 — Apex Predator Removal (Ecology)

Trophic cascades alternate down the food chain. Pick the chain length explicitly before writing your answer. The 3-level Wolves -> Elk -> Plants chain is the simplest case. For a 4-level chain (orca -> otter -> urchin -> kelp), the cascade alternates further: apex removed -> otter up -> urchin down -> kelp up.

L1 Disruption	Wolves (top predator) are removed from the ecosystem (e.g., wolf removal from Yellowstone)
L2 Population	Elk (primary consumers) are no longer controlled by predation; their mortality decreases and population grows
L3 System	The expanded elk population overgrazes producers (willows, aspens, riparian plants); plant biomass and biodiversity decline; cascading habitat changes affect other species (beavers, songbirds, riverbank stability)
L4 Justification	Top-down regulation: apex predators control herbivore populations, indirectly maintaining producer communities and overall biodiversity through a trophic cascade

8 Scenario 8 — Insulin Receptor Loss-of-Function (Type 2 Diabetes Model)

L1 Disruption	Insulin receptors on muscle and adipose cells are mutated or downregulated
L2 Molecular	Insulin cannot trigger the signaling cascade that mobilizes GLUT4 transporters to the membrane
L3 System	Glucose uptake from the bloodstream into target cells fails; blood glucose stays elevated after meals (hyperglycemia)
L4 Justification	Negative feedback regulation of blood glucose requires functional insulin signaling; without receptor function, the feedback loop is broken

Page focus: these scenarios cover molecular, cellular, organismal, and ecological logic.

6. Verb-Specific Response Patterns + One-Liner Upgrades

Adjust the chain depending on the command verb

Verb-Specific Response Patterns

Verb	Levels emphasized	Expected response shape
Predict	L1 -> L3	State the outcome clearly with direction (increase/decrease/stop)
Explain	L1 -> L4 (full chain)	Connect each step with biological reasoning
Justify	L4 emphasized	Cite the underlying principle that makes your prediction true
Describe	L2 -> L3	Detail what happens, less emphasis on why

If the verb is predict or explain, write the full 4-level chain.
If the verb is justify, weight your answer toward the mechanism (L4).
If the verb is describe, you can compress L4 but you still need L1–L3.

Sufficient vs. Insufficient One-Liners

1 Enzyme inhibitor

Insufficient:
"The reaction will not happen."

Sufficient:
The competitive inhibitor binds the active site, preventing substrate binding; the reaction ratte decreases. The effect can be partially overcome by increasing substrate concentration because competition is concentration-dependent.

2 Membrane channel mutation

Insufficient:
"The cell will be affected."

Sufficient:
Without functional Na^+ channels, the cell cannot generate an action potential, so the neuron cannot propagate a signal. The all-or-nothing depolarization depends on rapid Na^+ influx through voltage-gated channels.

3 Apex predator loss

Insufficient:
"The ecosystem will change."

Sufficient:
Without wolves, the elk population grows unchecked, overgrazes the dominant producers (willows and aspens), and biodiversity declines through a top-down trophic cascade.

Page focus: replace vague one-liners with causal, mechanistic language.

2. The 4-Level Cascade Framework

Write one clear sentence for each level

1 sentence here

L1 — DISRUPTION.

What was changed?

State the disruption in precise biological terms. Don't just paraphrase the question — name the specific component (gene, protein, structure, condition) that's altered.

Sample language: *The active site of enzyme X is mutated, changing one amino acid in the binding pocket.*

1 sentence here

L2 — IMMEDIATE MOLECULAR / CELLULAR EFFECT.

What stops working at the protein or structure level?

Translate the disruption into a direct functional consequence. Stay at the molecular level here — don't jump ahead to the organism.

Sample language: *The substrate can no longer bind the active site in the correct orientation, so the enzyme cannot catalyze the reaction.*

1 sentence here

L3 — SYSTEM-LEVEL EFFECT.

How does the cell, tissue, organ, organism, or population respond?

Scale up: connect the molecular failure to the broader system the question asked about.

Sample language: *Without the catalyzed reaction, the metabolic pathway is blocked, and the cell cannot produce ATP through this route.*

1 sentence here

L4 — EVIDENCE / JUSTIFICATION.

Why must this happen?

Cite the underlying biological principle that makes the chain true. This is where you separate yourself from students who just guess.

Sample language: *Enzyme function depends on the precise three-dimensional shape of the active site; even a single amino acid substitution can alter that shape and abolish substrate binding.*

Memory hook: Disruption → molecular effect → system effect → justification.

Page focus: learn the 4-level logic before memorizing scenarios.

3. Why "Too Narrow" and "Too Wide" Both Lose Points

What a weak chain looks like vs. a complete chain

1 — Too narrow — stops at L2

"The mutation breaks the enzyme."

Problem:
No system-level effect, no justification.
1 pt out of 4.

2 — Too wide — jumps to L4 with no chain

"The organism will die because enzymes are essential for life."

Problem:
No mechanism shown. The grader has no way to award the chain points.
0–1 pt out of 4.

3 — Just right — full L1 -> L4 chain

"The active-site mutation prevents substrate binding (L1->L2). Without catalysis, the metabolic pathway downstream of this enzyme is blocked, and the cell cannot generate ATP from this route (L3). Enzyme activity depends on precise active-site geometry, so even a single amino acid change abolishes function (L4)."

Score: 4/4.

What graders reward

- Show the chain step by step.
- Scale from molecular effect to system consequence.
- End with biological justification.

Bottom line:

Stopping early or jumping too far both lose points; full-chain reasoning earns full credit.

Page focus: avoid incomplete answers and chain gaps.