

AP Biology asks you to design and interpret investigations, not to recall a protocol. Nearly all of the marks below come from four habits: naming the independent and dependent variable, saying what is held constant, quoting data with units, and stating whether a difference is statistically significant.

Designing an investigation

Name the independent variable, the dependent variable and at least two controlled variables. A question that says “design an experiment” awards a point for each, and they are the cheapest marks on the paper.

Describe the CONTROL GROUP, not just “a control”. It must be identical in every way except the independent variable – say so explicitly.

State how the dependent variable will be MEASURED, with units. “Measure growth” scores nothing; “measure height in mm every 24 hours” earns the point.

Include replication and say why: repeated trials reduce the effect of random error and let you calculate a mean.

Predict the result in the form “if ... then ... because ...”, and make the reasoning biological rather than a restatement of the prediction.

Handling data

Quote data when you are asked to justify a claim: cite the actual numbers and units from the table or graph, not “the graph goes up”.

Read error bars correctly. Overlapping error bars mean the difference is probably NOT significant; non-overlapping bars support a real difference.

Standard error decreases as sample size increases – that is why more trials give a stronger conclusion.

Plot the independent variable on the x-axis and the dependent on the y-axis, label both with units, and use a scale that fills the grid.

Do not draw a line of best fit through data that show no trend, and never extrapolate beyond the range you measured.

Statistics on the formula sheet

Chi-square test – compares observed with expected counts; calculate $\chi^2 = \Sigma(\text{observed} - \text{expected})^2 / \text{expected}$ and compare it with the critical value at the correct degrees of freedom

Degrees of freedom – the number of categories minus one – a common lost mark is using the sample size instead

Null hypothesis – the statement that any difference between observed and expected results is due to chance alone

p = 0.05 0.05 – the threshold used in this course; if χ^2 exceeds the critical value, reject the null hypothesis and call the difference significant

Standard error – an estimate of how far a sample mean is likely to lie from the true population mean; plotted as error bars

The investigations you must be able to reason about

Diffusion and osmosis: use percent change in mass, not raw mass, so that dialysis bags or potato cores of different starting size can be compared.

Enzyme catalysis: rate is measured as product formed per unit time; identify whether the limiting factor is substrate concentration, temperature or pH.

Photosynthesis (floating disk): the rate measure is the time for half the disks to rise, and the control is disks in water without bicarbonate.

Cellular respiration (respirometer): the control vial with no organism corrects for changes in temperature and air pressure – say what it corrects FOR.

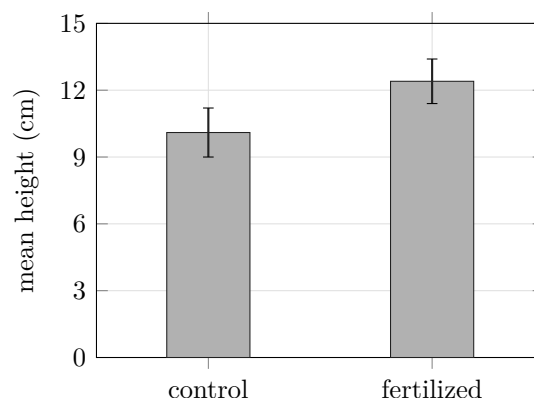
Transpiration: relate the rate to the environmental variable through stomatal opening, not simply to “more water lost”.

Population genetics: use Hardy-Weinberg only after stating that its five conditions are assumed, and remember $p + q = 1$ while $p^2 + 2pq + q^2 = 1$.

Worked analysis: error bars of ± 2 SE : ± 2

Ten bean plants were grown with a nitrogen fertilizer and ten without, and their heights measured after 14 days. Fertilized: mean 12.4 cm, $s = 1.6$ cm. Control: mean 10.1 cm, $s = 1.8$ cm.

1. $SE_{\bar{x}} = s/\sqrt{n}$: fertilized $1.6 \div \sqrt{10} = 0.51$ cm; control $1.8 \div \sqrt{10} = 0.57$ cm.
2. ± 2 SE: fertilized 12.4 ± 1.0 cm (11.4 to 13.4 cm); control 10.1 ± 1.1 cm (9.0 to 11.2 cm).
3. The two intervals do not overlap, so the difference between the means is likely to be statistically significant.



Means with error bars of ± 2 SE. The caption must say what the bars show – ± 2 SE, ± 1 SD or a 95% confidence interval are read differently.

Claim with evidence and reasoning: ‘Fertilized plants grew taller (12.4 cm against 10.1 cm), and the ± 2 SE bars do not overlap, so the difference is likely significant. Nitrogen is needed to make amino acids and nucleotides, so more nitrogen allows more growth.’

Worked analysis: a chi-square test :

A dihybrid cross of two heterozygous pea plants gave 160 offspring. Null hypothesis: the genes assort independently, so the offspring fall in a 9 : 3 : 3 : 1 ratio and any difference is due to chance.

Phenotype	Observed o	Expected e	$(o - e)^2/e$
round, yellow	95	90	0.28
round, green	28	30	0.13
wrinkled, yellow	27	30	0.30
wrinkled, green	10	10	0.00

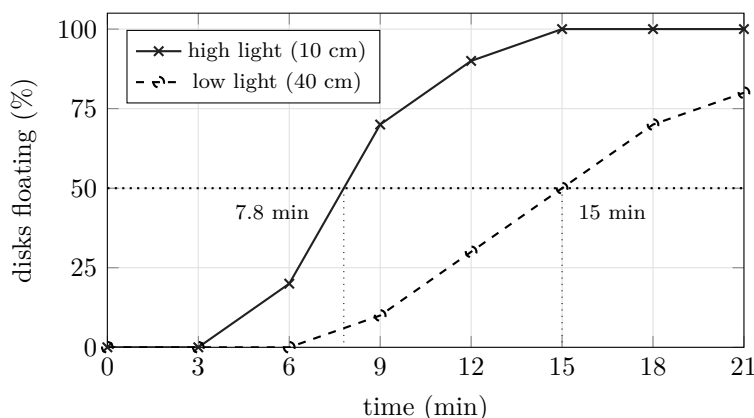
Expected = 9/16, 3/16, 3/16 and 1/16 of 160. $\chi^2 = 0.28 + 0.13 + 0.30 + 0.00 = 0.71$.

Degrees of freedom = 4 categories – 1 = 3; the critical value at $p = 0.05$ is 7.81. Since $0.71 < 7.81$, fail to reject the null hypothesis: the data are consistent with independent assortment.

‘Fail to reject’ is the wording, not ‘accept’ or ‘prove’. A χ^2 below the critical value shows only that the data do not contradict the hypothesis.

Worked analysis: floating leaf disks :

Ten spinach leaf disks had the air drawn out of their air spaces with a syringe, so they sank in 0.2% sodium bicarbonate solution (a source of CO_2). One cup was placed 10 cm from a lamp (high light), one at 40 cm (low light). The number floating was counted every 3 minutes: oxygen made in photosynthesis collects in the air spaces and lifts each disk.



Each point is a count, joined in time order. ET_{50} is read where each line crosses 50%.

ET_{50} , the estimated time for 50% of the disks to float, is about 7.8 min in high light and 15 min in low light. Because a SHORTER time means a faster rate, report the rate as $1/\text{ET}_{50}$: 0.13 min^{-1} against 0.067 min^{-1} , about twice as fast in high light.

Claim, evidence, reasoning: light intensity increased the rate of photosynthesis (claim); ET_{50} halved from 15 to 7.8 min (evidence); more light drives more of the light-dependent reactions, so oxygen accumulates in the air spaces faster (reasoning).

Controls and limits: the same leaf, the same number and size of disks, the same bicarbonate solution and temperature; a cup of disks in water without bicarbonate should barely float (no CO_2). The lamp also heats the nearer cup – a heat shield or LED lamp removes this confound. Ten disks per cup is a small sample: repeat with more cups and give ± 2 SE of the ET_{50} values.