A-Level Biology

*Biology is not thought of as a calculating subject, and that is exactly why its arithmetic marks are the cheapest ones on the paper to lose. Where a statistical test is set, the formula is usually printed beside the question – but the **conditions for choosing that test**, and every relationship below, are recalled. Work in a single set of units before substituting anything, and write the unit on the answer.* 生物的计算题分值不高但极易丢分：先统一单位，再代入，最后写单位。

Units and scale – settle these before any calculation

1 mm = 1000 μm and 1 μm = 1000 nm. A measurement in millimetres and a cell size in micrometres cannot go into the same fraction until one of them is converted.

换算:1 mm = 1000 μm,1 μm = 1000 nm。

Volumes: 1 dm^3 = 1000 cm^3 and 1 cm^3 = 1000 mm^3. A concentration in mol dm^{-3} needs the volume in dm^3.

体积换算:1 dm^3 = 1000 cm^3。

Round only at the END, and give the answer to the same number of significant figures as the data – usually two or three. A magnification is written with a multiplication sign and NO unit: ×3000.

只在最后四舍五入; 放大倍数写作 ×3000, 无单位。

Microscopy and cell size

Magnification 放大倍数 — magnification = image size ÷ actual size. Rearranged, actual size = image size ÷ magnification. Both sizes must be in the SAME unit before dividing, and magnification itself has no unit.

Total magnification of a microscope 显微镜总放大倍数 — eyepiece magnification × objective magnification.

Resolution 分辨率 — the smallest distance between two points that can still be seen as separate. It is not magnification: an image can be enlarged without ever resolving more detail.

Surface area to volume ratio 表面积与体积之比 — surface area ÷ volume, quoted as "x : 1". It FALLS as an organism gets larger, which is why large organisms need transport and exchange systems.

A cell drawn 60 mm long is actually 20 μm long. Find the magnification.

Magnification = ×3000.

Convert first: $60\ mm = 60 \times 1000 = 60\,000\ \mu m$

$Magnification = 60\,000 \div 20 = \times 3000$

Compare the surface area to volume ratio of a cube of side 2 mm with one of side 4 mm.

The 2 mm cube is 3 : 1, the 4 mm cube is 1.5 : 1 – doubling the side halves the ratio.

Side 2 mm: $surface\ area = 6 \times 2^2 = 24\ mm^2,\ volume = 2^3 = 8\ mm^3,\ ratio = 3 : 1$

Side 4 mm: $surface\ area = 6 \times 4^2 = 96\ mm^2,\ volume = 4^3 = 64\ mm^3,\ ratio = 1.5 : 1$

Rates, changes and cell counts

Rate 速率 — change in the measured quantity ÷ time taken. The unit follows the working – $cm^3\ min^{-1}$, $\mu mol\ s^{-1}$ – and is part of the answer.

Rate from a graph 由图像求速率 — the gradient of a tangent for an instantaneous rate, or the gradient of the straight initial section for an initial rate. Draw the triangle on the graph; the examiner marks it.

Percentage change 百分比变化 — (final value − initial value) ÷ initial value ×100. Always divide by the ORIGINAL, and keep the minus sign for a decrease.

Mitotic index 有丝分裂指数 — number of cells visibly in mitosis ÷ total number of cells counted. Multiply by 100 only if the question asks for a percentage.

Rf value 比移值 — distance moved by the spot ÷ distance moved by the solvent front, measured from the same origin line to the CENTRE of the spot. It is always between 0 and 1 and has no unit.

Cardiac output 心输出量 — stroke volume × heart rate. With stroke volume in cm^3 and heart rate per minute, the answer is in $cm^3\ min^{-1}$; divide by 1000 for $dm^3\ min^{-1}$.

A student counts 60 cells in a root tip and 12 are in mitosis. Find the mitotic index.

Mitotic index = 0.20, or 20%.

Mitotic index $= 12 \div 60 = 0.20$

As a percentage, $0.20 \times 100 = 20\%$

Water potential and transport

Water potential 水势 — $\Psi = \Psi_s + \Psi_p$: water potential = solute potential + pressure potential. Units are kPa, and pure water at atmospheric pressure is 0 – so every solution has a NEGATIVE water potential.

Direction of water movement 水分移动方向 — water moves by osmosis from a HIGHER (less negative) water potential to a LOWER (more negative) one, down a water-potential gradient. "−200 kPa is higher than −800 kPa" is the comparison that is most often got backwards.

Solute potential 溶质势 — always negative or zero, and becomes more negative as solute concentration rises.

Pressure potential 压力势 — usually positive in a turgid plant cell, where the cell wall pushes back; zero at incipient plasmolysis.

Genetics and inheritance

Hardy–Weinberg, allele frequencies 哈迪 — 温伯格等位基因频率 — $p + q = 1$, where p is the frequency of the dominant allele and q the recessive.

Hardy–Weinberg, genotype frequencies 哈迪 — 温伯格基因型频率 — $p^2 + 2pq + q^2 = 1$: p^2 homozygous dominant, $2pq$ heterozygous, q^2 homozygous recessive. Start from q^2, because the recessive phenotype is the one that can be counted.

Conditions the Hardy–Weinberg equations assume 哈迪 — 温伯格前提条件 — a large population, random mating, no mutation, no migration and no selection. A question asking why the observed frequency differs is asking which of these has failed.

One person in 25 shows a recessive condition. Find the frequency of heterozygous carriers.

About 32% of the population are carriers.

$q^2 = 1/25 = 0.04, \; so \; q = \sqrt{0.04} = 0.2$

$p = 1 - 0.2 = 0.8$

$Carriers = 2pq = 2 \times 0.8 \times 0.2 = 0.32, \; i.e. \; 32\%$

Ecology and energy

Simpson's index of diversity 辛普森多样性指数 — $D = 1 - \sum (n/N)^2$, where n is the number of individuals of one species and N the total. D runs from 0 to just below 1, and HIGHER means more diverse.

Efficiency of energy transfer 能量传递效率 — energy at one trophic level ÷ energy at the level below $\times 100$. Typically around 10% between consumers, and lower from producers.

Net primary production 净初级生产量 — gross primary production − respiratory losses. It is what is actually available to the next trophic level.

A population contains 10 of species A, 8 of species B and 2 of species C. Find Simpson's index of diversity.

$D = 0.58$.

$N = 10 + 8 + 2 = 20$

$\sum (n/N)^2 = 0.5^2 + 0.4^2 + 0.1^2 = 0.25 + 0.16 + 0.01 = 0.42$

$D = 1 - 0.42 = 0.58$

Statistics – choosing the test is the marked skill

Standard deviation 标准差 — $s = \sqrt{\dfrac{\sum (x - \bar{x})^2}{n - 1}}$. It measures the SPREAD of one set of data; a large s means the mean is a poor summary.

Standard error of the mean 标准误 — $SE = s/\sqrt{n}$. It measures how reliable the MEAN is, and it falls as the sample grows – which is the reason to repeat.

95\% confidence interval 95\% 置信区间 — $\bar{x} \pm 2 \times SE$, drawn as error bars. If two sets of error bars do NOT overlap, the difference between the means is likely to be significant.

Chi-squared test 卡方检验 — $\chi^2 = \sum \dfrac{(O - E)^2}{E}$, for COUNTS in categories – a genetic cross, a distribution between habitats. Degrees of freedom = number of classes -1.

t-test t 检验 — compares the MEANS of two sets of measurements. Use it when the data are continuous and roughly normally distributed, with degrees of freedom $= n_1 + n_2 - 2$.

Spearman's rank correlation 斯皮尔曼等级相关 — $r_s = 1 - \dfrac{6 \sum d^2}{n^3 - n}$, where d is the difference in ranks. Use it to ask whether two variables are ASSOCIATED, never whether one causes the other.

Reading a table of critical values 查临界值表 — compare the calculated value with the critical value at $p = 0.05$ for the right degrees of freedom. For χ^2 and t, calculated GREATER than critical means reject the null hypothesis; the difference is significant.

A cross predicted a 3 : 1 ratio among 160 offspring. The observed numbers were 132 and 28. Test the ratio at $p = 0.05$, where the critical value for 1 degree of freedom is 3.84.

$\chi^2 = 4.8$, which is greater than 3.84, so the null hypothesis is rejected: the difference from a 3 : 1 ratio is significant and something other than chance is acting.

Expected $= 160 \times \frac{3}{4} = 120$ *and* $160 \times \frac{1}{4} = 40$

$$\chi^2 = \frac{(132-120)^2}{120} + \frac{(28-40)^2}{40} = \frac{144}{120} + \frac{144}{40}$$

$$= 1.2 + 3.6 = 4.8$$

Degrees of freedom $= 2 - 1 = 1$; $4.8 > 3.84$, *so the result is significant at* $p = 0.05$

Where these marks are actually lost

Mixing units inside one fraction. Millimetres over micrometres is the commonest error in the whole subject, and it is worth every mark in the question.

同一算式内单位不统一，是最常见的失分点。

Using E instead of O in the χ^2 denominator. The bottom line is always the EXPECTED value.

卡方公式分母永远是期望值 E。

Comparing negative water potentials as if they were positive. −200 kPa is HIGHER than −800 kPa, so water moves from the first to the second.

水势为负值,-200 kPa 高于 -800 kPa。

Stating a conclusion without the comparison. "$\chi^2 = 4.8$" earns the calculation mark; "$4.8 > 3.84$ at 1 degree of freedom, so the difference is significant" earns the rest.

必须把计算值与临界值比较后再下结论。

Writing a unit on a magnification, an Rf value or a diversity index. All three are ratios and have none.

放大倍数、Rf 值与多样性指数均无单位。