Statistics in Biology

Further guidance

A common question in our 'Preparing to Teach' meetings has been how we will assess statistical tests in Biology in the AS papers and the A-level papers. This resource has been designed to supplement the information in the Biology Practical Handbook. The information in it will be added to the second edition of the Biology Practical Handbook in summer 2015.

The Department for Education criteria for A-level Biology (*GCE AS and A-level subject content for biology, chemistry, physics and psychology*) include the following mathematical skills that are relevant to statistics.

Code	Mathematical skill	How students may be tested
MS 1.9	Select and use a statistical test.	Students may be tested on their ability to select and use: • the chi-squared test to test the significance of the difference between observed and expected results • the Student's t-test • the correlation coefficient.
MS 1.10	Understand measures of dispersion, including standard deviation and range.	Students may be tested on their ability to: • calculate the standard deviation • understand why standard deviation might be a more useful measure of dispersion for a given set of data, eg where there is an outlying result.

The description of these skills has been included verbatim in AQA's specification for AS and A-level Biology. Since these statements are not in bold type, they could all potentially be examined in both AS and A-level papers.

In teaching the AQA Biology AS and A-level specifications, we recommend that 'the correlation coefficient' with which students become familiar is Spearman's rank, as in the legacy specification. Ultimately, though, the choice is left to the teacher.

Consequently, if a question in a written test requires students to recognise that a correlation coefficient is the appropriate statistical test to use with given data, the answers 'Spearman's rank', 'correlation coefficient' or any named correlation coefficient will be credited.

In written examinations, students might be asked to perform simple calculations such as finding a mean value. Students will not be asked to perform a calculation using a statistical test (or to calculate the standard deviation of a mean). This policy reflects the recognition by examiners and teachers that the tariff in the legacy ISA and EMPA does not reflect the time spent in performing such calculations. We would expect students will perform such calculations during their class work, however. Whilst teachers might feel there is some value in students performing these calculations manually, we anticipate that most students will use electronic devices. The use of such devices also reflects the general agreement of representatives from higher education and from industry that there is little value in students calculating test statistics manually as in most commercial and academic institutions computers are used to carry out the numerical calculations.

In preparing for written examinations, it will be important for students to understand how to select a statistical test that is appropriate for given data and to be able interpret the results of such a statistical test. Students could also be asked to justify their choices and interpretation.

Although the subject criteria do not differentiate between AS and A-level, AQA papers will expect progression in the understanding of statistical tests in AS and A-level exams.

Traditionally, statistics have been taught as part of the second (A2) year of the course. We are confident that the inclusion of statistics in first year (co-teachable AS) can be managed within the class time and that sound understanding by students can be achieved with very little effect on teaching time.

In AS exams, students could be expected to:	In A-level exams, students could also be expected to:
Formulate a null hypothesis • for the experiments they perform during their class work • when given appropriate information, for experiments carried out by others.	Evaluate the null hypothesis of another investigator.
Devise and justify an appropriate table in which to record their raw data.	
Devise and justify an appropriate way to represent their processed data	Evaluate the way in which another investigator has represented processed

graphically.	data.
Select and justify the selection of an appropriate statistical test for data they will subsequently collect themselves or data that might be collected by others. The statistical tests are restricted to: • chi-squared test when the data are categoric • the Student's *t* test when comparing the mean values of two sets of data • a correlation coefficient when examining an association between two sets of data.	Evaluate the choice of a statistical test made by another investigator.
Interpret a given probability value in terms of the probability of the difference between observed data and expected data (chi-squared test), the difference between the means of two samples (Student's *t* test) or a correlation between two variables (correlation coefficient) being due to chance.	Interpret a given probability value in terms of acceptance or rejection of a null hypothesis, using 0.05 as the critical probability value. Evaluate the conclusions from the same data made by another commentator. Show an understanding of 'degrees of freedom' so that, when given appropriate information, a student can use a given result of a statistical test to find the correct probability value from an abridged table of values.

Teaching statistics at AS

There are many opportunities for students to be introduced to statistical concepts during their AS course. In particular, the start of every investigative practical presents an opportunity for students to:

- formulate a null hypothesis that is appropriate for the investigation they will perform, eg temperature (the independent variable) has no effect on the rate of an enzyme-catalysed reaction (the dependent variable)
- devise an appropriate way to tabulate the raw data they will collect
- devise an appropriate way to represent their processed data graphically.

The following examples show how the choice and justification of appropriate statistical tests could be included in class work during an AS Biology course. Students could also be encouraged to calculate, and interpret the result of, their

chosen statistical test. These are intended only as a guide to areas in which the statistical tests could be used and are not specification requirements.

Section	Opportunities for skills development
3.1.4.2 Required practical 1	Students could select and use an appropriate statistical test to find the significance of differences in the rates of reaction following use of a continuous variable (eg pH, temperature, enzyme concentration or substrate concentration) or of a discontinuous variable (eg presence and absence of an enzyme inhibitor).
3.2.1.1	Students could select and use an appropriate statistical test to find the significance of different mean numbers of a particular organelle (eg mitochondria or chloroplasts) in different types of cells.
3.2.2 Required practical 2	Students could select and use an appropriate statistical test to find the significance of differences in the number of cells undergoing mitosis at two close, but different, distances from the root tip.
3.3.2	Students could select and use an appropriate statistical test to find the significance of a correlation between data about an environmental variable and data about the incidence of a particular lung disease.
3.3.4.1	Students could select and use an appropriate statistical test to find the significance of a correlation between data about an environmental variable and data about the incidence of a particular cardiovascular disease.
3.3.4.2	Students could select and use an appropriate statistical test to find the significance of differences in the number of stomata on the upper and lower surfaces of leaves of a single plant species or on the lower surfaces of leaves of different plant species.
3.3.4 Required practical 6	Students could select and use an appropriate statistical test to find the significance of differences in the effect of different antibiotics on the growth of a species of bacterium of or a single antibiotic on the growth of more than one species of bacterium.
3.4.7	Students could select and use an appropriate statistical test to find the significance of differences in the mean values they have collected or been given.