InkBiology

ANSWER BOOK

Statistics for biologists: spread, error bars and the three tests

Scientific method and quantitative biology · Unit B00

AQA MS 1.2, 1.3, 1.5–1.7, 1.9–1.11 · OCR A Module 1.1.4; mathematical requirements (statistics)
Edexcel A Mathematical skills appendix (statistics)
CAIE Paper 5 (analysis, conclusions and evaluation)

6 questions · 22 marks

NAVY EDITION

inkphysics.co.uk/biology/ · youtube.com/@InkPhysics

SECTION A · Short, 1 to 2 marks

A1 **B1** there is no significant difference between the mean number of stomata per square millimetre on sun leaves and the mean number on shade leaves. **B1** the conventional significance level is p = 0.05, below which the null hypothesis is rejected. [2]

SECTION B · Standard, 3 to 5 marks

B1 **M1** expected values are 400 × 3/4 = 300 tall and 400 × 1/4 = 100 dwarf, both comfortably above 5. **M1** (280 - 300)² ÷ 300 = 1.33 and (120 - 100)² ÷ 100 = 4.00. **A1** chi-squared = 1.33 + 4.00 = 5.33. **B1** degrees of freedom = 2 categories - 1 = 1, and the calculated value of 5.33 is greater than the critical value of 3.84 at p = 0.05. **B1** the null hypothesis is rejected: there is a significant difference between the observed numbers and a 3:1 ratio, so the difference is unlikely to have arisen by chance alone. [5]

B2 **M1** mean = (12 + 14 + 15 + 17 + 22) ÷ 5 = 80 ÷ 5 = 16 mm. **M1** the deviations from the mean are -4, -2, -1, +1 and +6, and the squares of these total 16 + 4 + 1 + 1 + 36 = 58. **M1** divide by n - 1 rather than by n: 58 ÷ 4 = 14.5, then take the square root. **A1** standard deviation = 3.81 mm. [4]

B3 **B1** an error bar may show one standard deviation, one standard error or a 95 per cent confidence interval, and the three have different lengths drawn on the same data, so the same means can appear to overlap or not depending on the choice. **B1** standard-deviation bars describe variation between individuals and barely narrow however many organisms are measured, so two genuinely different means can easily have overlapping bars. **B1** standard-error bars describe how precisely each mean has been estimated and shrink roughly as one over the square root of the sample size, so with a large enough sample almost any two means separate. **B1** significance is decided only by comparing a calculated test value with a critical value at a stated probability, so bars can suggest that a test is worth doing and no more. [4]

B4 **B1** a t-test needs two separate sets of measurements each scattered about a mean, whereas Spearman's needs two different quantities measured on each of the same individuals or quadrats. **B1** a t-test asks whether the two means differ, whereas Spearman's asks whether the two variables vary together. **B1** the t-test uses the measurements themselves and assumes they are continuous and roughly normally distributed, whereas Spearman's replaces every measurement by its rank and never sees the values. **B1** degrees of freedom for the t-test are $n_1 + n_2 - 2$, whereas Spearman's critical value is read against n, the number of pairs; for both, a calculated value at or above the critical value means the null hypothesis is rejected. [4]

B5 **B1** significance depends on the size of the sample as well as on the size of the difference, so a sample of 2000 from each lake can detect a difference this small. **B1** significant means unlikely to have arisen by chance under the null hypothesis; it does not mean the difference is large, and 0.4 g is a tiny fraction of the mass of a fish. **B1** the sentence reporting a significant result should give the size of the difference as well, and further work would be needed to show whether a difference this small has any effect on the fish. [3]