AP Biology Labs

13 Required Investigations

Quick reference for FRQ + MCQ
Free at Sophriva

EXAM SHARE	FORMAT	INVESTIGATIONS	SPRINT TIME
25%	FRQ + MCQ	13 classic	~90 min

Inside this pack

- **All 13 College Board required investigations at a glance**
- **Per-lab key concept, data type, and FRQ trap to watch**
- **Common cross-lab patterns: H + IV + DV + control + key calc**

AP Biology Labs Sprint Review

All 13 Classic Investigations — FRQ + MCQ Quick Reference

13 Investigations | Exam Format: FRQ + MCQ data | Sprint Time: ~90 min

1 Why Labs Matter

- calculation covers most tested lab reasoning.
- AP Biology requires 25% lab time for inquiry-based work.

control + key calculation.

2 13 Investigations at a Glance

1 INV 1 Artificial Selection — Unit 7

Key concept: Heritable variation causes phenotype shift across generations

Data: Bar graph: mean ± SE by generation; compare selected vs control

2 INV 2 Mathematical Modeling — Unit 7

p, q

$p^2+2pq+q^2=1$

Key concept: Hardy-Weinberg and evolutionary forces

Data: Use $p+q=1$ and $p^2+2pq+q^2=1$; start from q^2

3 INV 3 Comparing DNA Sequences — Unit 7

Key concept: Molecular evidence for evolution and phylogeny

Data: % DNA or amino acid similarity; build cladogram

4 INV 4 Diffusion & Osmosis — Unit 2

Key concept: Water potential, osmosis direction, solute effects

Data: % mass change = (final–initial)/ initial × 100

5 INV 5 Photosynthesis — Unit 3

Key concept: Rate of photosynthesis vs light, CO_2, temperature

Data: Leaf disk assay: ET_{50} and rate = $1/ET_{50}$

6 INV 6 Cellular Respiration — Unit 3

Key concept: O_2 consumption by seeds; temperature effects

Data: Respirometer rate; subtract bead control

7 INV 7 Cell Division: Mitosis & Meiosis — Unit 4/5

Key concept: Mitotic index and crossing over

Data: Mitotic index = cells in mitosis / total cells × 100

8 INV 8 Bacterial Transformation — Unit 6

Key concept: DNA uptake and antibiotic selection

Data: Transformation efficiency = colonies / µg DNA

9 INV 9 Restriction Enzyme Analysis & Gel — Unit 6

Key concept: Restriction digest and fragment separation

Data: Smaller fragments travel farther; use ladder

10 INV 10 Energy Dynamics — Unit 8

Key concept: Energy transfer efficiency across trophic levels

Data: % energy transfer = energy out / energy in × 100

11 INV 11 Transpiration — Unit 2

Key concept: Water loss via stomata and environmental effects

Data: Potometer rate = distance moved / time

12 INV 12 Fruit Fly Behavior — Unit 8

Key concept: Taxis, kinesis, and behavioral choice

Data: Choice chamber percentages and chi-square vs expected 50/50

13 INV 13 Enzyme Activity — Unit 3

Key concept: Effect of pH, temperature, substrate, inhibitor on rate

Important Note

In AP Biology exam contexts. They are not the only valid labs, but they are the highest-yield review set.

INV 1–2 Review

Artificial Selection and Hardy-Weinberg Modeling

Unit 7 | Focus: heredity + evolution | Data: graphs + equations

1 INV 1 Artificial Selection

1 Core Setup

- **Model organism:** Wisconsin Fast Plants (*Brassica rapa*) or brine shrimp.
- **Trait:** trichome density, seed weight, or another heritable continuous trait.
- **IV:** selection criterion (select high vs select randomly).
- **DV:** mean trait value per generation.
- **Control:** randomly mated group under the same conditions with NO selection.

2 What It Shows

- If the mean shifts in the selected line, the trait is heritable.
- Demonstrates Darwin's four postulates: variation, heritability, overproduction, differential reproduction.
- Compare mean ± SE across generations; use a bar graph with error bars.
- Response often slows over time as genetic variation is depleted.

3 Trap Alert

- The correct control is a randomly mated group, not an untreated nonreproducing group.
- Without that control, change could be due to environment or drift.

2 INV 2 Mathematical Modeling: Hardy-Weinberg

1 Core Setup

- Use cards, beads, or a computer model to simulate random mating.
- Test violations by adding selection, drift, gene flow, or mutation.
- HWE is the null model: populations are not evolving.

2 Key Equations

$$p + q = 1$$

$$p^2 + 2pq + q^2 = 1$$

Start from q^2, not from the dominant phenotype.

3 Calculation Flow

q^2 → q^2 = recessive phenotype frequency

↓

$\sqrt{\ }$ → q = square root of q^2

↓

p → $p = 1 - q$

↓

$2pq$ → $2pq$ = carrier frequency

4 What to Remember

- Small populations show stronger drift; large populations stay closer to HWE.
- Violating any of the five HWE conditions causes deviation.
- Never write "accept H_0", write "fail to reject H_0".

5 Exam Sniper

- Showing each calculation step can earn partial credit.

Fast Review Hits

- Selected line shifts = heritable trait.
- Randomly mated group = correct control for artificial selection.
- In HWE, start with q^2.
- "Fail to reject H_0" is the correct statistics wording.

INV 3–4 Review

DNA Sequence Analysis and Diffusion & Osmosis

Units 7 + 2

Focus: phylogeny + water movement

Data: similarity matrices + % mass change

3 INV 3 Comparing DNA Sequences to Investigate Evolutionary Relationships

1) Method

- Use bioinformatics databases such as BLAST and NCBI.
- Align DNA or amino acid sequences from multiple species.
- Calculate percent identity or number of differences between species pairs.
- Use the similarity matrix to build a cladogram.

2) Interpretation

- More DNA or amino acid similarity means a more recent common ancestor.
- Molecular data is often more reliable than morphology because it avoids convergent evolution confusion.
- Highly conserved sequences such as cytochrome c or rRNA are useful across distant taxa.
- The universal genetic code supports common ancestry.
- Cladogram topology: closer branches mean a more recent MRCA.

3) Trap Alert

- More differences means less related, not "more evolved".
- Two tips of a cladogram are equally evolved.
- Build the cladogram from data, not from assumptions about primitiveness.

4 INV 4 Diffusion & Osmosis

1) Core Setup

- **Part A**: dialysis tubing with sucrose placed in solutions, then measure mass change.
- **Part B**: potato cores or celery pieces in different sucrose concentrations.
- **IV**: external sucrose concentration.
- **DV**: percent mass change, not absolute mass change.

2) Key Formula

$$\% \text{ mass change} = \frac{(\text{final} - \text{initial})}{\text{initial}} \times 100$$

3) Interpretation

- Isotonic point is where % mass change = 0.
- Hypotonic solution → mass increases because water enters.
- Hypertonic solution → mass decreases because water exits.
- Water potential: $\Psi = \Psi_s + \Psi_p$.
- Water moves from higher Ψ to lower Ψ.
- On a graph of % mass change vs molarity, the x-axis intercept is the isotonic concentration.

4) Trap Alert

- Always use percent mass change because samples start at different masses.
- No mass change means isotonic and reveals the solute concentration inside the tissue.

Fast Review Hits

- More DNA similarity = closer evolutionary relationship.
- Conserved genes are useful across distant taxa.
- Use % mass change, not raw mass change.
- The x-axis intercept of the osmosis graph is the isotonic point.

INV 5–6 Review

Photosynthesis and Cellular Respiration

Unit 3 | Focus: energy transformations | Data: ET_{50} + respirometers

5 INV 5 Photosynthesis

1 Core Setup

- Vacuum-infiltrate leaf disks with bicarbonate solution as a CO_2 source so the disks sink.
- Expose disks to different light intensities, CO_2 concentrations, or temperatures.
- Measure ET_{50}: time for 50% of the disks to float.
- IV: light intensity, CO_2, or temperature.
- DV: photosynthesis rate.

2 Key Interpretation

- Disks float because photosynthesis produces O_2 and restores buoyancy.
- Faster floating means faster photosynthesis.
- Rate = 1 / ET_{50}.
- Rate usually increases with more light, more CO_2, and higher temperature up to an optimum.
- Rate levels off at a saturation point when another factor becomes limiting.

3 Dark Control

- In the dark, disks should remain sunk because respiration consumes O_2 and photosynthesis does not occur.
- The dark control is required to isolate photosynthesis from respiration.

4 Trap Alert

- Graphing the number of floating disks over time shows an upward curve toward saturation.

6 INV 6 Cellular Respiration

1 Core Setup

- Germinating seeds are placed in sealed tubes or respirometers with KOH and a colored water indicator.
- Typical comparison: germinating seeds warm, germinating seeds cold, and beads or nonliving control.
- IV: temperature or germinating vs nongerminating condition.
- DV: rate of O_2 consumption, often mL per minute per gram.

2 Key Interpretation

- O_2 consumption pulls the indicator because total gas volume decreases.
- KOH absorbs CO_2, so indicator movement reflects O_2 consumption only.
- Germinating seeds respire faster than dormant or nongerminating controls.
- Higher temperature usually increases respiration up to an optimum.

3 Essential Correction

Corrected biological rate = experimental rate – nonliving bead control rate.

4 Trap Alert

- Without KOH, CO_2 released would offset O_2 consumed and the indicator would barely move.
- You must subtract the nonliving control to correct for physical pressure or temperature changes.

Fast Review Hits

Photosynthesis rate = 1 / ET_{50}.

Floating leaf disks indicate O_2 production.

KOH removes CO_2 from the respiration setup.

Respiration data must be corrected by subtracting the bead control.

INV 7–8 Review

Cell Division and Bacterial Transformation

Units 4/5 + 6

Focus: PMAT + gene transfer

Data: mitotic index + plate interpretation

7 INV 7 Cell Division: Mitosis & Meiosis

1 Mitosis

- Use onion root tip or whitefish blastula slides.
- Identify and count cells in each phase.
- Mitotic index = cells in mitosis / total cells × 100.
- Most cells are in interphase because it is the longest phase.
- Mitotic index is higher in rapidly dividing tissue such as the root tip.
- **Phase ID**: prophase = chromatin condenses; metaphase = chromosomes align; anaphase = chromatids separate; telophase = two nuclei form.

2 Meiosis / Sordaria

- Use *Sordaria fimicola* asci to study crossing over.
- Nonrecombinant pattern: 4 + 4.
- Recombinant pattern: 2 + 2 + 2 + 2.
- % recombination = recombinant asci / total asci × 100.
- Map distance = % recombination ÷ 2, in centimorgans.

3 Trap Alert

- Count only PMAT cells in the mitotic-index numerator.
- In Sordaria, divide the recombination percentage by 2.

8 INV 8 Bacterial Transformation

1 Core Setup

- Transform *E. coli* with a plasmid carrying ampicillin resistance (amp^R) and GFP.
- GFP makes transformed colonies glow under UV light.
- The antibiotic-resistance gene is the selectable marker.

2 Four Plates

Plate 1
+DNA / +ampicillin

only transformed bacteria grow.

Plate 2
+DNA / no ampicillin

lawn of bacteria grows.

Plate 3
−DNA / +ampicillin

no colonies; correct negative control.

Plate 4
−DNA / no ampicillin

lawn; confirms bacteria were viable.

3 Key Measurement

$$\text{Transformation efficiency} = \frac{\text{number of colonies on +amp plate}}{\mu\text{g DNA added}}$$

4 Interpretation

- Colonies on the +DNA / +amp plate represent successful transformation events.
- Only bacteria that took up the plasmid survive on ampicillin.

5 Trap Alert

- No colonies on the −DNA / +amp plate is expected and means the control worked.
- Interpret all four plates together.

Fast Review Hits

- Mitotic index measures the fraction of cells in PMAT.
- Root tips have many interphase cells but still high cell division overall.
- Sordaria map distance = recombination ÷ 2.
- No growth on −DNA / +amp is expected, not failure.

INV 9–10 Review

Restriction Enzymes, Gel Electrophoresis, and Energy Dynamics

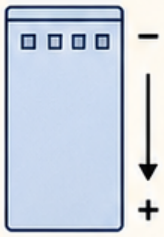
Units 6 + 8

Focus: DNA fragments + trophic transfer

Data: gel bands + percent efficiency

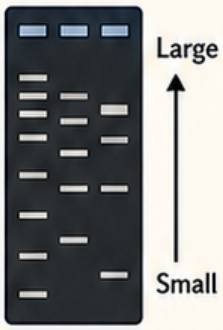
9 INV 9 Restriction Enzyme Analysis & Gel Electrophoresis

1 Core Setup



- Restriction enzymes cut DNA at specific palindromic recognition sites.
- Digested samples are loaded into wells at the top of an agarose gel.
- DNA migrates toward the positive electrode.
- Stains such as ethidium bromide or similar dyes reveal bands under UV light.

2 How to Read the Gel



- Use a DNA ladder lane to estimate unknown fragment sizes.
- Smaller fragments travel faster and therefore farther from the wells.
- Bands near the top are large; bands near the bottom are small.
- DNA fingerprinting compares band patterns between samples.
- RFLP means restriction fragment length polymorphism.

3 Band Logic

- For linear DNA, number of fragments = number of cut sites + 1.
- For circular DNA, number of fragments = number of cut sites.
- If a circular plasmid gives 2 bands, it has 2 cut sites.
- The sum of fragment sizes should equal the original DNA size.

4 Trap Alert

- Never reverse the direction-size relationship: small fragments go farther.

10 INV 10 Energy Dynamics

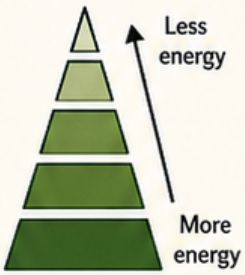
1 Core Setup

- Measure energy content or biomass at producer and consumer levels in a model ecosystem.
- Often uses Fast Plants as producers and herbivorous insects as primary consumers.
- IV: trophic level.
- DV: energy content in kcal or biomass in g per unit area.

2 Key Formula

$$\% \text{ energy transfer} = \frac{\text{energy at higher level}}{\text{energy at lower level}} \times 100$$

3 What to Expect



- Transfer efficiency is usually about 10%.
- Energy decreases at each higher trophic level.
- Endotherms are less efficient consumers than ectotherms and need more food energy.
- Energy pyramids and biomass pyramids narrow toward the top.
- Energy flows one way; matter cycles.

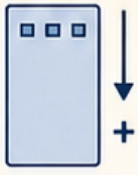
4 Worked Example

If producers have 1,000 kcal and primary consumers have 80 kcal, transfer efficiency = 8%.

5 Trap Alert

- Do not confuse a biomass pyramid with a numbers pyramid.

Fast Review Hits



Wells are at the top; DNA moves downward toward the positive electrode.

Ladder lane = size reference.

Small DNA fragments move farther.

Trophic transfer efficiency is calculated using higher level / lower level × 100.

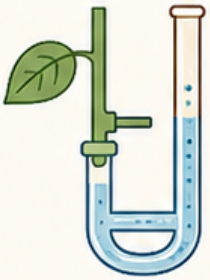
INV 11–12 Review

Transpiration and Fruit Fly Behavior

Units 2 + 8 | Focus: water loss + behavior | Data: potometer rate + chi-square

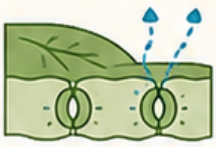
INV 11 Transpiration

1 Core Setup



- Cut a plant stem underwater and connect it to a potometer with a sealed water column and air bubble.
- Measure air-bubble movement as a proxy for water uptake and transpiration.
- Test factors such as wind, humidity, temperature, light, and petroleum jelly on leaves.
- **IV:** environmental condition.
- **DV:** rate of bubble movement in cm/min or percent change in leaf mass.

2 Biological Mechanism



- Transpiration is driven by cohesion-tension.
- Water evaporates from mesophyll, exits through stomata, and pulls more water upward.

3 Expected Effects

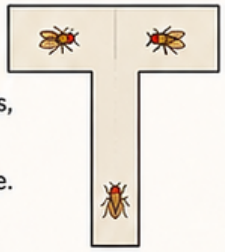
	Wind or fan	→	transpiration increases.
	High humidity	→	transpiration decreases.
	High temperature	→	transpiration increases.
	Light	→ →	stomata open transpiration increases.
	Dark	→ →	stomata close transpiration decreases.
	Petroleum jelly on the lower leaf surface	→	strongly decreases transpiration.

Trap Alert

- High humidity decreases transpiration because it reduces the water-vapor gradient.
- Most stomata are on the lower leaf surface.

INV 12 Fruit Fly Behavior

1 Core Setup



- Place *Drosophila* in a T-maze or choice chamber with two contrasting conditions, such as light vs dark or moist vs dry.
- Count flies on each side after a set time.
- **IV:** the stimulus type.
- **DV:** percent of flies on each side or preference index.
- **Control:** both sides identical, so the expected result is 50/50.

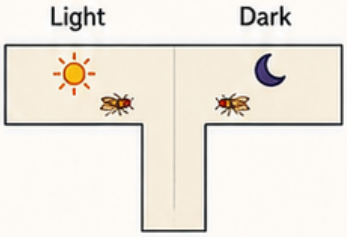
2 Behavior Terms

- **Positive taxis** = directed movement toward a stimulus.
- **Kinesis** = undirected change in speed or turning rate, not direction.

3 Statistics Box

- Use chi-square to compare observed counts with the expected 50/50 split.
- df = 1.
- Critical value at $p = 0.05$ is 3.841.
- If $\chi^2 > 3.841$ → reject H_0.
- If $\chi^2 < 3.841$ → fail to reject H_0.

4 Mini Example



- 30 flies total; observed 22 light and 8 dark; expected 15 and 15.
- $\chi^2 = 6.53$, so reject H_0 and conclude a significant light preference.

Trap Alert

- "Fail to reject H_0" is correct; never write "accept H_0".
- Use multiple trials and many flies to reduce sampling error.

Fast Review Hits

Humidity lowers transpiration; wind raises it.

Potometer bubble movement is a proxy for water loss.

Taxis is directional; kinesis is non-directional.

χ^2 Fruit-fly choice data often require chi-square.

INV 13 Review

Enzyme Activity — Catalase / Peroxidase

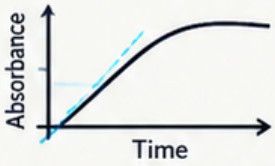
Unit 3 | Focus: enzyme rate | Data: absorbance over time

INV 13 Enzyme Activity

1 Core Setup

- Use catalase from turnip or liver, or peroxidase from horseradish.
- Combine enzyme with substrate such as H_2O_2 or ABTS.
- Measure absorbance over time with a spectrophotometer or colorimeter.
- Test pH, temperature, substrate concentration, or inhibitor presence.
- **IV:** pH, temperature, substrate concentration, or inhibitor.
- **DV:** change in absorbance per unit time = enzyme activity rate.

2 What to Measure



Initial rate = slope of the earliest linear time points.

Do not use total change at the endpoint.

3 Key Interpretation

- Enzyme activity is fastest early, when substrate is abundant.
- Optimal pH and temperature produce peak activity.
- Above the optimum, denaturation causes the rate to drop sharply.
- Heat denaturation is usually irreversible.
- Cold slows the reaction but usually does not denature the enzyme.

4 Controls

- Boiled enzyme control: no activity, confirms the effect is biological.
- Blank or buffer control: no enzyme, detects nonenzymatic absorbance change.

5 Trap Alert

Endpoint readings can underestimate the true optimum because fast reactions may plateau early.

FRQ-Style Design Question

A student tests catalase activity at pH 4, 6, 8, 10, and 12. She measures absorbance only at time 0 and time 5 minutes, then records total change. Her data show maximum activity at pH 8. A classmate argues that the design is flawed. What is the flaw, and how should the experiment be corrected?

A. She should use more H_2O_2 concentrations.

B. She measured total change at 5 min instead of initial rate; reactions at different pH values may plateau at different times. ✓

C. She should include a positive control with higher pH.

D. Catalase does not work at neutral pH.

Answer Logic

- **Correct answer: B.**
- At optimal pH, substrate may be exhausted quickly and the curve may plateau before 5 minutes.
- At nonoptimal pH, the reaction may still be increasing at 5 minutes.
- Therefore, endpoint totals do not fairly compare rates.
- **Better method:** measure absorbance every 30 seconds, graph absorbance vs time, and use the initial slope of the linear phase.

Fast Review Hits

- Always use the initial rate, not the endpoint.
- Boiled enzyme = negative control for activity.
- Heat denatures; cold usually just slows.
- The best enzyme-rate comparison uses repeated time points and early linear slopes.

Science Practices & FRQ Framework

How AP Biology uses labs on the exam

SP 1–6 | Experimental Design | Data Analysis + Argumentation

AP Biology Science Practices — Quick Reference

Practice	Meaning	Exam Application
1 Models & Representations	Describe, create, and interpret diagrams, graphs, cladograms, and models.	Reading graphs, interpreting cladograms, drawing setups.
2 Quantitative Skills	Use calculations, ratios, percentages, formulas, and mathematical reasoning.	Percent mass change, Hardy–Weinberg, chi-square, 10% rule, mitotic index, water potential.
3 Scientific Questions	Pose, refine, and evaluate testable hypotheses.	Design-an-experiment FRQs.
4 Data Collection & Experimental Design	Identify IV, DV, controls, replicates, and methods.	State the design and reduce error.
5 Data Analysis & Evaluation	Identify trends, patterns, anomalies, and evidence-based conclusions.	Explain what the data support or refute.
6 Scientific Argumentation	Make claims with evidence and reasoning; evaluate alternatives.	Write "the data support or do not support the hypothesis because…"

Build a Full Experimental Design Answer

1. **State a hypothesis:** "If [IV] changes, then [DV] will change because [mechanism]."
2. **Identify the IV:** the single variable you change.
3. **Identify the DV:** what you measure.
4. **List controlled variables:** everything else kept constant.
5. **Define the control group:** no treatment or baseline condition.
6. **Explain how the DV is measured:** balance, ruler, colorimeter, colony count, etc.
7. **Predict expected results** if the hypothesis is correct.
8. **Mention replicates or sample size** to reduce random error.

Data Analysis FRQ Sentence Pattern

1. First describe the trend: "As X increases, Y increases/decreases."
2. Then explain the mechanism.
3. Then conclude whether the data support the hypothesis.

Statistics Reminder

1. State the p-value context.
2. Compare χ^2 to the critical value.
3. Then say "reject H_0" or "fail to reject H_0".

Fast Review Hits

- A full design answer must include hypothesis, IV, DV, controls, and measurement.
- Always describe the trend before explaining it.
- Claims need evidence.
- Replication improves reliability.

Final Review: Errors + Checklist

High-frequency lab mistakes to avoid before the exam

Most-Tested Traps | Final Checklist | Exam-Day Wording

High-Frequency Lab Errors to Avoid

1 INV 4 Osmosis

Use percent mass change, not absolute mass change.

Absolute mass change ignores starting mass differences between treatments.

2 INV 6 Respiration

Subtract the nonliving bead control.

Beads also change mass and would inflate your respiration rate.

3 INV 13 Enzyme

Use the initial rate, not the endpoint.

Enzyme activity is measured at the start, before substrate becomes limiting.

4 INV 8 Transformation

No colonies on –DNA / +amp is expected.

Without DNA, bacteria can't grow even with the antibiotic resistance gene.

5 INV 9 Gel

Smaller fragments travel farther.

Small fragments pass through pores more easily, so they migrate farther.

6 INV 2 / 12 Statistics

Never say "accept H_0"; say "fail to reject H_0".

You do not prove the null hypothesis; you only test whether to reject it.

7 INV 5 Photosynthesis

A dark control is required in the floating-leaf-disk assay.

It shows O_2 production is due to photosynthesis, not other factors.

8 INV 11 Transpiration

High humidity decreases transpiration.

Moist air reduces the vapor pressure gradient, lowering the rate of water loss.

Labs Pre-Exam Checklist

- **INV 1:** Control = randomly mated group; response to selection shows heritability.
- **INV 2:** Start from $q^2 \rightarrow q \rightarrow p \rightarrow 2pq$; never write "accept H_0".
- **INV 3:** More DNA similarity = more closely related; molecular data often beats morphology.
- **INV 4:** % mass change = (final–initial)/initial × 100; isotonic = 0% change.
- **INV 5:** Floating disks = O_2 from photosynthesis; rate = $1/ET_{50}$; dark control required.
- **INV 6:** Subtract bead control; KOH absorbs CO_2.
- **INV 7:** Mitotic index = cells in mitosis / total cells × 100; *Sordaria* map distance = recombination ÷ 2.
- **INV 8:** No colonies on –DNA / +amp is expected; transformation efficiency = colonies / µg DNA.
- **INV 9:** Small fragments are farther from wells; fragment sizes sum to original DNA size.
- **INV 10:** % energy transfer = higher level / lower level × 100; about 10% per trophic level.
- **INV 11:** High humidity lowers transpiration; fan increases it; most stomata are on the lower leaf surface.
- **INV 12:** Expected = 50/50, df = 1, critical value = 3.841.
- **INV 13:** Use the initial slope; boiled enzyme control is useful; cold slows but heat denatures.
- **Every design FRQ needs:** hypothesis + IV + DV + controlled variables + control group + measurement method + expected result.
- **For data analysis:** describe trend, explain mechanism, conclude support or lack of support.
- **For statistics:** compare χ^2 with the critical value, then reject or fail to reject H_0.
- **Every experiment needs a *negative control;*** *some* also need a positive control.

Final Motivator

Know the setup, know the variable, know the control, know the calculation — and lab FRQs become predictable.

★ *Most common wording win:* *"The data support / do not support the hypothesis because..."*

Done with the labs? Now get marked.

We don't give you questions to grind through.
Upload your own AP Bio Lab FRQ — we score it like an AP Reader and show you the exact rubric points you missed.

1

Score

Marked against the published College Board rubric.

2

See

The exact rubric point you gained or dropped, line by line.

3

Practice

Fix lab-question patterns before exam day.

Scan to register — free, no card required