Advanced Higher Biology

Unit 3—Investigative Biology

Student name: ____________

Class: __________________

Teacher: ________________

Glossary

Word	**Meaning**
Scientific cycle	
Peer reviewed article	
The 3 Rs	
Ethics	
Hypothesis	
Null hypothesis	
Informed consent	
Right to with draw	
Confidentiality	
Pilot study	
Independent variable	
Dependent variable	
Confounding variable	
Randomised block design	
Discrete variable	

Continuous variable	
Qualitative data	
Quantitative data	
Ranked data	
Simple study design	
Multifactorial study design	
Positive correlation	
Negative correlation	
Causation	
In vitro	
In vivo	
Mean	
Median	
Mode	
Range	
Box plot	
Interquartile range	
Field study	
Observational study	

Positive control	
Negative control	
Placebo	
Placebo effect	
Double blind study	
Sampling	
True mean	
Representative sample	
Selection bias	
Random sampling	
Double blind study	
Sampling	
Double blind study	
Sampling	
True mean	
Representative sample	
Random sampling	
Systematic Sampling	

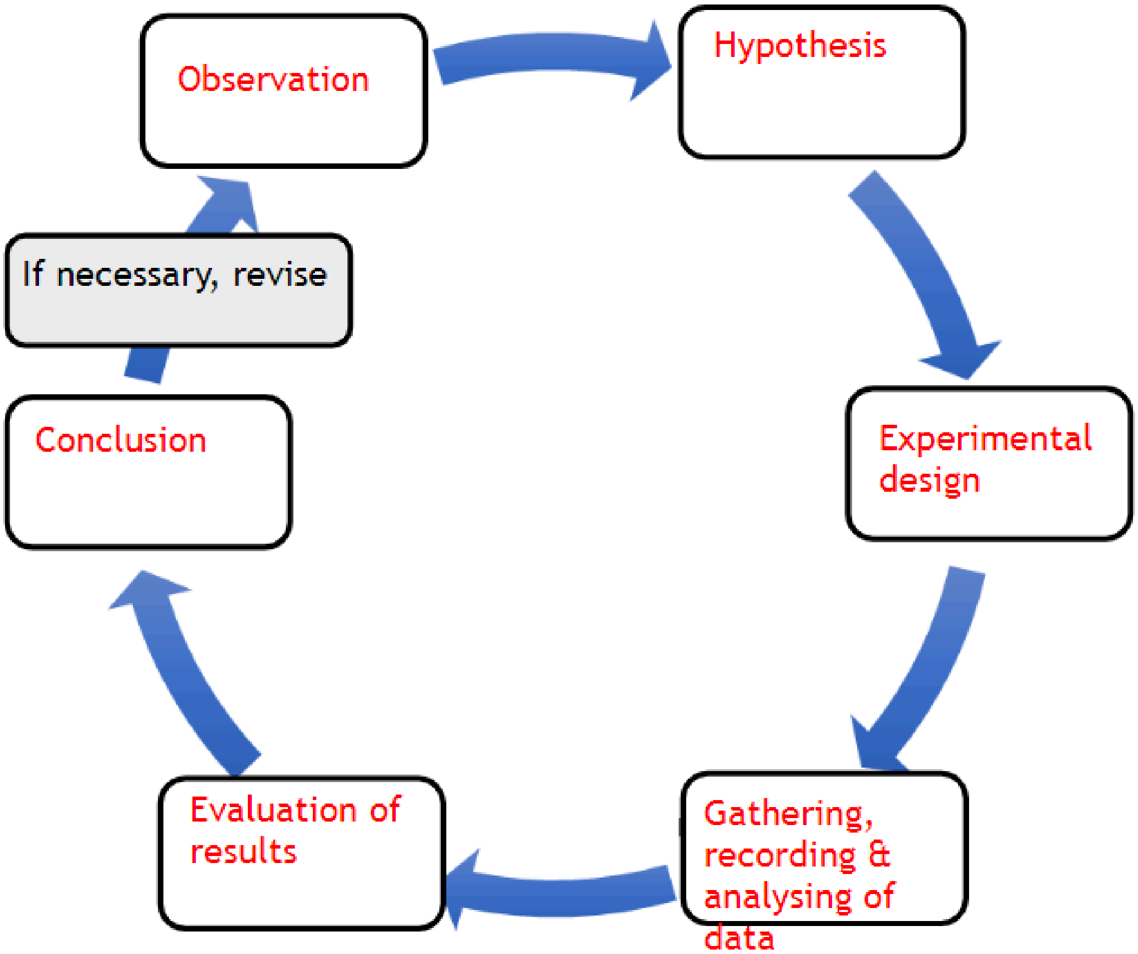
Representative sample	
Random sampling	
Systematic Sampling	
Stratified sampling	
Reliability	
Accuracy	
Precision	
Validity	
Standard deviation	
Statistically significant	
Error bar	
Outlier	
Anomalous result	
Replicate	
Independent replicate	
Legislation	
Abstract	
Citation/ reference	

1. Scientific Principles and Process

a) Scientific Method

In science, refinement of ideas is the norm, and scientific knowledge can be thought of as the current best explanation, which may then be updated after evaluation of further experimental evidence.

Biologists will follow the Scientific Cycle in order to complete their investigations.



If necessary, revise the hypothesis.

Quite often biological investigations will fail to find an effect. This is called a negative effect, and this is still a valid finding, as long as the investigation has been well designed. Data or conclusions that are conflicting (do not agree with each other) can be resolved through careful evaluation or will usually lead to further experimentation.

In order to be valid, results must be reproducible. If they are one-off, they are usually treated with caution.

Null Hypothesis:

Examples of Null Hypothesis:

Statistics can be used to identify if results are caused by chance or not. Scientific ideas only become accepted once they have been checked independently.

b) Scientific Literature & communication

Communication within the scientific community is incredibly important. It allows findings to be shared with others to further their research.

It is important that method, data, analysis and conclusions are published in scientific reports so that others are able to repeat an experiment.

Sharing Science

Original scientific findings are shared in a variety of ways. These include seminars, talks and posters at conferences, and publishing in academic journals.

Review Articles

Review articles within scientific journals summarise current knowledge and recent findings in a particular field.

Peer Review

Any published data should be peer reviewed and critically evaluated by specialists who are experts in the relevant field. This ensures scientifically correct information is being shared within the community.

Science in the media

In recent years the wider media has given more coverage to science stories meaning that the public has developed a greater understanding of science. Unfortunately, they often misrepresent the findings so this coverage must be critically evaluated.

c) Scientific Ethics

Ethics:

While judgements and interpretations of scientific evidence may be disputed, integrity and honesty are of key importance in science. It relies on the reporting of unbiased presentation of results, citing and providing references and avoiding plagiarism.

The replication of experiments by others reduces the opportunity for dishonesty or the deliberate misuse of science.

Animal Studies

Animals are often used in biological studies. Scientists have a duty to ensure animal suffering is kept to a minimum. To do this they must adhere to “The 3 R’s”.

Replacement:

Reduction:

Refinement:

Human Studies

When using human subjects there are several concepts that must be used to ensure human rights are adhered to.

Informed consent:

The right to withdraw:

Confidentiality:

Any scientific research on living organisms should be justified and any risks in completing the research should be assessed. This includes taking into account the risk to and safety of subject species, individuals, investigators and the environment.

Legislation and Regulations

Legislation:

Legislation, regulation, policy and funding can all influence scientific research.

The value or quality of science investigations must be justifiable in terms of the benefits of its outcome, including the pursuit of scientific knowledge. As a result of the risks involved, many areas of scientific research are highly regulated and licensed by governments.

2. Experimentation

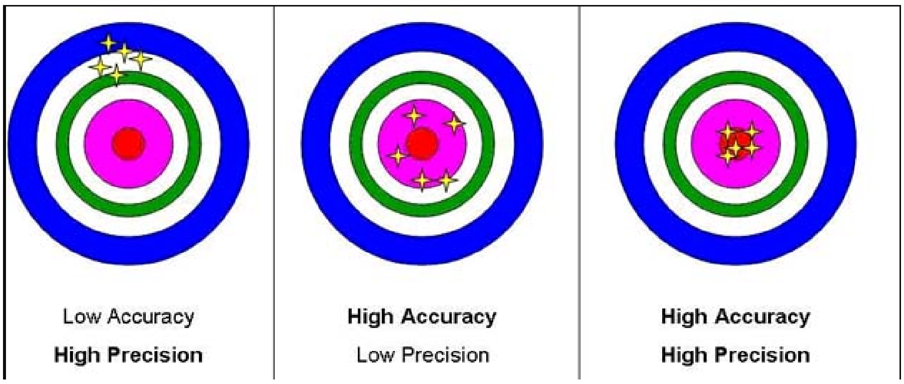
Validity, Reliability, Accuracy and Precision

Validity:

Reliability:

Accuracy:

Precision:

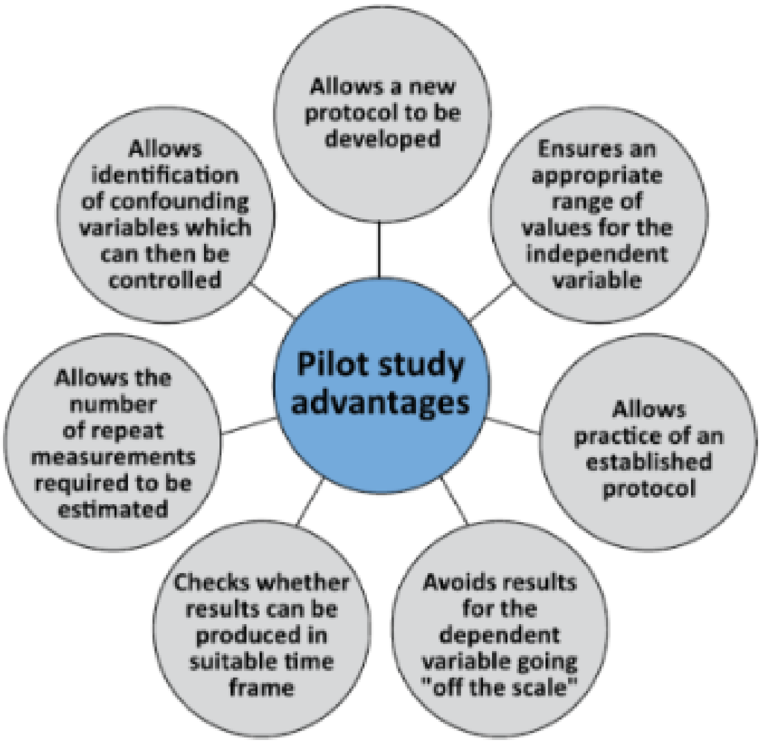


a) Pilot Study

Pilot study:

Pilot studies are integral to the development of an investigation. They help to plan procedures, assess validity and check techniques. This allows evaluation and modification of experimental design.

They can also be used to ensure you have an appropriate range of values for the independent variable. In addition, it allows the investigator to establish the number of repeat measurements required to give a representative value for each independent datum point.



You are expected to complete a pilot study as part of your coursework. It will allow you to complete a test run of your investigation before completing your final investigation for your project.

Experimental Design

Developing an aim

The aim should state what is being investigated in the study. It should always include both the independent and dependent variables. If possible the aim should be directional as this makes it easier to write a conclusion.

Example of a suitable aim:

Independent and Dependent Variables

Variable:

Variables can be continuous or discrete.

Continuous:

Discrete:

Experiments involve the manipulation of the independent variable by the instigator.

Independent variable:

Dependent variable:

They will compare an experimental treatment group to a control group.

Simple versus multifactorial study design

Experiments can be designed to be either simple (one independent variable) or multifactorial (more than one independent variable).

The control of laboratory conditions allows simple experiments to be conducted more easily than in the field. However, a drawback of a simple experiment is that its findings may not be applicable to a wider setting.

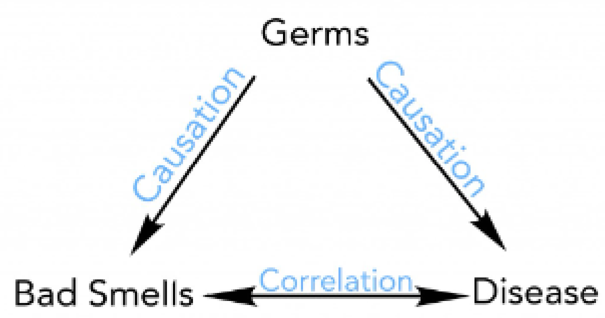
A multifactorial experiment involves a combination of more than one independent variable or combination of treatments.

Observational studies

Sometimes investigators may use groups that already exist, so there is no truly independent variable. In observational studies the independent variable is not directly controlled by the investigator, for ethical or logistical reasons.

Example of observational study:

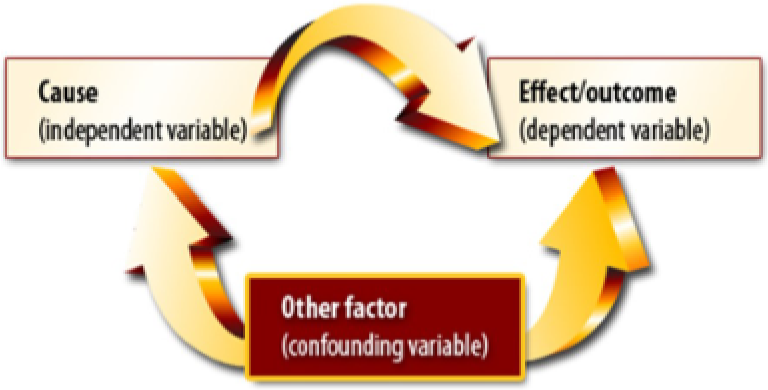
Observational studies are good at detecting correlation, but since they do not directly test a hypothesis, they are less useful for determining causation.



Confounding Variables

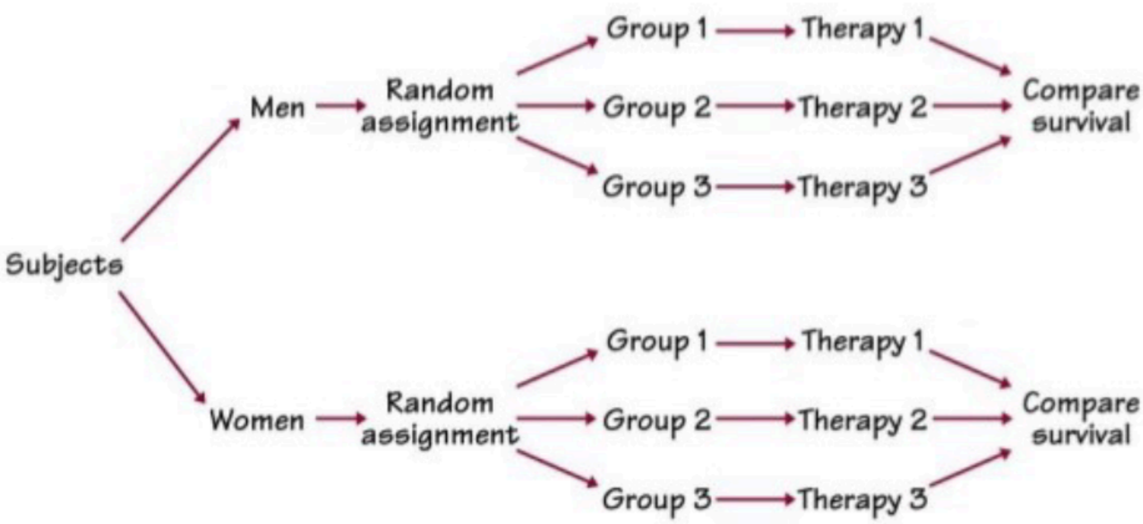
Due to the complexities of biological systems, other variables besides the independent variable may affect the dependent variable. These confounding variables must be held constant if possible, or at least monitored so that their effect on the results can be accounted for in the analysis.

Confounding variable:



Randomised block design

In cases where confounding variables cannot easily be controlled, a randomised block design could be used.



Randomised blocks of treatment and control groups can be distributed in such a way that the influence of any confounding variable is likely to be the same across the treatment and control groups.

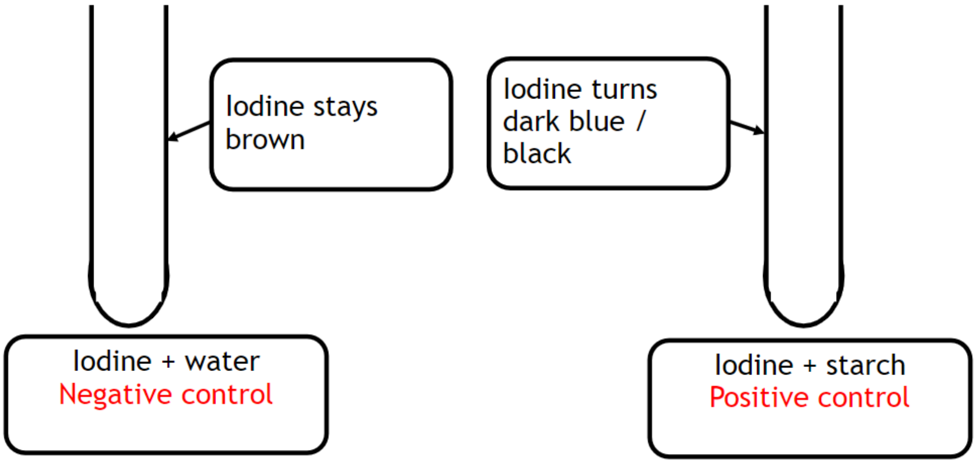
Controls

Controls:

Control results are used for comparison with the results of treatment groups. There are two categories of control that can be used.

Negative Controls:

Positive Controls:



Sometimes it is not possible to have a negative control e.g. the effect of pH. If this is the case then it should be justified.

In vivo and in vitro studies

In vivo:

In vitro:

Examples:

	Advantages	Disadvantages
In vitro		
In vivo		

Clinical trials using human subjects

Studies that investigate the effectiveness of new medicines or treatments for diseases are called clinical trials

In order to be sure that the observed improvements (in, for example, a medical condition) are due to the test medication and not another factor, trials must be carefully controlled.

Placebo

A type of negative control called a placebo can be given to a human control group on a clinical trial. Typically, groups of trial participants will be randomly assigned to either the test or placebo group.

Often neither the researcher nor the trial participant will know which group they are in until the end of the study. This is called a double-blind study design (a design used to eliminate bias).

Placebo effort

The placebo effect is a measurable change in the dependent variable because of a patient's expectations rather than changes in the independent variable.

In other words, use of a placebo accounts for psychological effects that trial participants may experience purely through the process of being treated.

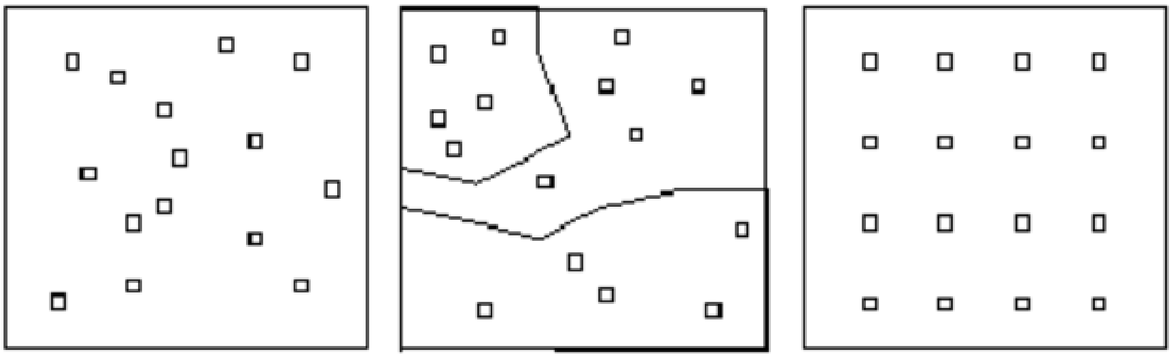
c) Sampling

Where it is impractical to measure every individual, a representative sample of the population is selected. The extent of the natural variation within a population determines the appropriate sample size that should be taken. More variable populations require a larger sample size. A representative sample should share the same mean and the same degree of variation about the mean as the population as a whole.

Random Sampling:

Systematic sampling:

Stratified sampling:



Sampling and population variation

All populations show natural variation.
More variable populations will require a larger sample size.
Less variable populations can be measured effectively with a small sample.

Representative sample:

d) Reliability

Reliability:

Variation in experimental results

Variation in experimental results may be due to the reliability of measurement methods and/or inherent variation in the specimens. Variation can be influenced by the precision and accuracy of the repeated measurements

Reliability and natural variation

The natural variation in the biological material being used can be determined by measuring a sample of individuals from the population. The mean of these repeated measurements will give an indication of the true value being measured.

The range of values is a measure of the extent of variation in the results.

- If there is a narrow range, then the variation is low.
- If the natural variation of biological material is high, a larger sample size is necessary to obtain a reliable mean value.

Selection bias

Selection bias:

Sometimes selection bias may have prevented a representative sample being selected. Also sample size may not be sufficient to decide without bias whether the change to the independent variable has caused an effect in the dependent variable.
Selection bias therefore affects validity and reliability.

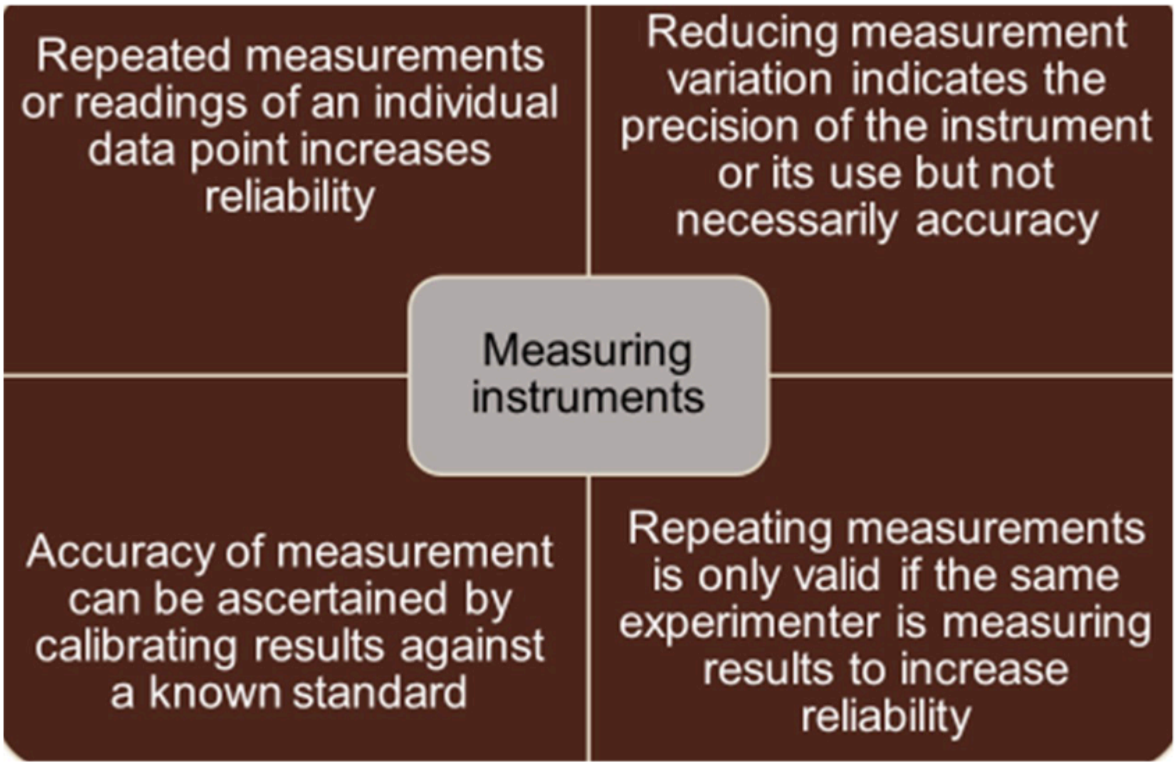
Inadequate sample size

Sample size may not be sufficient to decide without bias whether the change to the independent variable has caused an effect in the dependent variable.

Inadequate sample size means the sample may not be representative of the whole population. It therefore affects validity and reliability.

Reliability of measurement methods

The reliability of measuring instruments or procedures can be determined by repeated measurements or readings of an individual datum point. The variation observed indicates the precision of the measurement instrument or procedure but not necessarily its accuracy.



Reliability and sample size

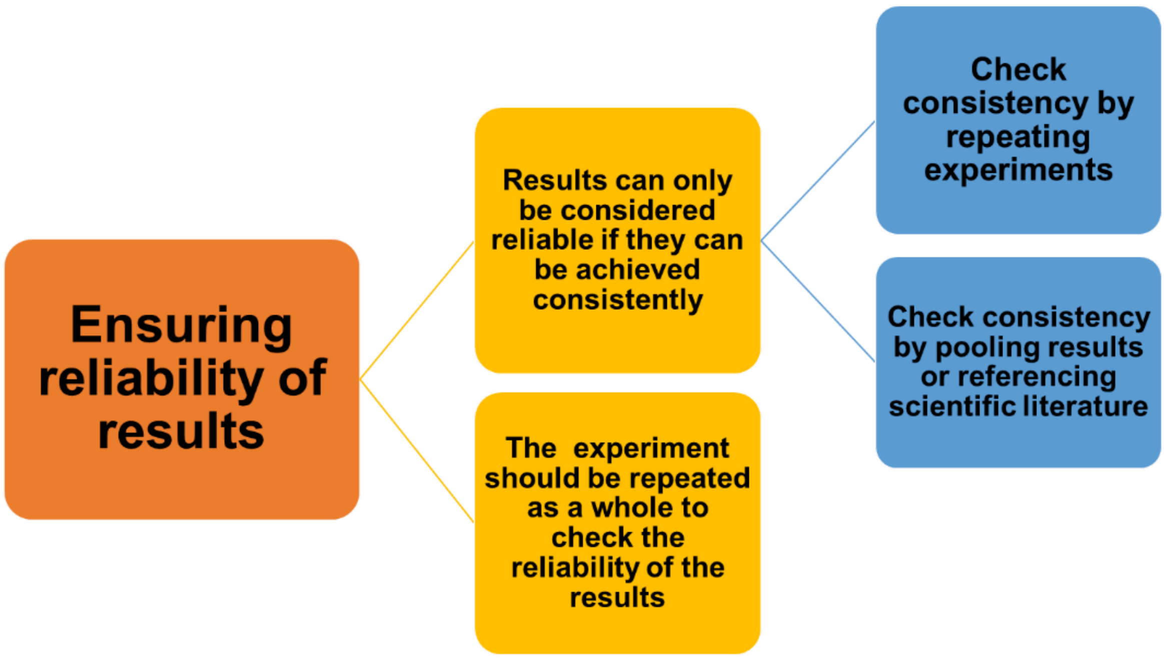
Measurement of individual data points should be repeated to indicate how reliable they are. These are called replicates.

Less reliable replicates:

Reliability and independent replication

Independent replication of the entire experiment (but using freshly prepared materials and on a different day) should be carried out to produce independent data sets.
The independent data sets can be compared to indicate consistency (and hence reliability) of results.

Results can only be considered reliable if they are achieved consistently.



e) Presentation of Data

Data Types

Discrete and continuous variables give rise to qualitative, quantitative, or ranked data.

Qualitative:

Quantitative:

Ranked:

The type of variable being investigated has consequences for any graphical display or statistical tests that may be used.

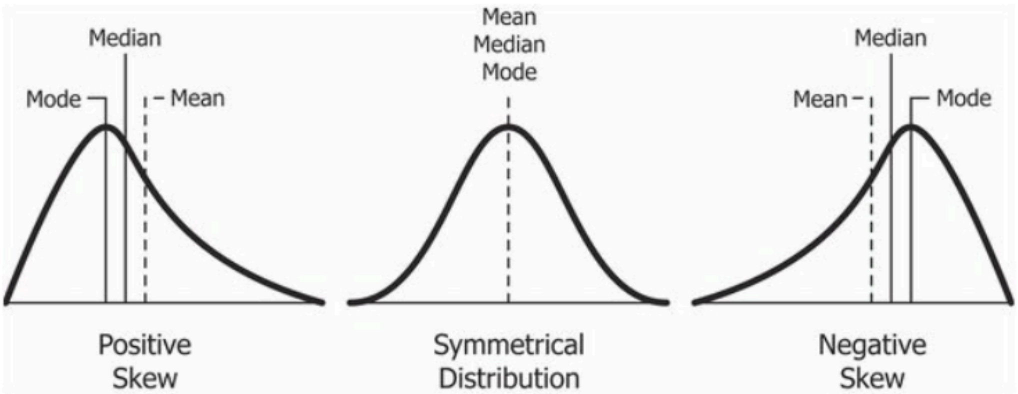
Variation in data and reliability

To get an idea of how varied your data are and therefore how reliable they are, data can be analysed.

Variation in data and range

The simplest way of telling how varied a data set is, is to work out the range. This is the largest value minus the smallest value. Range is generally not used when analysing data as it can be distorted by extreme values (outliers).

Numerical calculations when analysing data



Mean:

Median:

Mode:

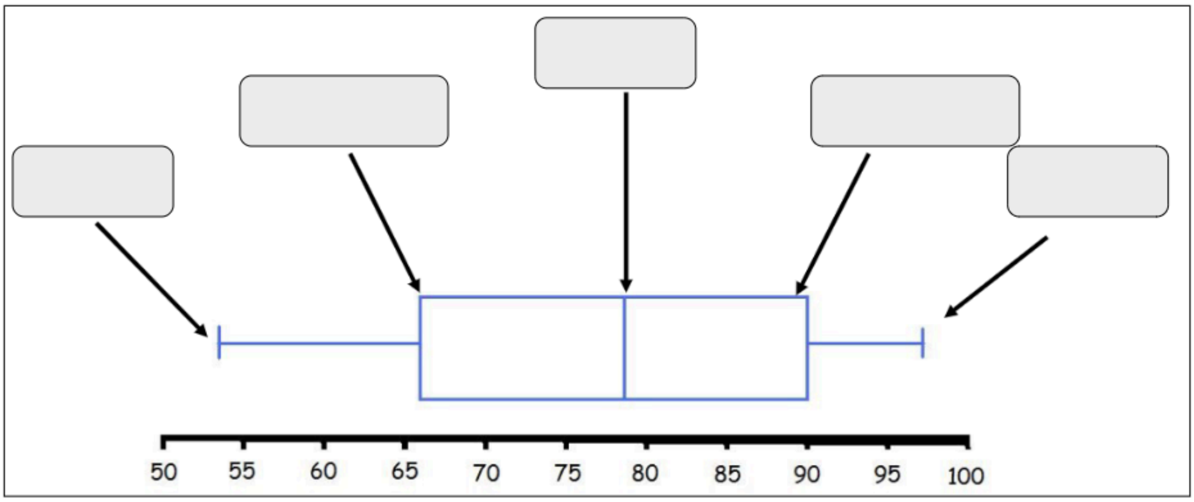
Variation about the median

Box plots (also called a box and whisker plot) can be used to show variation about the median:

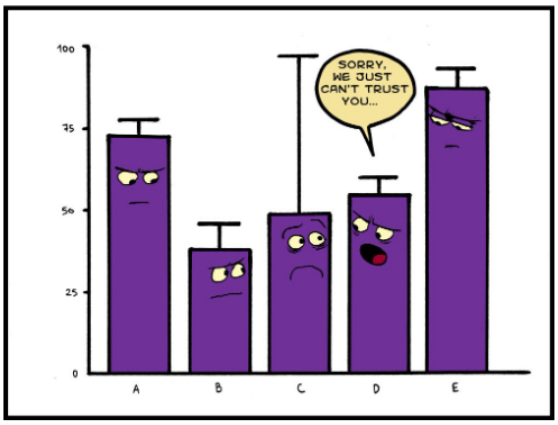
- ♦ within the same data set
- ♦ between different data sets.

Box plots and the five-number summary

A box plot displays the five-number summary of a set of data; this is the minimum, first quartile, median, third quartile, and maximum.



Interpreting graphical data



Variation and reliability

It can be useful to measure the variability:
1. Between individual replicates of a data set.

2. Between independent replicates of an experiment/study.

Measurement of variability within and between data sets can inform about reliability.

Standard deviation (SD) and variability about the mean of a data set

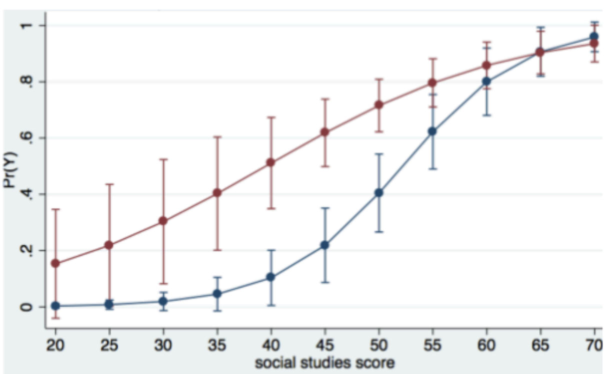
Standard deviation (SD) is one way of telling how much each measurement of a data set differs from the meant of the data set.

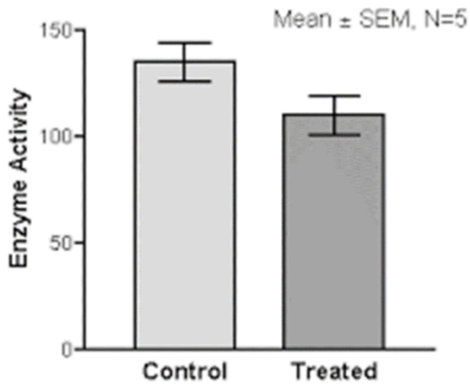
The greater the SD of a data set, the more variable the data (and the less reliable)

Other measures of variation about the mean (aside from SD) include:
- Standard Error of the Mean (SEM)
- Confidence Intervals (CIs)

Error bars

Error bars are used to represent measures of variation about the mean (e.g. SD) on a graph. Examples of line and bar graphs with error bars are shown below:





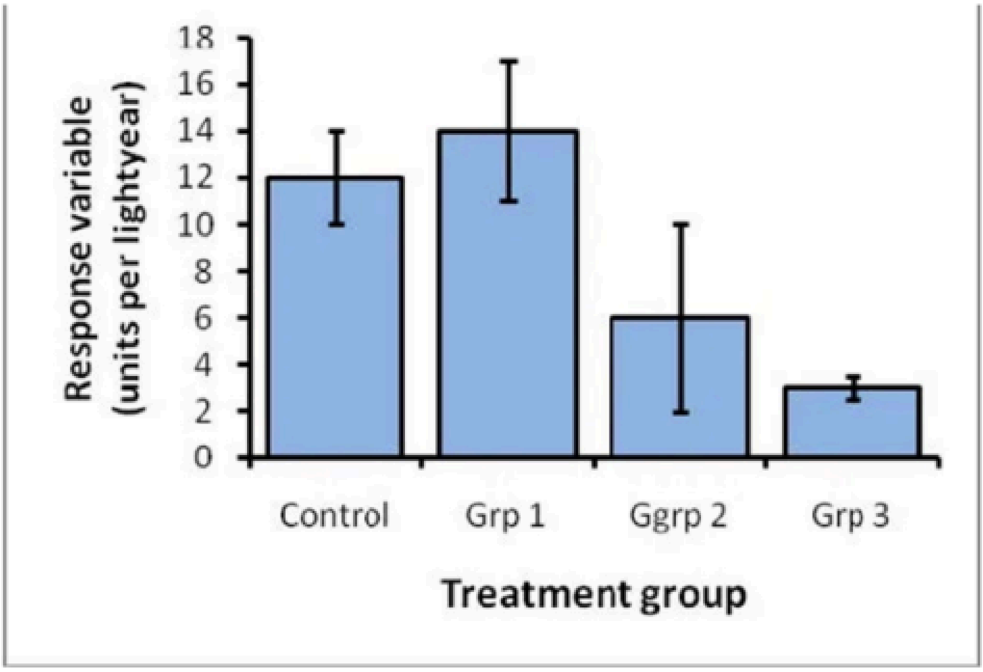
Error bars and variation

Smaller error bars means:

Larger error bars means:

Error bars and significant difference

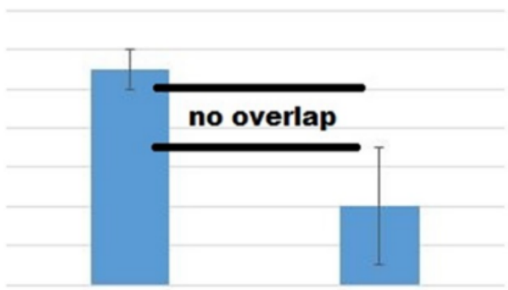
Often studies will involve several sets of data and looking to see if they are different. A typical scenario would be to compare treatment groups with a control group, as shown below:

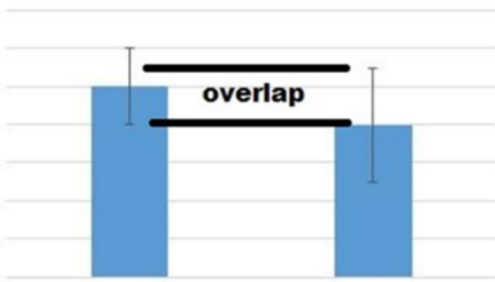


If there is a difference in means of the control and treatment groups, h**ow likely is it that this difference is due to chance alone?**

To answer this question, statistical tests are used to determine whether the differences between the means are likely or unlikely to have occurred by chance (you do not need to know specific statistical tests for the AH course).

Interpreting error bars can give an indication of whether or not a difference is more or less likely to be significant.





What does no overlap tell us about the difference in the data sets?

What does an overlap tell us about the difference in the data sets?

Significant difference means:

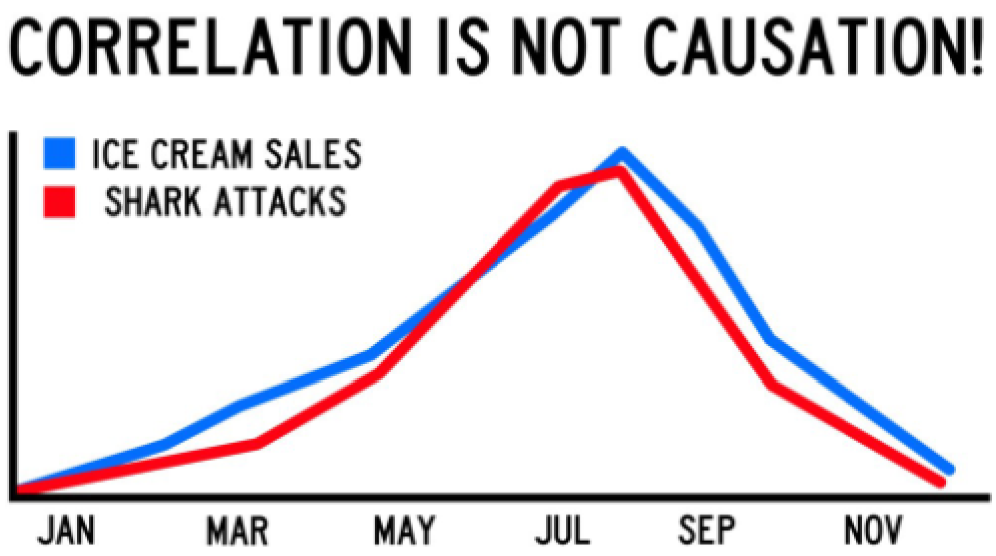
If the treatment mean differs from the control mean sufficiently for their error bars not to overlap, this indicates that the difference may be significant.

During data analysis, consideration should be given to the validity of outliers and anomalous results.

Correlation and causation

Correlation:

Causation:



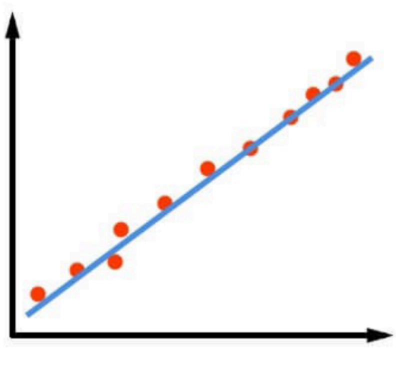
Both ice cream sales and shark attacks increase when the weather is hot and sunny, but they are not caused by each other (they are caused by good weather, with lots of people at the beach, both eating ice cream and having a swim in the sea)

Positive correlation:

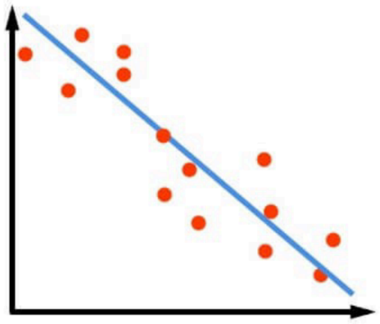
Negative correlation:

Strength of correlation

Strength of correlation is proportional to spread of values from line of best fit.



Describe the type and strength of correlation.



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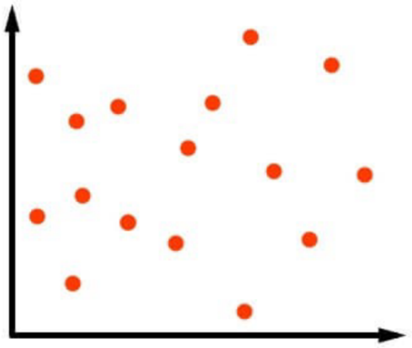

Describe the type and strength of correlation.

Reporting Biological Research

Scientific report should contain:

Title

Should provide a succinct explanation of the investigation and include the independent and dependent variables. It should also include the organism/system/molecule being studied.

Abstract

The abstract (or summary) outlines the main aims and findings of the investigation.

Aim

There will be at least one aim in an investigation, but often more. An aim must link the independent and dependent variables

Hypothes(es)

The introduction should include at least one hypothesis. This is a prediction for the outcome of the investigation if a certain theory were true. The hypothesis is the statement that the investigation is designed to test.

Underlying Biology

This section gives an introduction to the biology behind your project. Four main aspects should be considered when writing this sections.

- The biological terms/ideas should be explained clearly and accurately.
- Biological terms/ideas are at an appropriate depth. This means that for your project these should be at Advanced higher level or beyond.
- There should be enough information in this section to allow an appropriate level of analysis, interpretation, or discussion of results.
- The biological importance of the study should be justified. This should explain why the investigation is worth doing but does not have to justify it in terms of an immediate benefit to humans or to the environment.

The information in this section should be cited and the sources listed in the reference section.

b) Procedures

A method section should contain sufficient information to allow another investigator to repeat the work. The experimental design should address the intended aim and test the hypothesis. It should allow the treatment effects to be compared to controls.
The validity of an experiment may be compromised when factors other than the independent variable influence the value of the dependent variable. The validity and reliability of the experimental design should be evaluated. An experimental design that does not address the intended aim or test the hypothesis is invalid.

Any confounding variables should be considered or standardised across the treatments.

An appropriate sample size should be used and there should also be an independent replicate carried out. This is when the whole experiment is repeated with new resources when possible.

Within the method it is important to justify how a pilot study influenced the procedures.

c) Results

Once raw data is collected it should be presented in your report. The independent replicate results should be presented separately and then an average of the data sets should be calculated. Interpretation is then required which may include (as appropriate) graphs, mean, median, mode, standard deviation and range. The data should be presented in a clear, logical manner suitable for analysis.

d) Evaluating results and conclusions

The final section of a scientific report is evaluation of the results and conclusions.

Conclusions should always refer to the aim, the results and the hypothesis.

The validity and reliability of the experimental design should be taken into account and discussed. Consideration should be given as to whether the results can be attributed to simply correlation or causation.

Evaluation of conclusions should also refer to existing knowledge and the results of other investigations.

Scientific writing should reveal an awareness of the contribution of scientific research to increasing scientific knowledge and to the social, economic and industrial life of the community.

References

A reference list should be included providing the full references for the citations that have been given in the report. There are two main ways you can cite and reference in your project — the Harvard and the Vancouver method. You will be provided with more information on how to reference individual sources in your candidate guide when writing up your project.

More information on writing up your project is available in the project candidate guide.