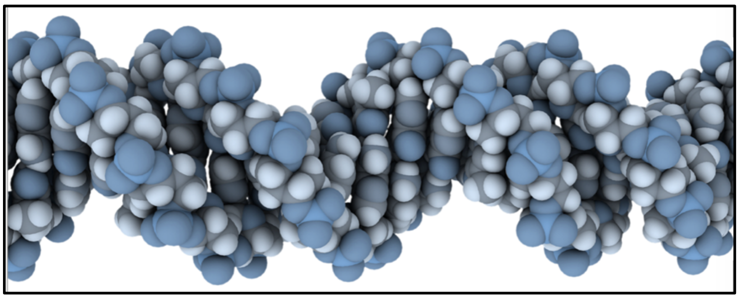
SWINBURNE
SENIOR SECONDARY COLLEGE

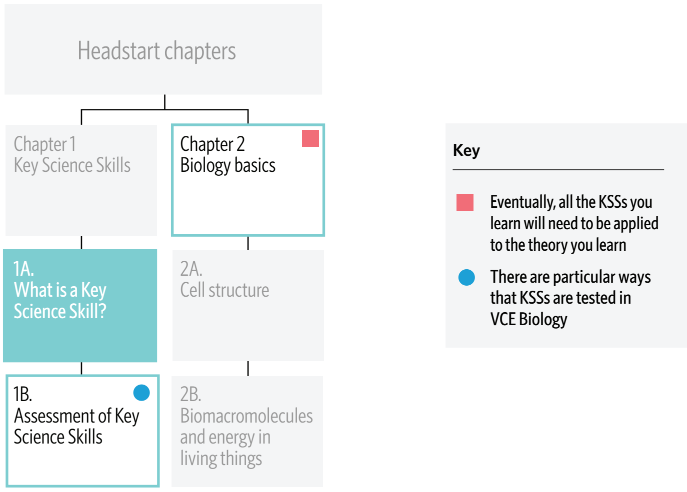
Unit 3 Biology
HOLIDAY HOMEWORK
2020



Teacher(s)/ Subject Coordinator:	Jory Clark clark.jory@sssc.vic.edu.au
Work required in preparation for start of 2020:	1. **EDROLO:** Sign on via school website / student resources. 2. Complete the first 3 Chapters from Unit 3: Area of Study 1 in online & in workbook. 3. Join our Unit 3 Biology Google Classroom. Follow invitation from your Swinburne Email or join using **CODE: z3t759** 4. Use the resources and links in Classroom to help complete the workbook questions. 5. Preview the resources and videos available for topics in Unit 3.
Textbooks and other resources:	• **EDROLO TEXTBOOK**: Biology for VCE Units 3 & 4 Student Workbook is still being finalised. Available end of January 2020. • **Biol Notes**: Units 3 & 4 (A+ publishing) Very useful for exam prep • ATAR Notes: http://www.atarnotes.com/
Key Links:	• WEHI: Molecular Machinery and Animations: https://www.youtube.com/channel/UCdBrXvlJn60zgpIQcZ0Fe7w • Protein Data Base 101: https://pdb101.rcsb.org/
Due date:	**Edrolo Workbook Chapters 1 & Edrolo ONLINE Tutorial completed by; Friday, 7th February 2020**

1A WHAT IS A KEY SCIENCE SKILL?

Experiment. Fail. Learn. Repeat.



In this lesson you will learn what Key Science Skills (KSSs) are and how to design a valid, ethical, and safe experiment.

Study design dot points

- independent, dependent, and controlled variables
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including laboratory work (biochemistry, cytology, immunology) and/or fieldwork (geomorphology); precision, accuracy, reliability, and validity of data; and minimisation of experimental bias
- ethics and issues of research including identification and application of relevant health, safety, and bioethical guidelines
- methods of organising, analysing and evaluating primary data to identify patterns and relationships including sources of error and limitations of data and methodologies
- models, theories, and classification keys, and their use in organising and explaining observed phenomena and biological concepts including their limitations
- the nature of evidence that supports or refutes a hypothesis, model, or theory

Key knowledge units

Science and Key Science Skills	4.3.1
What does a 'good' experiment look like?	4.3.2
Ethics and safety in science	4.3.3

Science and Key Science Skills 4.3.1

OVERVIEW

Science uses the scientific method to test hypotheses and explain observations. Use of Key Science Skills ensures that your tests are scientific (reproducible, repeatable, and valid).

THEORY DETAILS

Biology is a science, but what on Earth is science? Science is both a body of knowledge and the process of acquiring new knowledge through the scientific method. Put simply, the scientific method involves gaining knowledge through observation or testing. If knowledge is gained, but not through observation or testing, the new knowledge is not considered scientific. Figure 1 outlines the scientific method in more detail.

What has this got to do with your VCE Biology SACs and exams? Well, every time you use the scientific method - to research theories, to design an experiment, or to analyse and present data - you demonstrate KSSs. The KSSs tested in VCE Biology are outlined on pages 10 and 11 of the VCE Biology Study Design and summarised in Table 1.

Tip Previous exams have not tested the steps in the scientific method, but they may be assessed in your SACs.

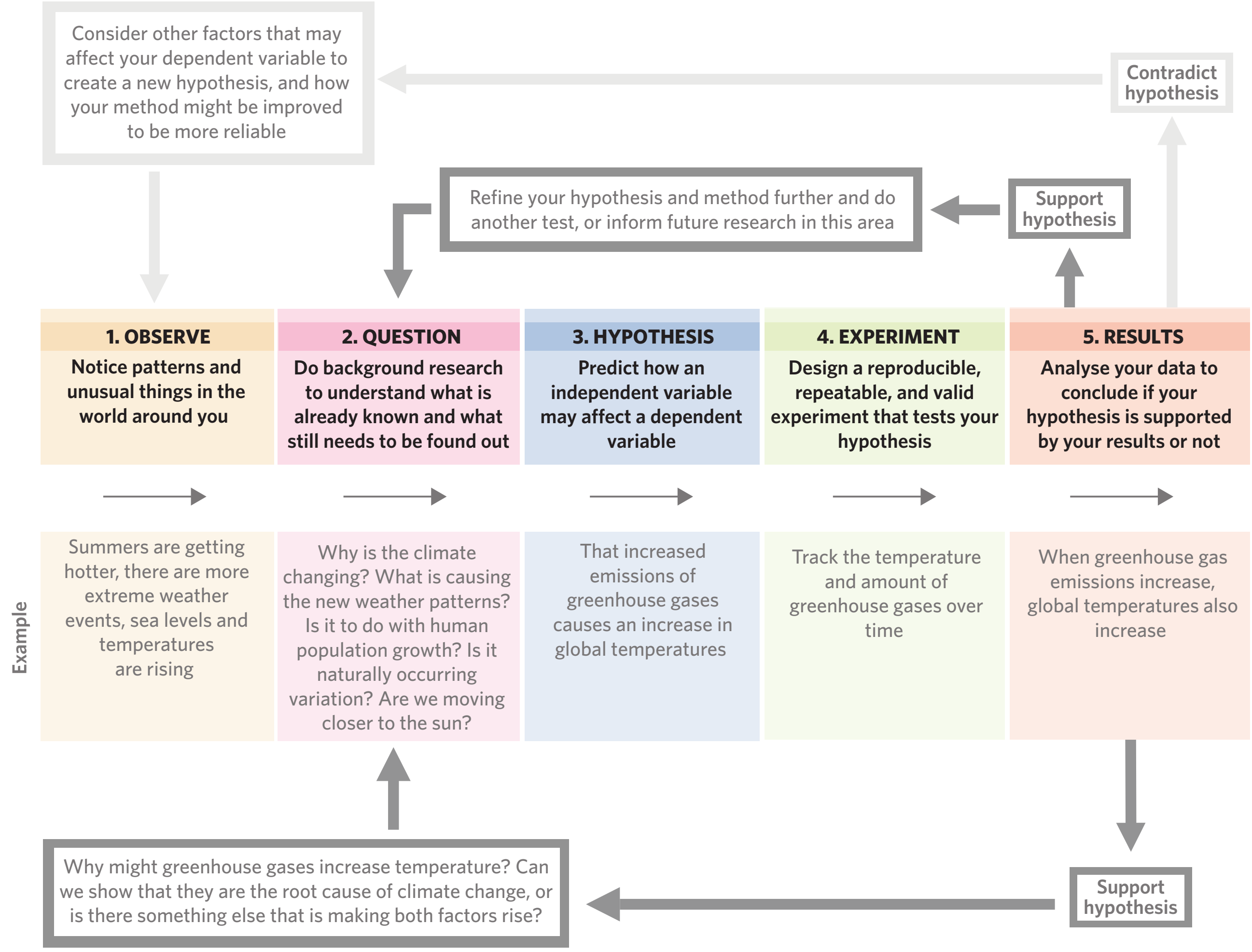


Figure 1 The scientific method

Table 1 The KSSs tested in VCE Biology and examples of how you might demonstrate that skill when testing a new drug

KSS	Example - testing new medicines
Develop aims and questions, formulate hypotheses, and identify variables	*Question:* Does a new drug help fight the flu? *Aim:* To determine if a new drug reduces the symptoms of the flu. *Variables:* the **IV** is the treatment with the drug, the **DV** is the presence of flu symptoms. *Hypothesis:* That individuals given the drug will have less flu symptoms than individuals not given the drug.
Plan and undertake investigations, including using controls and **replicates**	Get a large sample (e.g. 40) of mice. Infect all the mice with the flu virus. Ensure the mice are kept in the same conditions. Give half the mice the new drug. Give the other half of the mice a **placebo**, ensuring that both groups are handled in the same manner. Measure the occurrence of flu symptoms in each group over the following days and weeks.
Comply with safety and ethical guidelines	Ethicists recommend testing new drugs on cell cultures and animals before humans. If tested on animals, the experiment should stop if side effects of the new drug cause great discomfort. In addition, if the drug is effective, the impact of not giving it to the control group should be considered. In terms of safety, the scientists developing the drug should ensure they wear appropriate protective gear and use well-maintained equipment.
Conduct investigations to collect and record **qualitative** and **quantitative** data	Every day, the scientists should: • count any mortalities • record the number of sneezes over five minutes in each mouse • measure the body temperature of each mouse • take blood samples from each mouse, and determine the number of immune cells and inflammatory markers in a sample. Because there are 20 individuals in each group, they can take an average of each group to get a more **precise** result.

independent variable (IV) the factor(s) that is manipulated in an experiment

dependent variable (DV) the factor(s) changed by the manipulation of the IV

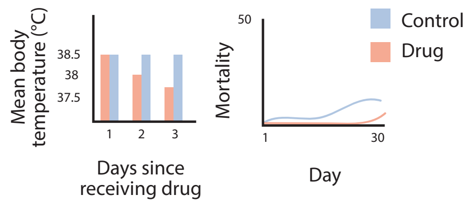
placebo a substance that has no therapeutic benefit or side effects and can be used as a control when testing new drugs

replicate multiple experimental runs exposed to the same level of the IV

qualitative data non-numerical data, typically collected through observations and interviews. Also known as categorical data

quantitative data numerical data that expresses an amount or range of values

precise two or more measurements that closely agree with each other

Analyse and evaluate data, methods, and scientific models. This includes: • Interpreting ratios, percentages, and means • Explaining the effect of replication and sample size on reliability • Analysing accuracy, precision, reliability, validity, **uncertainty**, **bias**, and **errors** of results • Suggesting improvements and limitations of experiments	 Data like those above may be presented in the results. Limitations that could be discussed include: • testing nasal or throat swabs for the presence of the flu virus may increase the **accuracy** of results • using common tests like the rapid flu diagnostic test could improve the application of results to new contexts • mice sneezing may be caused by other factors, such as allergens. This could be an invalid method to measure the impact of the IV. • there could have been problems sampling the mice, keeping conditions constant, or other issues with the method • there may be different results if the drug is tested on humans • a larger sample size would increase the replication, precision, and reliability of the results. Strengths that could be discussed include: • the experiment proceeds ***in vivo*** rather than ***in vitro***, so it may provide more contextually relevant results • multiple methods of measuring flu symptoms are used, so if the results agree across methods, they are likely very reliable • the scientists do not use measurements that may be subject to bias, like 'how sick the mouse looks'.
Draw evidence-based conclusions	*Drawing conclusions:* report what your data shows, not what you had expected to see. This is one of the reasons why a hypothesis is important! You can show what you used to think, and how evidence (may have) changed your position. *Implications:* if the drug is effective, what are the biological, social, economic, and ethical implications? Does the use of this drug challenge any other research, media opinions, or certain community beliefs? If there are minor side effects or risks involved, how can scientists communicate these clearly and honestly to pharmacists and patients?
Communicate and explain scientific ideas by using biological terminology and clear, concise language	The scientists could achieve this by: • Using topic sentences for paragraphs and subheadings for sections in their report • Writing short, direct sentences • Using terms such as 'firstly', 'secondly' to signpost ideas • Using terms such as 'in contrast to' or 'as opposed to' to compare ideas • Including a reference list and acknowledgements section.

Luckily for you, the standard structure of experiments and laboratory reports (aim, **hypothesis**, etc.) makes you practice the scientific method and demonstrate many of the KSSs. If you don't understand some of the terms in Table 1, don't worry - we are going to dive in and look at why things like controls, accuracy, and replication make experiments reliable in the next section.

Tip VCAA suggest using the following template to write hypotheses – simply insert your DV, IV, and appropriate changes in the right spots!

Template:

If the [DV] is affected by the [IV], then [effect on the DV] when [change in IV].

We can use this template to write a new hypothesis for the influenza drug experiment from Table 1:

If the presence of flu symptoms is affected by the treatment with the drug, then mice will show fewer flu symptoms when they are given the drug.

VCAA emphasise that different writing styles for hypotheses can be equally valid, but it is important to include the direction of change in the DV and IV (by saying 'more', 'increase', 'smaller' etc.). Some hypotheses also include reasons for the prediction.

accurate a measurement that is close to the 'true' value of the quantity being measured

uncertainty a quantification of the error associated with a measurement, often represented by the symbol '±' after a reading

experimenter bias the inclination for scientists conducting research to alter their results based on their prior beliefs, for example by selecting an unrepresentative sample or by recording the results they expect to see

error the difference between the measured value and the true value of what is being measured

personal error mistakes or miscalculations due to human fault. Can be eliminated by performing the experiment again correctly

random error variation in results caused by uncontrollable conditions between replicates in the measuring process, resulting in a less precise spread of readings. Can be reduced using more replicates or refining the measurement process

systematic error faults that cause measurements to differ from the true value by a consistent amount each time a measurement is made, resulting in a less accurate result. Can be reduced by calibrating and maintaining instruments

in vitro processes or experiments performed outside a living organism (e.g. in a culture dish, test tube)

in vivo processes or experiments performed in the body

hypothesis a testable statement that describes how experimenters expect the dependent variable to change as the independent variable changes

What does a 'good' experiment look like? 4.3.2

OVERVIEW

Good experimental design should include a dependent variable (DV) and an independent variable (IV); a control group; a hypothesis; replication of groups; attempts to minimise bias, error, and confounding factors; a large and representative sample; accurate and precise data collection; and clear communication. Your experiment must also be ethical, safe, and the data needs to be presented clearly.

THEORY DETAILS

One of the beautiful things about science is that things that are 'true' one day can be disproven the next. Scientists draw the most reasonable conclusions based on the evidence available at the time. If evidence to the contrary arises, what is 'true' can also change. However, we cannot shift paradigms unless we can trust the results of an experiment. To trust results, the experiment must be designed to be **reproducible**, **repeatable**, and **valid**. These characteristics ensure that any conclusions drawn are 'evidence-based', **reliable**, and meaningful.

How do I design a good experiment?

There are a number of things you can do to ensure you are designing a strong experiment that will produce meaningful results that are reproducible, repeatable, and valid.

representative sample the subset of a population (e.g. of bacteria, tomato plants, yeast) that takes part in the experiment and accurately reflects the characteristics of the larger group

reproducible an experiment/measurement in which a group of scientists, using the original methods designed by others, can obtain the same results as another group's experiment

repeatable an experiment/measurement in which scientists, using the methods they designed, can obtain the same result multiple times

valid a measurement or experiment that actually tests what it claims to be evaluating

reliable describes a measurement, tool, or experiment that produces similar results when repeated and reproduced, and therefore can be trusted

In science, I must make sure my experiment is:

Reproducible	Repeatable	Valid
Different scientists can get the same results when they follow the same method as the original scientists	The same scientists can get the same results when they replicate the experiment	The experiment measures what it claims to be measuring

I can ensure this by designing an experiment that:

1. tests the effect of an **independent variable(s)** on one **dependent variable**

The IV is the thing you control or change. The DV is the thing you measure. You want to test if/how your IV affects your DV. Both of these should be mentioned in your **hypothesis**, which should predict how the IV influences the DV.

The groups that have the IV applied to them are known as the 'treatment' or 'experimental' groups

2. has a **'control'** treatment

Positive control: apply a treatment that is known to produce a positive response in the DV.

Negative control: apply a treatment that is known to produce no effect on the DV (e.g. remove the IV).

This is a treatment where the IV is not applied to the DV.

The results from control groups are compared to experimental groups, and any difference between the groups is attributed to the IV.

3. has **replicates** of each treatment group and control group

Replication means you have multiple groups under the same conditions. This means that your results are not outliers or due to random error, and you can take the average of your replicates for each treatment group. If your experiment is well-designed, the values for different replicates of the same treatment should be similar. If they are similar, this tells you that your measurements are **precise**.

4. minimises potential for **uncontrolled** variables and sources of error

Personal errors are mistakes or miscalculations. They can be eliminated by doing the experiment again. **Systematic errors** cause readings to differ by a consistent amount from the true value each time. For example, when an instrument is not calibrated correctly. They affect the **accuracy** of the experiment. Replication does not reduce the impact of systematic errors. **Random errors** are unpredictable variations in the measurement process that result in a spread of readings. For example, when a quantity is estimated by reading between lines on a measuring instrument. They affect the **precision** of the experiment. You can reduce random errors with increased replication or by refining the measurement process.

Uncontrolled factors are potential variables besides the IV that may affect your results. You should remove them or control them by keeping them constant. At the very least, you should measure them so you know how they change. If one is likely to influence your results, it is a **confounding** factor.

5. collects data that is **reliable**

To collect reliable data: Get a large, unbiased sample
- Be **accurate**
- Be **precise**

Minimise **uncertainty** in measurements

To minimise uncertainty, you need to ensure the tool you are using to measure is appropriate. For example, don't use a 100 mL beaker to measure 5 mL of liquid.

An accurate measurement is one that is close to what is considered to be the 'true' value. An experiment can be made 'more accurate' by reducing measurement/systematic error (e.g. by using more sophisticated instruments). Precision refers to how closely two or more measurements are to each other. Precision can be increased by having a larger sample size and using appropriately graduated instruments.

6. minimises potential for **uncontrolled** variables and sources of error

This means you need to present data in a meaningful way, give a clear method section so your work can be reproduced, and consider safety and ethical factors.

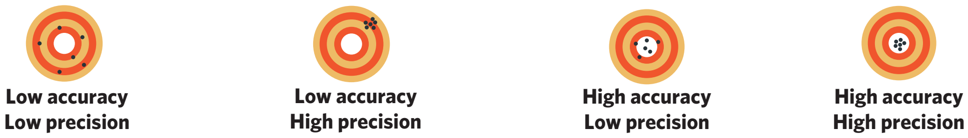


Figure 3 Accurate results are close to the true value whereas precise results have very little spread around the mean value.

You can think of the characteristics of a good experiment as a checklist (RICCHER).

- Replication
- Independent variable/dependent variable
- Control
- Clear communication
- Hypothesis
- Errors minimised
- Reliable data.

If you read about an experiment that is overlooking one or more of these factors (RICCHER), you need to decide if you can still trust the results presented. Read through the annotated excerpt from a student's log book. Have they included all these parts of the experiment? Can you trust their results?

This student hasn't communicated very clearly here: in the methods they state much more specific locations.

The IV (the thing you are changing) is the location sampled. The DV (the thing you are measuring) is the amount of bacteria.

Bacteria in the house

Introduction

The aim of this experiment was to determine the relative amounts of bacteria in different household areas. In particular, the amount of bacterial growth on plates from swabs in the toilet, kitchen bench, shower, couch, and bedroom were compared. The hypothesis was that the toilet seat would have the most bacteria, and that the couch would have the least.

Method

1. Eighteen Petri dishes with nutrient agar jelly were prepared using standard techniques. The lids on the Petri dishes were kept on as much as possible to prevent possible contamination.
2. A cotton bud was moistened with distilled water, then wiped across the toilet seat. The swab was pressed into the nutrient agar on one plate for five seconds, then removed. The Petri dish was covered quickly with its lid to minimise time exposed to air. This was repeated twice more.
3. Step 2 was repeated with the kitchen bench, shower curtain, couch seat, and mattress. For the final three Petri dishes, the moistened cotton ball was pressed to the surface of the nutrient agar for five seconds without swabbing any surface.
4. All dishes were labelled clearly, then incubated at 25°C for three days.
5. After incubation, the number of bacterial colonies on each Petri dish were counted, and the diameter of colonies was measured. The results were averaged across replicates.

Results

	Number of colonies					
Replicate #	Toilet	Mattress	Couch	Kitchen bench	Shower curtain	Control
1	15	15	14	3	22	3
2	12	14	8	5	28	2
3	10	15	2	6	28	2
Mean	12.3	14.7	8.0	4.7	26.0	2.3

They state their hypothesis, which includes the IV, DV, and direction of change!

The treatment groups have been replicated three times - this means the experimenters will know if their results are precise, and reduce the likelihood of outliers affecting their results.

The student has included a control treatment, where the independent variable is not applied! If no/little growth occurs on the control plates, they can be sure any effect they observe is due to the IV (location sampled).

Some factors that may affect the results have been minimised - they state how they try to prevent contamination by keeping lids on the Petri dishes.

Are there any other potential sources of error or confounding variables? E.g. the pressure they apply to the cotton swab? Is the same person taking the samples each time (different people may do it differently)? They should have considered these things before beginning the experiment, and will hopefully bring it up in the discussion.

How was diameter measured? Colonies are very small so a very precise ruler would be required. Also, the results for diameter are not presented, which causes us to question the reliability and integrity of the experimenter.

Given the experiment wanted to measure the 'amount' of bacteria in certain household locations, the students need to consider if counting the number of colonies is a valid way to measure 'amount'. It is possible that measuring the number of different types of bacteria would provide more valid results. This would need to be considered in the discussion.

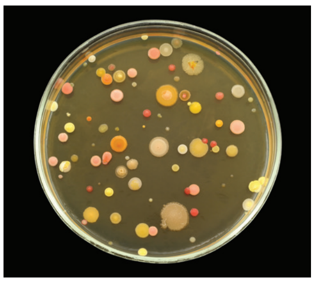


Image: Satirus/Shutterstock.com

Figure 4 The students may have seen something like this growing on their Petri dishes in the annotated experiment 'Bacteria in the house'.

You can see from the annotations of the log book excerpt that there are many strengths to the experimental design (green): they include a negative control, an IV and DV, some consideration of potential error, and replication. However, there are also lots of potential improvements to be made (red). This doesn't mean the experiment is useless, but it is important that any limitations are clearly communicated in the discussion.

Case study

Shifting paradigms in Biology

Biological models and theories change when more evidence is gathered. Some key changes include:

- *Evolutionary theory.* Scientists used to accept the biblical doctrine that all living things had been the same since creation. Then, Charles Darwin presented evidence that species like the Galápagos finches could change over time, and that new species could arise from older ones. Evolution by natural selection is now the dominant theory of how living things change over time.
- *Gene transfer.* Scientists used to assert that genes could only be passed down from parents. But in the 20th Century biologists discovered that bacteria could transfer genes horizontally between individuals, like swapping clothes. The fields of evolution and phylogenetics are still trying to include, understand, and adapt to this new understanding of genetic transmission.
- *Taxonomies.* The classification of species changes as new technologies improve our understanding of how organisms are related. For example, all 12 000 species of grass (from bamboo to spinifex) used to be classified into one genus, *Poa*. Now, there are 771 genera.

Control groups and experimental groups

Some terms can get confusing when discussing experimental design. Note that a '**control group**' is also often referred to as the 'experimental control' or simply as the 'control'. This is the group to which no IV is applied. The opposite of a control group is an **experimental group** (often referred to as a treatment group). For example, if you measured the impact of fertilizer levels (IV) on tomato plant growth (DV), a control group would be a group of plants that are not fertilized at all (but are otherwise exposed to the same conditions as the experimental groups). Different experimental groups might be the 'low fertilizer' group and the 'high fertilizer' group.

lesson link In ***lesson 14C***, you will learn about how scientists are constantly changing their explanation of how *Homo sapiens* (humans) evolved as new fossil and DNA evidence is discovered.

Case study

The placebo as a control treatment

Placebos are often used in control groups, especially when testing medicines. They are typically pills that look identical to the treatment drug, but have no active ingredients and do not result in therapeutic benefit. This means that the participants do not know if they are part of the experiment group or the control group. In such studies, we often note an improvement in patients treated with the placebo. This improvement is known as the 'placebo effect' and is due to the psychological beliefs of the person (i.e. if you believe you are going to get better, you will probably get better).

control group a group of individuals/samples that are not exposed to the independent variable. Also known as an **experimental control**, **control treatment**, or **'the control'**

experimental group a group of individuals/samples in which the independent variable is manipulated. Also known as the **treatment group**

confounding variable an uncontrolled variable that affects the validity of the results

Types of control groups

There are two types of control groups: positive controls and negative controls. Negative controls are the most common. They are groups to which the IV is not applied. Negative controls are not expected to produce results. If they do, we know that something other than the IV (**a confounding factor**) may be causing the change in the DV and our experiment is flawed. Positive controls are groups where you expect to see results. Scientists apply a treatment which induces a well-understood effect on the DV, so they can see if the effect of the IV is comparable.

Imagine an experiment testing the effect of a new pesticide on crop yield. A negative control group would be a field not exposed to the pesticide. A positive control group would be a field exposed to an already-existing pesticide that is known to be effective at protecting crops from pests. The experimental group would be the field exposed to the new pesticide.

Controlled and uncontrolled variables

A '**controlled variable**' (also known as a 'constant variable') is a factor that remains the same throughout the experiment in an effort to reduce the chance of other factors (besides the IV) influencing the DV. For example, when testing the impact of fertilizer levels (IV) on tomato plant growth (DV), you would want to make sure that each group of plants with different fertilizer levels were exposed to the same level of sunlight, water, and wind. If they weren't constant, these factors would be **uncontrolled variables** that could potentially confound the results, making the experiment inaccurate and invalid (Figure 5).

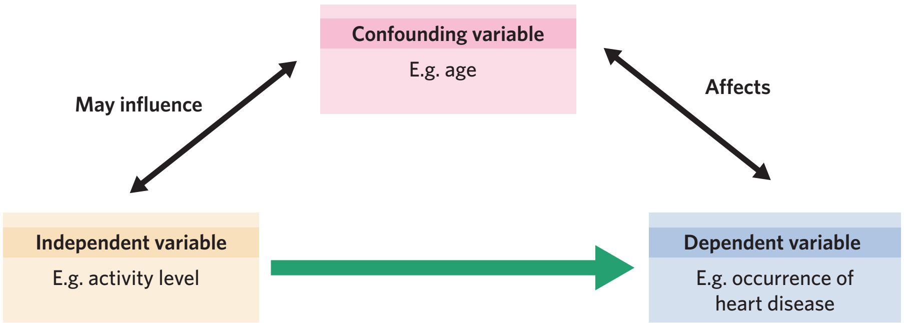
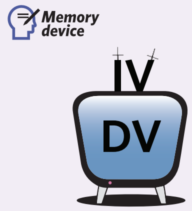


Figure 5 In this experiment scientists are interested in determining if activity levels directly impact a person's likelihood of developing heart disease. Age is another variable in this experiment, however, since it can influence a person's activity level (old people exercise less) and a person's likelihood of developing heart disease (older people are more likely to develop heart disease). If it is not controlled for (by only including people of a similar age in the experiment) it will serve as a confounding variable, making it difficult to determine if exercise alone has an impact on heart disease.



Remember the IV-DV-TV! Old TVs had antennae on top of them. When you moved the antennae, it affected what you saw on the screen. In this way, the antenna is the thing you manipulate (the IV) and the image is the thing you watch/measure (the DV).

controlled variable a factor that is kept constant throughout the experiment. Also known as a **constant variable**

uncontrolled variable a factor that is not kept constant or accounted for throughout the experiment. Also known as an **extraneous variable**

Ethics and safety in science 4.3.3

OVERVIEW

The ethical principles of integrity, justice, beneficence, and respect can help you decide if an experiment is ethically designed. Risk assessments are important parts of preparing a safe experiment, especially in a laboratory environment where lots of people could be impacted by unsafe practices.

THEORY DETAILS

Ethical principles

Experiments must be ethical. This sounds obvious, but you'd be surprised by the number of horrible tests undertaken throughout history in the name of science. Ethical conduct is valued so highly in modern day science that at universities, experimental procedures must be presented to an ethics board before being permitted to proceed. Ethics boards also require scientists to consider the potential consequences of any discoveries for individuals or communities. For VCE Biology, you should be able to analyse an experiment and consider if the experimenters have developed an ethically-sound method. To do this, you can consider the experiment through the lens of four ethical principles (Table 2).

Table 2 How to use the principles of integrity, justice, beneficence, and respect to analyse if an experiment is ethical

Ethical principle	Questions to ask
Integrity	Has this research been reported honestly? Are all sources of information referenced?
Justice	Have all points of view been considered? Is there equal access to and fair distribution of any benefits that have arisen from this research?
Beneficence	Has harm to living things been minimised? For example, if living things are kept in captivity, is their welfare secured? Are there long-term impacts on the health of participants?
Respect	Has this research considered the welfare, beliefs, perceptions, customs, and cultural heritage of those involved in the experiment (e.g. participants, those affected by the results)? Have all participants given their fully-informed consent to be involved?

Case study

The cost of science

Medical progress saves lives, but at what cost? Here are two experiments that have breached ethical boundaries:

1. Researchers in the 1960s set out to determine if personality is determined by nature (our genes) or nurture (how we are brought up). To do this, scientists separated identical twins and triplets from each other, and adopted them out as singlets. One set of triplets ended up finding each other, and were devastated that they were 'robbed' of a life together. The findings of the study are currently withheld, and will not be released until 2066, making the scientific community question the integrity of the research. Furthermore, it did not gain consent from participants and the consequences on participant wellbeing were not considered.
2. The 'father of modern gynecology', J. Marion Sims, is renowned for his discoveries regarding vesico-vaginal fistulas (tears in the tissue between the vagina and bladder), but he gained all his knowledge from performing surgery on slaves without anaesthesia. It is unlikely his patients gave consent and the surgery would have been very painful, so this experiment breaches the ethical principles of respect and beneficence. Further, it is unjust that Sims took advantage of a vulnerable and powerless sub-section of the population.

We can try to analyse the student's experiment 'Bacteria in the house' according to these principles. For example, there may be some questions surrounding the integrity of the experiment, as the student said they were measuring the diameter of bacterial colonies but didn't present this data in their results. In addition, the principle of beneficence dictates that the welfare of living things is considered. Ethicists don't usually worry about harming non-animal life such as bacteria, but the scientists themselves could become infected. Stringent protection and disinfection procedures should be outlined in the methods and followed to prevent the spread of bacteria. Notably, this is something missing from the student's experiment.

If an experiment involved the participation of people from different cultural backgrounds, the ethical principles of justice and respect would be very important to apply. Researchers and ethicists would have to ask questions like: does the research undermine any cultural values? How could the results impact different communities? Do we have the right to investigate this? Can we consult with stakeholders? If any money is made from the products of this research, who should get paid?

There are not always 'right' or 'wrong' answers to these questions, but scientists must ask them to decide if it is ethical to proceed with an experiment. If some ethical dilemmas arise, it is sometimes possible to redesign the experiment to avoid the issue.

Safety

An experiment needs to be safe in order to be reproduced by other scientists. More simply, getting hurt sucks and can have big consequences for you, your class, and your teacher - whether it is a small cut from a microscope slide or something more serious.

It is likely that, during Year 11 and 12, your teacher will ask you to take ownership of your own safety during an experiment by doing a risk assessment. This means more than simply 'not breaking anything' or 'not sticking your face in the beaker'. A risk assessment is a process where you consider all potential risks in the experiment according to your context, and identify ways to minimise risks (Table 3).

Table 3 Examples of factors that could be identified as possible risks, contextual factors, and strategies to minimise risk in a biological risk assessment

Aspect of risk assessment	Examples
Possible risks	• Sharp objects • Flammable materials • Hazardous chemicals • Open flames • Culturing of microorganisms. *cont'd*

Contextual factors	• The experience of staff and students with procedures • The behaviour of the class • Allergies of the class • Facilities available.
Strategies to minimise risk	• Wearing gloves, safety glasses, lab coats, enclosed footwear, and other appropriate personal protective equipment (PPE) • Following procedures • Following instructions from the teacher or laboratory during spills, breaks, or other accidents • Tying long hair back • Understanding and following standard handling procedures and Safety Data Sheets (SDSs) for specific chemicals (available online or through your risk assessment software) • Conducting experiments in an aseptic environment • Conducting experiments in isolation • Sanitising benches, equipment, and hands after lab work.

aseptic surgically clean and free from contamination by microorganisms. Also known as **sterile**

You can undertake a risk assessment online (e.g. riskassess.com.au) or using a printed template provided by your school. The online risk assessments are great because they usually outline standard handling procedures for all equipment and SDSs for chemicals.

Theory summary

You'll use and be tested on KSSs a lot during Units 3 & 4 VCE Biology. Sound experimental design involves creating repeatable, reproducible, and valid methods. Experiments should include a control, hypothesis, replication, clear communication, an IV, a DV, and attempts to minimise error and generate reliable data. Experiments should not proceed if they are unethical or unsafe.

1A QUESTIONS

Theory review questions

Question 1

What are the key terms from the lesson that match the following definitions?

a ____________ a group to which the IV is applied
b ____________ a type of error that affects the accuracy of a measurement, where readings differ from the true value by a consistent amount each time
c ____________ a quality of an experiment that measures what it claims to be measuring
d ____________ describes measurements that are close to the true value
e ____________ a factor other than the IV that might affect the DV
f ____________ a measurement that differs greatly from other results
g ____________ a group to which the IV is not applied
h ____________ unpredictable variations in the measurement process cause this type of error
i ____________ a measurement that is close to previous measurements
j ____________ describes an experiment that generates the same results when it is undertaken by different scientists
k ____________ describes a test in which the same operator can produce the same results multiple times
l ____________ the variable that is measured during the experiment
m ____________ the variable that is manipulated during the experiment

Question 2

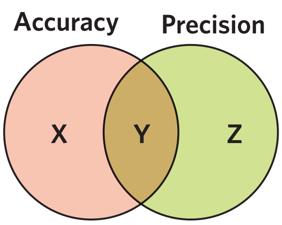
Which of the following options outlines all true statements about variables in experiments?

	Independent variable	Dependent variable	Controlled variable	Uncontrolled variable
A	Manipulated	Measured	A group in which the IV is not manipulated	A factor that might influence the results
B	Measured	Manipulated	Kept constant	Neither measured nor kept constant

C	Manipulated	Measured	Kept constant	Neither measured nor kept constant
D	Measured	Manipulated	Measured	Not measured but kept constant

Question 3

Which of the following options correctly describes X, Y, and Z?



	X	Y	Z
A	Measurements close to the 'true' value	Increases the number of replicates	Measurements that are close together
B	Measurements that are close together	Increases validity of results	Measurements close to the 'true' value
C	Measurements close to the 'true' value	Measurements that are close together	Removes uncertainty from experiments
D	Measurements close to the 'true' value	Increases reliability of results	Measurements that are close together

Question 4

Which of the following contain all true statements about control groups?

Control groups

A	are groups to which the IV is not applied.	don't need to be replicated because they are just a comparison.
B	are groups to which the IV is not applied.	should be replicated, as this will reduce the effect of outliers.
C	are groups to which the IV is applied.	should be replicated, as this will test the precision of measurement.
D	are groups to which a variable with a known, well-researched response is applied.	should be replicated, as this will make the experiment reproducible.

Question 5

Fill in the blanks in the following sentences.

_____I_____ errors decrease the precision of results. _____II_____ errors decrease the accuracy of results. One way to increase _____III_____ is to ensure all instruments are calibrated correctly. One way to increase _____IV_____ is to use appropriately sized measuring equipment.

	I	II	III	IV
A	Systematic	Random	precision	accuracy
B	Random	Systematic	precision	accuracy
C	Systematic	Random	accuracy	precision
D	Random	Systematic	accuracy	precision

Question 6

Which of the following statements is false?

A Confounding factors affect the validity of the test.

B Confounding factors may influence the dependent variable.

C Uncontrolled factors should not be mentioned in the discussion of a report.

D If an uncontrolled factor is measured or kept constant, it becomes a controlled factor.

Question 7

Identify the ethical principle(s) to which the following statements most clearly relate to.

NOTE: statements can be classified into multiple groups.

I A new drug is designed that can save lives, but it is too expensive for people without private health insurance to buy.

II One person in your group writes the discussion but everyone takes equal credit.

III The results of one trial are excluded from a report, as they contradict the other trials.

IV When keeping barramundi in an experimental tank, the water temperature is much warmer than the conditions they would experience in the wild.

V Patients with a debilitating disease are not part of the 'treatment group' that is given an experimental, but potentially life-saving, drug. Instead, they are given a placebo.

VI No consultation with the community occurs before a group of scientists study its members.

VII An experimental treatment to cure a disease involves blood transfusions, but the procedure is not considered ethical by some religious groups.

	Integrity	Justice	Beneficence	Respect
A	I, V	II, III	IV, V	VI, VII
B	II, III	I, V, VI	VI, VII	IV, V
C	II, III	VI, VII	IV, V	I, V
D	II, III	I, V, VI	IV, V	VI, VII

Exam-style questions

Key science skills

Use the following information to answer Questions 8—13.

Biologists investigating the regulation of body water in Peking ducks, *Anas platyrhynchos,* put forward the hypothesis that Peking ducks drink more as the saltiness of their drinking water increases.

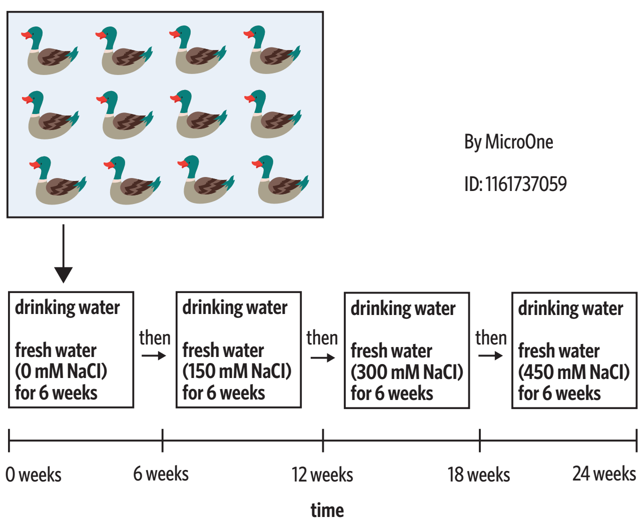
The drinking water was to be supplied in 70 litre wading pools and replenished twice each day. Twelve adult Peking ducks, males and females, were available and two experimental designs were suggested.

Design 1

The same twelve ducks are provided with drinking water of increasing saltiness over a 24-week period.

Design 2

The twelve ducks are randomly divided into four groups of three ducks and each group is exposed to drinking water of a different salt concentration.



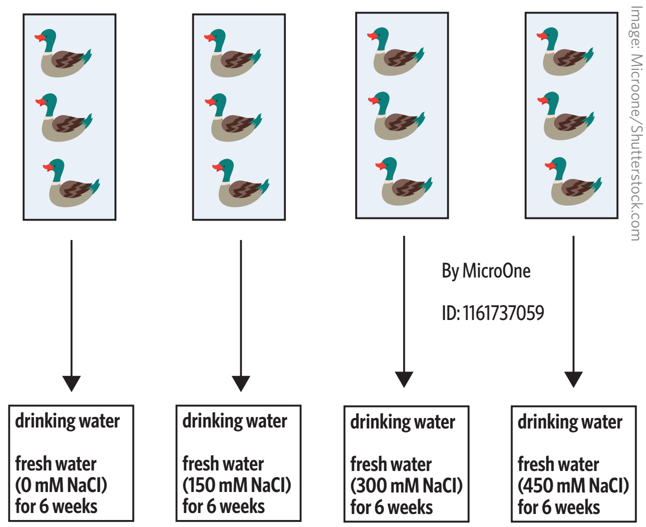


Image: Microone/Shutterstock.com

Question 8 (1 MARK)

The dependent variable is

A time.

B the gender of the ducks.

C the amount the ducks drink.

D the saltiness of the drinking water.

Adapted from VCAA 2004 Exam 1 Section A Q17

Question 9 (1 MARK)

The independent variable is

A time.

B the gender of the ducks.

C the amount the ducks drink.

D the saltiness of the drinking water.

Question 10 (1 MARK)

A controlled variable is

A the age of the ducks.

B the amount of water in the ponds.

C the saltiness of the drinking water.

D the ducks not exposed to the independent variable.

Question 11 (1 MARK)

An uncontrolled variable in Design 1 is

A the species of duck.

B the age of the duck.

C the number of replicates.

D the length of time in the ponds.

Question 12 (1 MARK)

One strength of Design 1 is that it better accounts for

A random error.

B systematic error.

C potential confounding factors.

D ethical and safety considerations.

Question 13 (1 MARK)

One strength of Design 2 is that it better accounts for

		Percentage of cross-pollination	
		at edge of non-GM crop	10 metres into non-GM crop
Trial 1 GM non-GM	no gap between plots	10	2
Trial 2 GM non-GM	5 metres between plots	1	0.5
Trial 3 GM non-GM	7 metres between plots	1	0.3

A validity.

B variation between individual ducks.

C time taken for the ducks to acclimatise to the conditions.

D the potential impact of previous conditions on duck drinking behaviour.

Question 14 (11 MARKS)

Some plants are resistant to attack by insects. The plants produce a protein that poisons the larval stage of some insects that feed on them. The production of the protein is under the control of a gene found in the plant. A particular species of crop plant that does not usually produce the protein was genetically engineered to contain this gene. Such plants are referred to as genetically modified (GM) plants. These GM plants do produce the insecticide protein.

Two farmers have properties next door to each other. They grow the same cereal crop.

- Farmer X wishes to grow GM crops that are resistant to attack by insects
- Farmer Y wishes to continue to grow non-GM crops.

Farmer Y was concerned that pollen from farmer X's GM crop could fertilise her non-GM plants, causing the next generation of Farmer Y's crops to produce the insect-poisoning protein.

The farmers agreed to carry out field trials to establish whether leaving a gap between crops reduced the likelihood of cross-pollination. A number of trials were planted so that the results of one trial did not interfere in any way with the results of another. The percentage of seeds produced at various positions as a result of cross-pollination was measured for each trial. The outline of these trials and the results gathered are shown in the following table.

a State the independent and dependent variables in the field trial. (1 MARK)

b Was a control group used in this experiment? Explain your response and, if not present, describe what a control group would consist of. (2 MARKS)

c From the data, what conclusions can be drawn about cross-pollination and the gap between crops? (2 MARKS)

d Farmer X was dissatisfied with the results of the trial, and insisted that they undertake another trial with replication.

  i Explain why this is a good suggestion. (1 MARK)

  ii Draw and explain an experimental setup the farmers could use in a field trial with replication. (2 MARKS)

e In an attempt to minimise error, a number of trials were planted at different times so that the results of one trial did not interfere in any way with the results of another. Explain one potential problem with this experimental design. (2 MARKS)

f Eventually, the farmers decided to plant their crops 5m away from each other, agreeing that this should keep the amount of cross-pollination low. After a few years, Farmer Y's initially non-GM crops were 50% GM. Despite this, Farmer Y was not displeased because her crops were growing far better than usual. Referring to an ethical principle, identify one ethical issue with the situation. (1 MARK)

Adapted from VCAA 2003 Exam 2 Section B Q4h

Question 15 (7 MARKS)

Before a drug is used for human therapy it is usually tested on animals. This is because results for animals often give some indication of how effective a drug may be in humans, and any potential side effects of the drug.

a Design an experiment, using mice, to test the effectiveness of a drug that targets viruses. (3 MARKS)

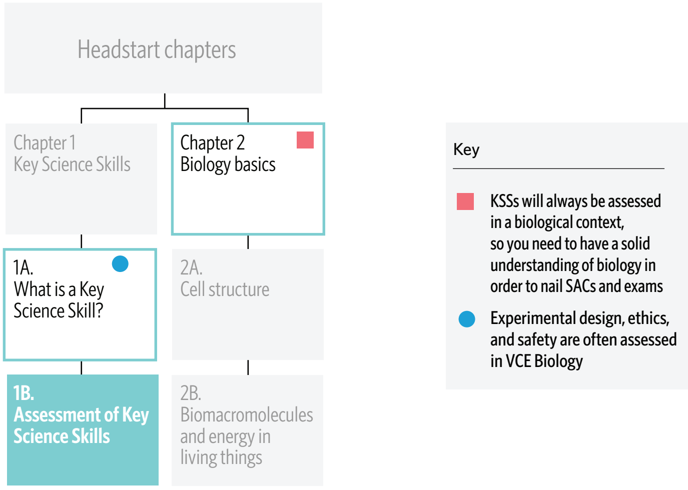
b Identify two ethical considerations the scientists should discuss before proceeding with the experiment. Suggest how they might be overcome. (2 MARKS)

c Identify two precautions the scientists should take to ensure the experiment is safe. (2 MARKS)

Adapted from VCAA 2006 Exam 1 Section B Q3c

1B ASSESSMENT OF KEY SCIENCE SKILLS

When analysing graphs and tables, make sure your conclusions are limited by, and do not go beyond, the data available. To assume anything more makes an 'ass' out of 'u' and 'me'.



In this lesson you will learn how to demonstrate your KSSs in School Assessed Coursework (SACs). In particular, you'll learn how to present your data.

Study design dot points

- the biological concepts specific to the investigation and their significance, including definitions of key terms, and biological representations
- the characteristics of scientific research methodologies and techniques of primary qualitative and quantitative data collection relevant to the selected investigation, including laboratory work (biochemistry, cytology, immunology) and/or fieldwork (geomorphology); precision, accuracy, reliability, and validity of data; and minimisation of experimental bias
- methods of organising, analysing, and evaluating primary data to identify patterns and relationships including sources of error and limitations of data and methodologies
- the nature of evidence that supports or refutes a hypothesis, model, or theory
- the key findings of the selected investigation and their relationship to cytological, biochemical, and/or evolutionary concepts
- the conventions of scientific report writing and scientific poster presentation including biological terminology and representations, standard abbreviations, units of measurement, and acknowledgment of references

Key knowledge units

Overview of assessment in Units 3 & 4 VCE Biology	4.3.4
The logbook	4.3.5
Practical reports	4.3.6
Poster presentation of a scientific investigation	4.3.7
How to present and analyse data	4.3.8

Overview of assessment in Units 3 & 4 VCE Biology 4.3.4

OVERVIEW

SACs make up 40% of your VCE Biology mark, and the exam makes up the remaining 60%. To be successful at these assessments, you need to revise the set theory, develop KSSs, and record all your practical activities in a logbook.

THEORY DETAILS

VCE Biology assesses students in a number of ways. Most of your marks are derived from your exam performance (60%), and the rest (40%) come from a variety of teacher-chosen tasks set for **School Assessed Coursework (SACs)**. Most of the time, SACs will involve collecting **primary** or **secondary data** and preparing practical reports, but they may also be tests, media responses, posters, and other activities. While your exam is marked externally, your teacher marks your SACs (although these can be moderated externally). Additionally, you are required to maintain a **logbook** throughout Unit 3 & 4 Biology.
In all of these assessments, you may be tested on both your theory knowledge and KSSs.

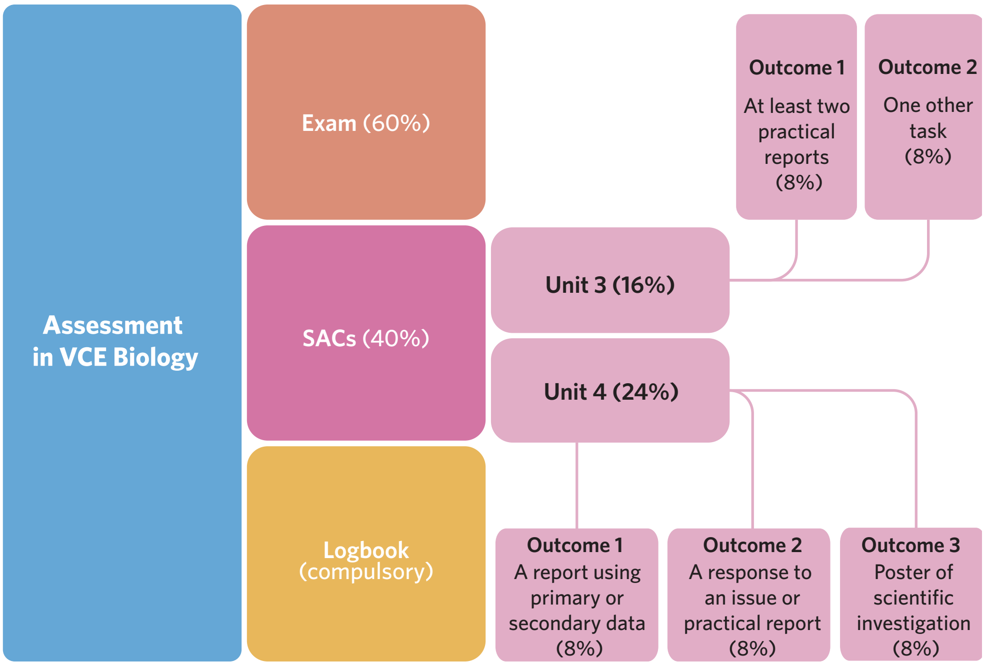


Figure 1 The components of your VCE Biology course that contribute to your final score

The logbook 4.3.5

OVERVIEW

Logbooks are a requirement of VCE Biology and are comprised of results from the investigations you undertake during the course.

What is a logbook?

Scientists don't need to have excellent memories. Instead, they keep a meticulous and organised record of their observations, discussions, experiments, analyses, and conclusions. Keeping a logbook should help you practice writing down and articulating your thoughts about biology. It will also mean that you won't break into a cold sweat when your teacher or lab partner asks you, 'Did the *Elodea* in the negative control group displace the water by 1.5 mL or 1.6 mL?'. You can just flick back to your notes.

Logbooks can be digital and/or paper-based. While there is no set format for a logbook, VCAA emphasise that the logbook is a record of all your practical activities and investigations over Units 3 & 4 Biology. This means that formal practical reports and SACs are typically recorded in your logbook. Your logbook may also contain:

- Surveys
- Interviews
- Reflections
- Results of simulations
- Qualitative and quantitative data
- Planning notes for experiments
- Responses to questions in a worksheet
- Results from activities or investigations
- Simple observations made during class
- Notes, images, or data from excursions
- Web-based investigations and research
- Notes of additional work completed outside of class
- Links to spreadsheet calculations or other digital records.

School Assessed Coursework (SAC) an internally-marked assessment (e.g. practical report, test, media response) that contributes to your overall study score in VCE Biology

primary data results collected from experiments, interviews, or surveys undertaken by the researcher

secondary data results from sources other than the researcher's own investigations

logbook a record of all your practical investigations. Maintaining a logbook is a compulsory component of VCE Biology

The purpose of collating all this in the logbook is to provide a basis for further learning. In particular, the logbook should help you:

- contribute to class discussions
- report back to class on activities
- reflect and draw conclusions from experiments and discussions
- record data and observations in an accurate and timely manner.

Tip Make sure you acknowledge or reference investigation partners, expert advice, secondary data sources, and any assistance you received. Also, write the date at the top of each entry.

Practical reports 4.3.6

OVERVIEW

Some of your SACs will be formal practical reports of experiments. The recommended structure for a practical report is title, abstract, introduction, methodology, results, discussion, conclusion, acknowledgements, then references.

THEORY DETAILS

Figure 1 shows that many of your SACs involve writing a practical report. You may also conduct experiments that do not contribute to your final marks but give you a chance to practice or explore a concept. In total, VCAA recommend that classes devote 3.5-5 hours of class time to practical work per Outcome, but 7-10 hours for Unit 4 Outcome 3. Typically, you will be asked to describe and discuss any experimental work in a **practical report.**

practical report a structured record of an experiment

raw data results that have not been processed, manipulated, or formatted for use

transformed data results that have been converted from their raw format into a more visually sensible presentation that is easier to analyse

In this section, we will describe the main parts of a practical report. Reports are typically written in third person (e.g. 'This study investigated...' or 'The results indicate that...') but some journals prefer first person (e.g. 'We found that...' or 'Our research shows...'). You should note that your teacher may have additional or different requirements for you to follow.

Table 1 The components of a practical report, including suggested length and tense of each section

Section	Suggested length	Suggested tense
Title The title may be written as a question or statement that describes the main thing you are trying to determine. Examples include: • How does light intensity affect the rate of photosynthesis? • Does the theory of natural selection explain the increasing carp (*Cyprinus carpio*) population in the Murray River? • The impact of pH on the rate of enzyme-catalysed reactions. • The isolation and characterisation of spermatogonial stem cells in the fat-tailed dunnart (*Sminthopsis crassicaudata*). • What does medical student study behaviour look like, and is it effective? • Bathing salmon in cold water is an effective treatment for removing skin parasites. Note that if you are investigating a particular species you may wish to include the species name in the title.	One sentence	Present
Abstract Abstracts are optional but recommended. In essence, the abstract is a short overview of the entire experiment. One formula you could use for writing an abstract is answering each of these questions in one sentence, then using linking words to make the paragraph flow: • What is the significance of the experiment? • What was the aim of the experiment? • What was your method? • What were your results? • Why are your results important? • Given these results, what should be researched next? Or, what are the broader implications of these results?	100-300 words	Past

Introduction
The purpose of the introduction is to justify why you needed to perform your experiment. Introductions generally contain the following information (not necessarily in this order).
• Background information. This may include:
  - Why the system or model is important to study
    - For example, photosynthesis is important to study as it plays a major role in controlling the levels of different gasses in our atmosphere
  - The broader implications of answering your particular question
  - Any prior research that has been undertaken
    › This may include pilot studies your class undertook or research by other sources
    › You may also wish to point out weaknesses with prior studies - these could be grounds for your research
    › Be sure to reference any secondary sources
  - Any gaps in knowledge, and how your experiment could fill that gap
• The aim of the experiment
• The variables tested
• The hypothesis
  - As well as a justification for your prediction
• The final sentence of the introduction is typically 'big picture', suggesting how what you discover could help the world or influence future research.
	Variable - check with your teacher, but usually one to four paragraphs	Past

Methodology The purpose of a method is to outline all the materials and steps you took during an experiment. Like a cooking recipe, it must be very detailed so that someone else could read it and follow your steps exactly. You can usually write the method in steps and in third person. We recommend using short sentences and removing all flowery language so that it is easy to understand. Make sure you: • Write the steps in order • Name any equipment used - You may wish to outline if/how the equipment was maintained or calibrated • Draw and label any complex experimental setups • State what you measured and when.	Usually no longer than half a page	Past
Results The purpose of the results section is to present the key findings of the study in a clear and honest manner. You do not usually present **raw data** in the results section, but manipulate it into **transformed data** (e.g. table, line graph, bar graph) that best shows any trend, patterns, or relationships that exist (see the next section in this lesson for more on presenting data). Each figure is accompanied by a brief (2-3 sentence) description of the key finding. If statistical analyses have been performed, they are presented here as well. Do not interpret or explain your findings in this section.	Variable — it depends on the number of figures and tables	Past

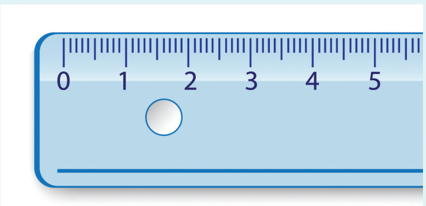
Tip Some instruments are more precise than others. For instance, the screen height of an iPhone X could be 14.9 cm (ruler), 14.86 cm (vernier calipers), or 14.859 cm (micrometre screw gauge). Clearly, there is more uncertainty associated with the ruler measurement than with the micrometre screw gauge measurement.

You may wish to quantify the uncertainty associated with measuring instruments in your methods. Digital devices like scales typically state the uncertainty on a sticker somewhere. For analogue instruments like rulers and measuring cylinders, uncertainty is a bit trickier.

If you have to set up the instrument before measuring (e.g. with a ruler, you need to put it in place before measuring), then the uncertainty is the smallest measurement. On the ruler shown in Figure 2, the uncertainty is ± 1 mm.

If you don't need to set the instrument up before measuring (e.g. a measuring cylinder, a thermometer), then the uncertainty is half of the smallest measurement.
In the measuring cylinder as shown in Figure 3 the smallest measurement is 1 mL, so the uncertainty is ± 0.5 mL.

Note that the uncertainty assigned to standard digital stopwatches is ± 0.1 second due to human reaction time.



ImageL: Dragance137/Shutterstock.com

Figure 2 A section of a ruler that has an uncertainty of ± 1 mm

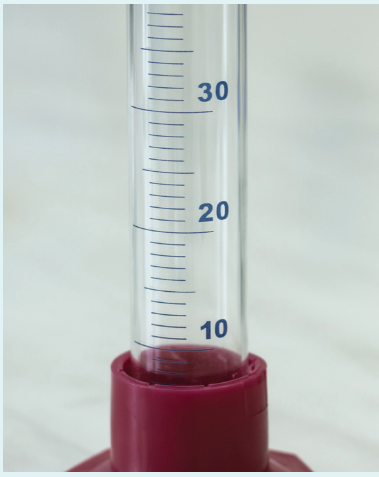


Image: oFFsoRRy/Shutterstock.com

Figure 3 A measuring cylinder that has an uncertainty of ± 0.5 mL

Discussion
The purpose of the discussion is to determine if the data obtained support the hypothesis and to explore the implications of the findings. It is very important that you highlight any problems that arose during the experiment in the discussion, as well as any limitations of the data.
One way you could structure a paragraph in your discussion would be to include:
• Restate one key result (e.g. the result from one figure)
• State if the result supports or refutes the hypothesis
• Discuss if your findings support or differ from prior research
  – Be sure to reference sources
• Weigh up the strengths and weaknesses of the data to determine if the result can be trusted
  – Identify reasons why this result may be invalid or unreliable. Here, you could refer to:
    › Personal, systematic, or random errors
    › Precision, accuracy, and uncertainty of data
    › Problems with the experimental design
    › Other studies that contradict your data
  – Identify reasons why the results may be limited - what is the data not telling us that would be useful to know?
  – Suggest how the method could be changed to overcome any problems
  – Identify any strengths that support the validity, reliability, and scope of the results.
	At least one paragraph — usually three or four	Mostly present

Conclusions
The purpose of this section is to summarise your study. Generally, conclusions begin by stating whether the hypothesis was supported. They also may include:
• Justification of why the hypothesis is supported/rejected
• Summary of limitations and improvements
• The broader implications of the results, for example
  – Future research
  – The impact on scientific knowledge
  – The impact on society/environment.
	One paragraph	A mix, but mostly present

Acknowledgements Individuals involved in the experiment should be recognised for specific contributions.	One to three sentences (not included in word count)	Present
References A list of references in a standard style (e.g. Harvard or APA) should be included.	Anywhere from 2 — 20 references (not included in word count)	N/A

Poster presentation of a scientific investigation 4.3.7

OVERVIEW

The poster presentation has the same sections as a practical report, but you must change your communication style so that information is transmitted more concisely and visually.

THEORY DETAILS

At scientific conferences, halls are filled with posters showing the latest research (Figure 4). As a result, it is important to develop your skills at making posters. In particular, they are different from reports in that:

- written sections are short and direct
- the results section is usually front and centre
- images can be included
- figures should be large and easy to read.

Remember that, for scientists, eye-catching and visually pleasant presentations mean more people will look at your poster as opposed to the hundreds of others up on the walls. This gives you a greater chance of sharing your results, meeting potential collaborators, receiving feedback, and advancing your career. The skills you use to make this poster - namely, being concise and presenting work clearly - are valued across all disciplines, not just science.

Because poster presentations are so important for scientists, for VCE Biology you will spend seven to ten hours creating a poster that presents an investigation of any topic from Units 3 & 4. The investigation may take place anytime during the year, and must involve the collection of primary data.

Figure 4 An example of a poster presentation at a scientific conference

The scientific investigation

The poster presents information about a scientific investigation that you undertake largely independently. This means that you will not be given a question or a prescribed procedure, as in a **structured inquiry.** Specifically, VCAA recommend you undertake either a **coupled** or **open inquiry**. In coupled inquiries, your teacher may choose an initial question to investigate, then you must build on and design a linked investigation. For example, your teacher might demonstrate how to measure the rate of photosynthesis. From there, you could design an experiment that tests the rate of photosynthesis in native plants compared to introduced species or you could test how changing pH affects photosynthesis in marine plants (a problem many will face due to ocean acidification). You decide upon the variables that you wish to investigate, within a predetermined framework.

In an open inquiry, you choose your own question and design your investigation. In this scenario, you may deep dive into any topic from Units 3 & 4 Biology or even design an experiment that explores multiple topics at once. Open enquiries are entirely based off student curiosity and interests, but your teacher can support you where necessary.

structured inquiry an investigation in which students explore a teacher-proposed question through a prescribed procedure

coupled inquiry n investigation in which students extend or build upon an initial, teacher-proposed question

open inquiry an investigation that is student-centred, whereby students develop their own question and experiment

A potential way to start with an open inquiry is to think about your hobbies - perhaps you have a passion for music, art, or sport. How might aspects of these disciplines interact with cellular respiration, enzyme-catalysed reactions, plant hormones, evolution, or antibiotics? For example, do different brands of sports drinks affect osmosis across plasma membranes? Or respiration rate in yeast cells? Alternatively, you could begin an open inquiry by considering current issues the world, or your hometown, is facing. For example, salt tolerance and drought tolerance are increasingly important for plants in a world affected by global warming. You could manipulate levels of water or salt and measure germination, growth, or photosynthesis in a local plant species.

Tip Be really careful when writing your question! Table 2 outlines some common problems with research questions.

Table 2 Suggested solutions for common mistakes with research questions

Poorly worded question	Problem	Improved question
Is it best to grow plants with natural or artificial light during the Australian winter?	The question is vague: what do the students mean by 'best'? Which plant species did they test?	Do snow pea plants (*Pisum sativum*) grow more with natural or artificial light during the Australian winter?
How does garlic inhibit the growth of *S. epidermis*?	Using 'How' questions suggest you need to explain the mechanism of action of garlic. This is not investigable with standard school equipment in less than ten hours. Also you should use the full scientific name, not an abbreviation.	What is the effect of garlic on the growth of *Staphylococcus epidermis*?

Creating the poster

The poster sections are the same as the sections of a practical report. However, there are some key differences in what is included in each section. Figure 5 shows a suggested layout of the poster, and explanations of how to approach each section. Note that VCAA mandate a word limit of 1000 (excluding references and acknowledgements) for this assessment.

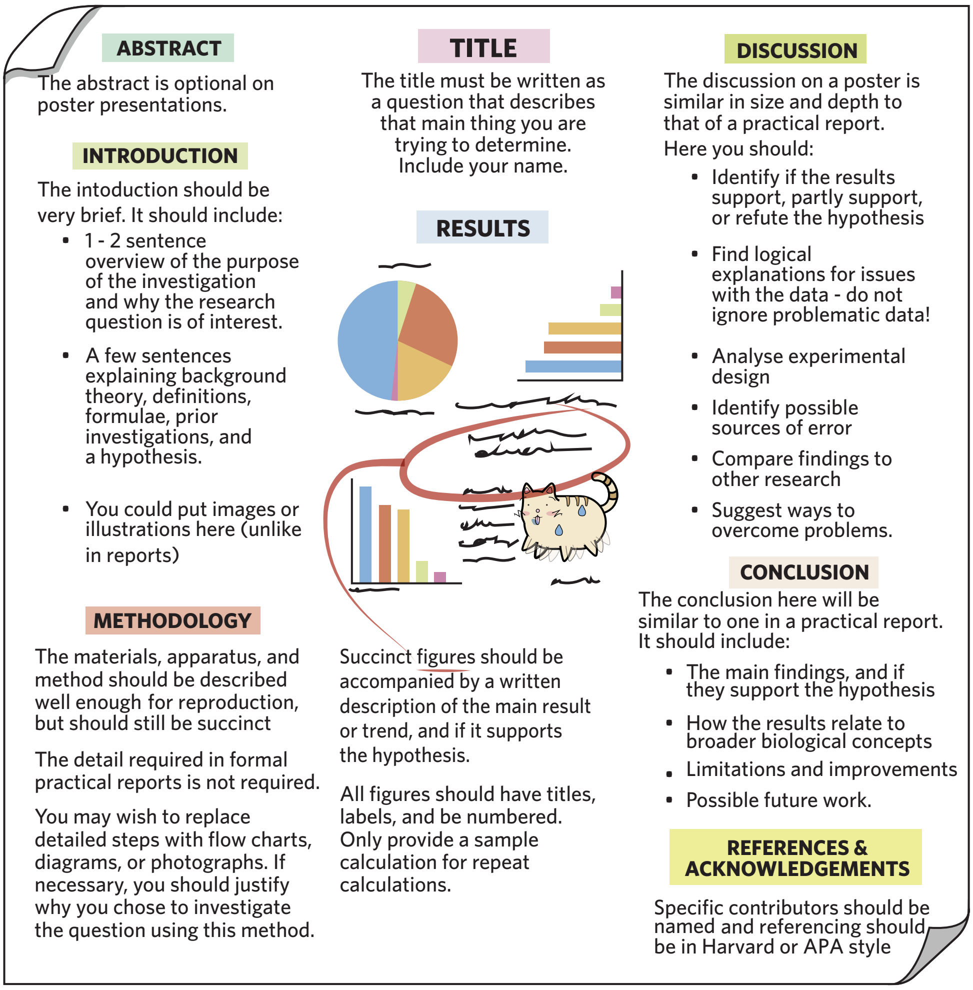


Figure 5 A suggested layout for the poster presentation, and descriptions of what to include in each section

When creating your poster, you must think carefully about your communication style. Some guidelines for effective scientific communication on your poster include:

- Logical sequencing
- Signposting key parts, such as the hypothesis, question, aim, and conclusion
- Reduce complexity
  - Inclusion of only the essential details
  - Use (defined) acronyms
  - Use dot points
- Using a range of visual aids to avoid overcrowding with text - some scientists recommend that at least 50% of the poster space is photos and figures.
- Use of font, font size, and colour to ensure the poster is easy to read (even from a distance)
- Correct spelling and grammar
- Test if someone with no background knowledge can understand it
- Label figures, images, and tables.

How to present and analyse data 4.3.8

OVERVIEW

In practical reports, posters, and exams you may need to present and interpret data.

Figure 6 The process of analysing, presenting, and discussing data

THEORY DETAILS

Imagine that it's the last period on a Friday. It's hot. Over the past hour and a half, you and your laboratory partner have managed to design a valid and repeatable experiment, thanks to lesson 1A. You've sweated over Bunsen burners, made precise measurements and battled to minimise error and bias during data collection. You're proud of yourselves. Very little went wrong, so you should have reliable data from which you can draw meaningful, reasonable conclusions. Right? But, as you look down at the scrimmage of numbers and letters in your logbook, you realise that you actually have no idea what it all means.

A crucial part of being a scientist is communicating your results clearly and honestly. In practical reports and posters, raw data is not usually presented because it can be hard to read, repetitive, irrelevant, or messy. Instead, data is manipulated so that the main result, pattern, or trend is obvious. Tables are not always the best way to show trends, so results sections will typically include graphs and charts.

numerical variables factors that are measured as a number such as height, count of population, and age

scatter plot a graph in which the relationship between variables is plotted using dots, through which a trendline may reveal correlation. Also known as a **scattergram**

categorical variables factors that are qualitative, typically describing a characteristic such as gender, birth order (1st, 2nd, 3rd), or nationality

bar graph a graph that shows changes in categorical variables using filled rectangles

dependent variable (DV) the factor(s) changed by the manipulation of the IV

independent variable (IV) the factor(s) that is manipulated in an experiment

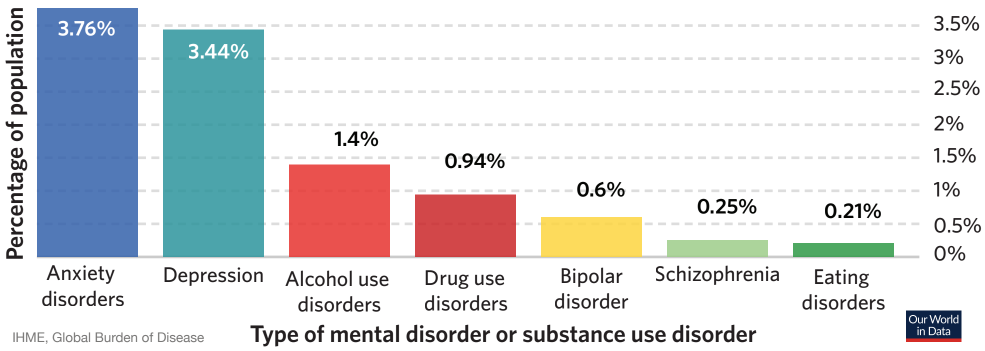
Types of graphs

The type of graph you choose depends on the type of data that you have collected. Table 3 outlines the different types of data you may collect, and how you can represent that type of data.

Table 3 Type of data you may collect about variables and how they are best graphed

Type of variable		Explanation	Typically graphed using a...
Numerical	**Continuous**	Data that can take any value between a set of real numbers e.g. height, age, mass, volume	**Line graph** or **scatter plot**
	Discrete	Data that take a particular value, and cannot take a fraction of that value e.g. count of individuals	
Categorical	**Ordinal**	Data that can be logically ordered e.g. size (small, medium, large), fin health score (1 = no fin damage, 2 = some fin damage, 3 = most of fin surface damaged), attitudes (agree, neutral, disagree)	**Bar graph** or pie chart
	Nominal	Data that cannot be organised in a logical sequence, e.g. gender, nationality, hair colour	

Bar charts (Figure 7) and pie graphs typically graph categorical data, whereas line graphs (Figure 8) and scatter plots (Figure 9) represent numerical data well. Scatter plots are particularly useful if you wish to compare two variables (e.g. the salary of women compared to the salary of men). If one variable is categorical but the other is continuous, bar graphs usually work well.



The categorical variable in this bar graph is the IV: Type of mental and substance use disorder

Figure 7 Bar graph showing the prevalence of mental disorders and substance use disorders in 2017

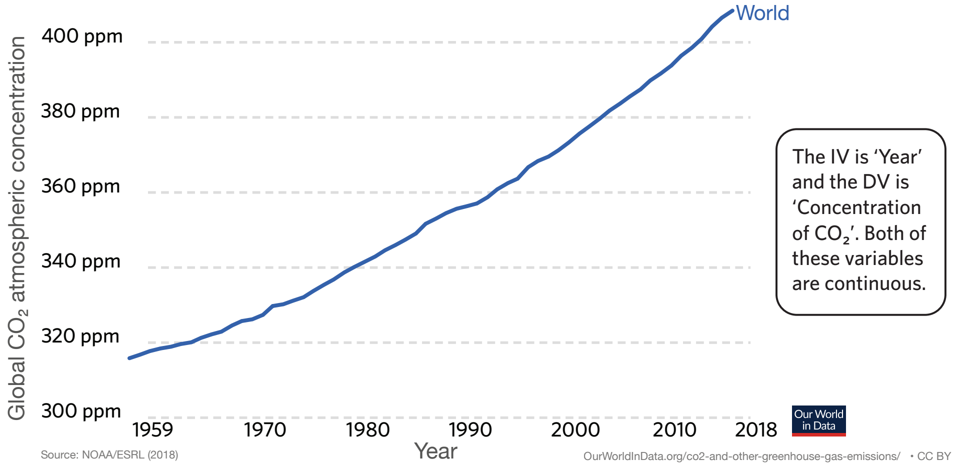


Figure 8 Line graph showing the change in global carbon dioxide atmospheric concentration over the past 60 years

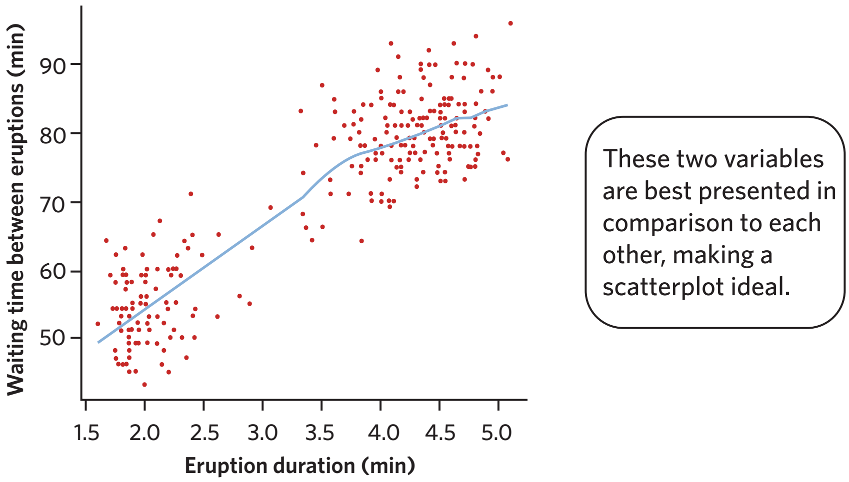


Figure 9 Scatter plot showing that the longer the wait time between eruptions of the geyser Old Faithful, the longer the duration of the next eruption

During experiments, you may record points within a range of continuous data, creating a scatterplot. For example, you may record the oxygen concentration in a sealed jar with a plant inside every five minutes. Oxygen concentration is continuous data, so you can draw a 'line of best fit' to show the general relationship between the variables. A line of best fit may pass through all the points, some of the points, or none of the points (Figure 10). A good rule of thumb when drawing a line of best fit is to ensure the number of points above and below the line are equal.

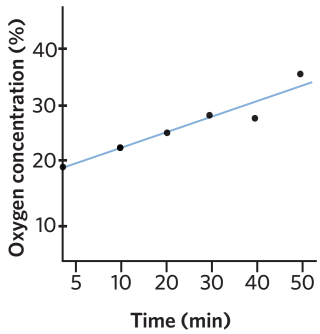


Figure 10 The line of best fit showing the general trend between two variables on a scatterplot

Formatting of results

Once you've drawn up your graph on paper or on the computer, you need to format it to maximise clarity and to ensure it fits scientific conventions. Some guidelines for formatting are:

- Ensure the graphics are clear and easily read
- The scale should be appropriate for the data, and labelled clearly
- Ensure the graphs do not have coloured backgrounds or grid lines, unless required to present results clearly
- Axis labels should be formatted in sentence case (Not in Title Case and NOT ALL CAPS). Only the first letter of the first word should be capitalised, as well as any proper nouns.
- Any calculations should be presented in a clear, non-repetitive manner (e.g. by using one sample calculation)
- Each graph should have a figure number and title underneath
- Each table should have a table number and title above
- The results section also includes text. The text should summarise the key finding for each graph in 1-2 sentences, including if the result supports the hypothesis.

Tip In most cases, the IV is represented on the horizontal axis and the DV is on the vertical axis.

Interpreting data

As a budding scientist, you should be able to draw sound conclusions from reliable evidence. Of course, first you need to confirm that your evidence is reliable - by checking if the data is accurate, precise, and valid (as explored in 1A). If you decide that any issues with the data collection do not undermine the overall result, you can then start to interpret data and draw conclusions. Here, we will investigate two common problems students have when interpreting data.

1 **Correlation** does not mean **causation**

Not all experiments will reveal a correlation between two variables (Figure 11). You may find that the DV and the IV are unrelated. Furthermore, even if your data indicate that your IV affects your DV in a consistent and measurable manner (e.g. if you increase the IV, the DV increases), this doesn't necessarily mean that the IV causes the change in DV. In other words, *correlation* of two variables does not mean that one *causes* the other.

An example of the correlation/causation problem can be observed when measuring the number of ice cream sales and the number of shark attacks. Looking at Figure 12, it would appear that high ice cream sales causes many shark attacks. However, the tight correlation of the variables does not rule out the possibility that something other than ice cream consumption is causing shark attacks. In fact, it seems much more likely that a confounding variable - hot weather making people cool off at the beach and/or buy ice cream - explains the relationship more clearly.

Even if you understand a system very well, there is always a possibility that you have overlooked a confounding factor or that the hypothesis is only supported in a controlled experimental context. Higher replication or an improved experimental design may produce different results. Consequently, scientists tend to use language that is not definitive when explaining their data in the discussion and conclusion. Instead of saying 'Without a doubt, the results clearly prove that...' they might say 'The results suggest... ' or 'The hypothesis was supported by...'. It is important to apply the same level of scrutiny when examining other people's results or secondary data.

2 Conclusions must be limited by, and not go beyond, the data available

Any conclusions drawn from data must be limited by, and not go beyond, the data available. For example, when drawing a line of best fit it is important not to force your line through zero. Consider Figure 13. Here, the scientists measured the height of a seedling every day since germination, but not on the day of germination. Although the seedling height is logically zero at day zero, as it has not grown at all, drawing a **trendline** that is forced through zero results in a different slope (red dotted line) to the trendline that actually best fits their data (blue line). In summary, draw trendlines that fit the data you collect, rather than the data that doesn't exist.

Additionally, the scientists stopped collecting data after ten days. Therefore, it is not correct to state that 'it will take the seedlings 20 more days to reach 9 cm', because we have no idea what happens to the rate of growth of seedlings after day ten. One could, however, say that 'if the rate of growth continues in the manner indicated by the results, then it will take the seedlings 20 more days to reach 9 cm'.

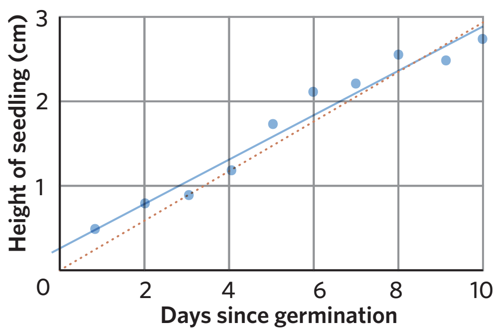


Figure 13 When drawing a trendline, avoid forcing your data through zero (red dotted line) as you end up with a different slope that doesn't accurately represent the data you collected (blue)

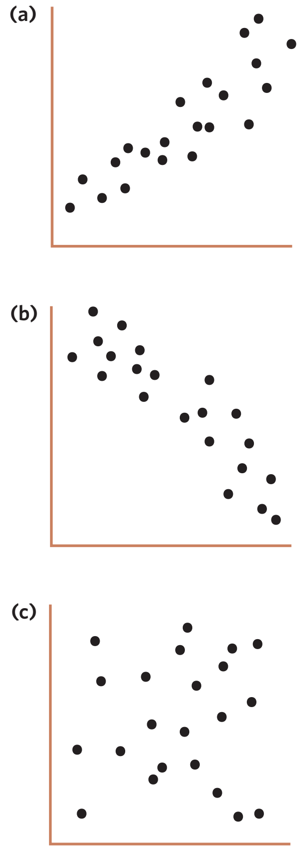


Figure 11 Scatter plot examples of **(a)** positive correlation, **(b)** negative correlation, and **(c)** no correlation

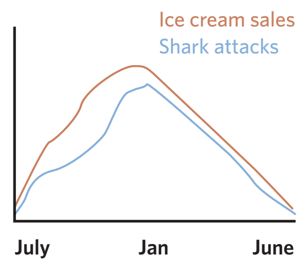


Figure 12 The number of ice cream sales and shark sales are correlated, but one does not cause the other

correlation demonstrated when there is a statistical relationship between two variables

causation demonstrated when change in one variable leads to reliable change in another

trendline a line that shows the main pattern followed by a set of points on a graph. Also known as a **line of best fit**

Tip On exams, you may be asked to *describe* data before you then explain it. A good plan of attack to describe data is to divide the graph into different sections.

For example, in this graph from the 2018 exam, it would be difficult to describe everything that is happening all at once. But we have superimposed colour over sections of the data that actually would be easy to describe.

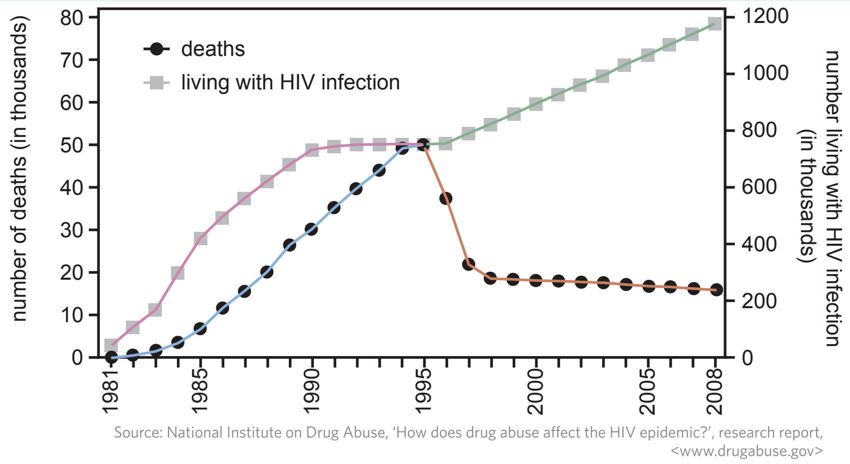


Figure 14 An exam question that requires students to interpret a line graph

Here is an example of how you could describe this data:

The number of deaths from HIV rose steadily from 1981, reaching a peak in 1995 at 50 000. This was followed by a sharp decline in deaths from 1995–1997, until plateauing around 20 000 for the next ten years. Meanwhile, the number of people living with HIV rose from close to zero to 800 000 between 1981 and 1990. It stayed at approximately 800 000 for five years, then the number increased linearly to 1 200 000 by 2008.

Note that the description includes numbers from the x and y axis to contextualise the overall pattern.

Theory summary

In VCE Biology, your understanding of theory and application of KSSs are tested during SACs (40%), the exam (60%), and by maintaining a logbook (hurdle requirement). During SACs, you will often be assessed in the format of practical reports. Each part of a practical report requires you to include particular information. Another major piece of assessment is the scientific poster of an investigation. Although it has similar sections to a practical report, the investigation must be independent and the poster requires succinct communication and a greater use of graphics.

1B QUESTIONS

Theory review questions

Question 1

What are the key terms from the lesson that match the following definitions?

a ______________ the section of a practical report that requires a high level of detail, so others can reproduce your experiment

b ______________ the variable that is usually plotted on the x axis

c ______________ the matching or relatedness of two variables

d ______________ the type of numerical data that takes a particular value, such as count of frequency

e ______________ the type of data that is best plotted on line graphs or scatterplot

f ______________ a type of inquiry style where students choose and design their own investigation autonomously

g ______________ the section of a practical report that ensures anyone who contributed to the investigation is recognised

h ______________ a line that shows that general pattern of data on a scatterplot

i ______________ non-numerical data whereby variables may be grouped by qualitative characteristics

j ______________ results that have just been collected and not manipulated in any way

Question 2

Each part of a practical report fulfils a particular function. Identify which section of the report match the following descriptions. NOTE: a single description can match with multiple or no report sections

I The aim and hypothesis are outlined for the first time.

II Previous research on the topic is explored.

III Graphs and tables are presented.

IV Relevant photos should be displayed.

V Instruments and their uncertainties are described here.

VI The degree to which the results support the hypothesis is described.

VII The limitations of the data are explored.

VIII The broader implications of the experiment are discussed.

	Introduction	Method	Results	Discussion
A	I, II, IV	V, IV	III, IV	II, IV, VI, VII, VIII
B	I, II, VIII	V	III, IV	II, VI, VII, VIII
C	I, II, III, VIII	V	III	II, VI, VII, VIII
D	I, II, VIII	V	III, IV	VI, VII, VIII

Question 3

Which of the following options contains all true statements regarding the communication style required in practical reports compared to scientific posters?

	Practical report	Poster
A	Concise but formal text, accompanied by clear raw data. Images not required.	Detailed and lengthy text for thoroughness. Results and images very important.
B	Detailed, informal, but thorough text accompanied with clear transformed data. Images not required.	Concise and direct text. Eye-catching images and graphs.
C	Detailed, formal, and thorough text accompanied with clear transformed data. Images not required.	Concise and direct text. Eye-catching images and graphs. Can exclude references for brevity.
D	Detailed, formal, and thorough text accompanied with clear transformed data. Images not required.	Concise and direct text. Eye-catching images and graphs.

Question 4

Which of the following correctly explains the difference between structured, coupled, and open inquiries?

A Unlike coupled and open inquires, students receive teacher feedback in structured inquiries.

B Unlike coupled and open inquires, students undertake an independent investigation in structured inquiries.

C Unlike structured and coupled inquiries, students follow a prescribed method in open inquiries.

D Unlike structured inquiries, students decide upon their own research question in coupled and open inquiries.

Question 5

Identify if the following variables are examples of continuous, discrete, ordinal, or nominal data.

I Mass of seed

II Population of sugar gliders

III Percentage of the population that is under 20 years old

IV Species

V Order of finishing a race

VI Number of petals on a flower

VII Likelihood of going to the gym on a given day (unlikely, 50-50, likely)

VIII Eye colour

	Continuous	Discrete	Ordinal	Nominal
A	I, III	II, VI	V, VII	IV, VIII
B	II, VI	I, III	V, VII	IV, VIII
C	I, III	II, VI	IV, VIII	V, VII
D	II, VI	I, III	IV, VIII	V, VII

Question 6

Fill in the blanks in the following sentences.

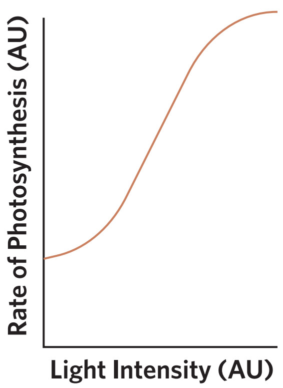
Bar graphs are best used for representing _____**I**_____ data, whereas line graphs or scatterplots can represent _____**II**_____ data. Generally, the _____**III**_____ is plotted on the x axis, and the _____ **IV**_____ is plotted on the y axis.

	I	II	III	IV
A	categorical	numerical	dependent variable	independent variable
B	numerical	categorical	dependent variable	independent variable
C	numerical	categorical	independent variable	dependent variable
D	categorical	numerical	independent variable	dependent variable

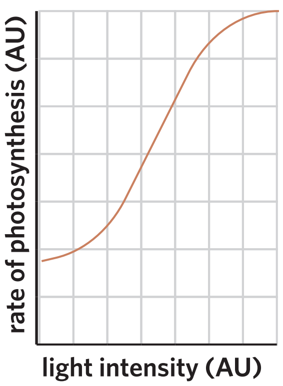
Question 7

Which of the following graphs has been formatted correctly?

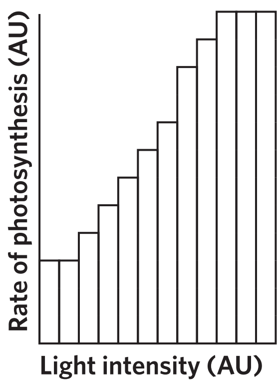
A



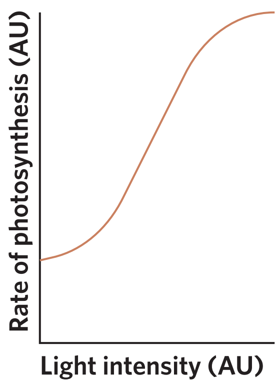
B



C



D



Question 8

Scientists need to examine their own, and others', data critically. Which of the following would not make a scientist doubt the reliability and validity of the results?

A A sentence in the discussion that states 'These results provide undeniable evidence that our hypothesis is true.'

B A scatterplot with a trendline that is not forced through zero.

C A description of an instrument used to measure the length of a bird's beak with an uncertainty of ± 3 cm.

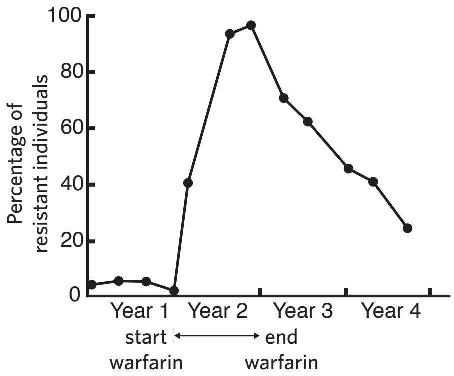
D Results that show a correlation between the IV and DV without any discussion of potential causes.

Exam-style questions

Key science skills

Use the following information to answer Questions 9 and 10.

Warfarin is a poison used to control rat populations. The graph shows changes in the proportion of rats resistant to warfarin in a particular population over a period of about 4 years. High levels of warfarin were used on this population during Year 2 but poisoning stopped at the end of this period. Rats are reproductively mature at an age of three months and can breed about every three weeks.



Question 9 (1 MARK)

Which of the following options best describes the data in the graph?

A The percentage of resistant individuals increases with time up to nearly 100%.

B The percentage of resistant individuals is less than 10% in Year 1, but rises sharply to around 95% in Year 2.

C The percentage of resistant individuals is initially low, then rises sharply in Year 2 to 95%, then falls again to around 25% in Year 4.

D The count of resistant individuals is low in Year 1, then rises sharply in Year 2 to reach a peak of around 98, then falls again to 60 in Year 3 and 25 in Year 4.

Adapted from VCAA 2002 Exam 2 Section B Q7

Question 10 (1 MARK)

A line graph was used to represent this data because

A the independent variable is on the x axis and the dependent variable is on the y axis.

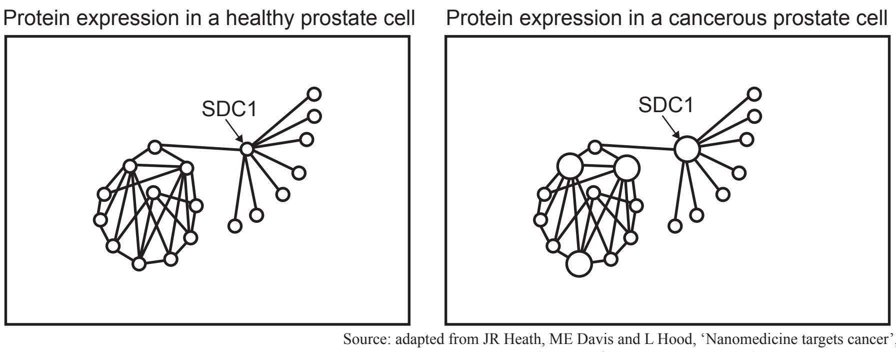
B the dependent variable is continuous but the independent variable is ordinal.

C both variables are continuous.

D both variables are categorical.

Question 11 (1 MARK)

The diagrams show some of the interactions between the proteins found in healthy prostate cells compared to the interactions between the proteins found in cancerous prostate cells.



Source: adapted from JR Heath, ME Davis and L Hood, 'Nanomedicine targets cancer', in *Scientific American*, 300(2), February 2009, pp. 44–51

From the diagrams, it is reasonable to say that

A protein expression is the same in both healthy and cancerous prostate cells.

B SDC1 protein expression does not affect other proteins when expressed in healthy prostate cells.

C SDC1 protein expression is greater in cancerous prostate cells than in healthy prostate cells.

D There are no proteins expressed in healthy prostate cells, and four proteins expressed in cancerous prostate cells.

Adapted from VCAA 2017 Sample Exam Section B Q6f

Use the following information to answer Questions 12 and 13.

Four groups of students carried out an experiment in which the effect of glucose concentration on the fermentation rate of yeast was measured. The fermentation rate was determined by the rate of temperature change of the fermenting mixture. Before beginning the experiment, each group practised measuring the temperature of water and checked the group's thermometer against an electronic thermometer that gave a true measure of temperature. The following results were obtained during the practice.

Group	**Each group's thermometer readings (°C)**			**Electronic thermometer reading (°C)**
	1st measurement	**2nd measurement**	**3rd measurement**	
1	18.0	18.0	18.5	19.0
2	18.5	19.0	19.5	19.0
3	17.0	20.3	21.1	19.0
4	17.0	16.0	16.0	20.1

Question 12 (1 MARK)

Which one of the following statements is correct?

A Group 3's measurements are the least accurate.

B Group 1's measurements are the most accurate and most precise.

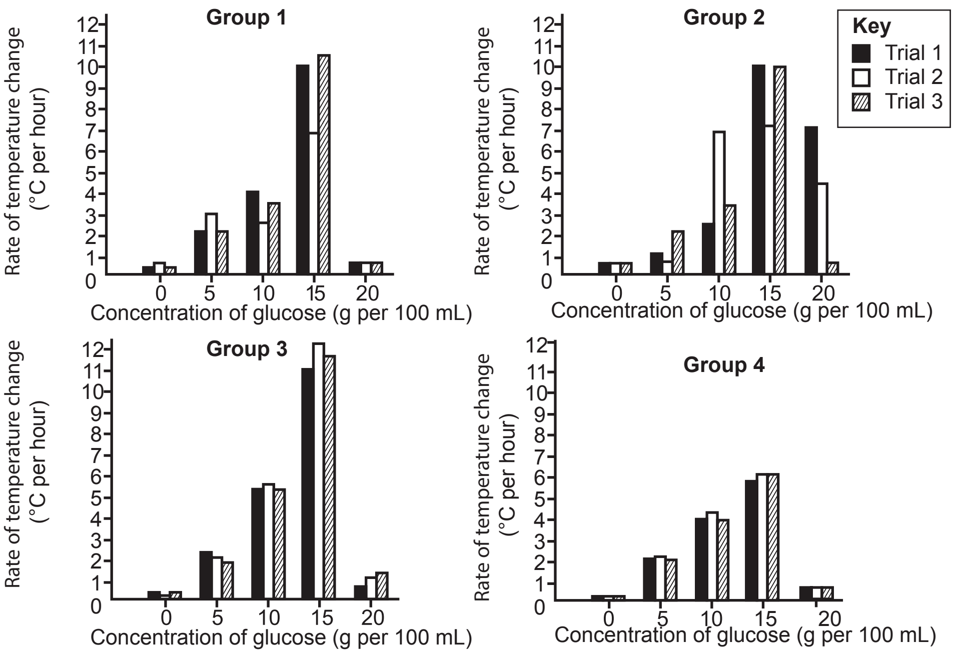
C Group 4's measurements are the least accurate and the least precise.

D Group 2's measurements are the most accurate but not the most precise.

Adapted from VCAA 2018 Section A Q11

Question 13 (1 MARK)

Each group conducted the experiment three times (Trial 1, Trial 2, Trial 3). Five different concentrations of glucose were used in each trial. Each group plotted its results on a graph. The black bar represents Trial 1, the white bar represents Trial 2 and the striped bar represents Trial 3.



Which one of the following statements about the experiment's results cannot be concluded from the graphs?

A All the groups have equally valid results because they followed the same method.

B Group 4's results are more reliable than the other groups'.

C Group 3's data is more reliable than Group 1's data.

D Group 2's data is inaccurate.

Adapted from VCAA 2018 Section A Q12

Question 14 (15 MARKS)

Ibrahim wanted to investigate the effectiveness of an antifungal medication against the common house hold fungi *Aspergillus niger*. He prepared five different concentrations of the antifungal. He wrote the following method:

1. Collect ten agar plates containing Sabouraud dextrose agar.
2. Label two agar plates with one of the five different concentrations of the antifungal. Repeat for every concentration.
3. Put on a pair of disposable gloves.
4. With tweezers, collect 0.2 g of the *A. niger* spores from the culture and place them in the centre of the first agar plate.
5. Spread the spores over the agar plate with the spreader provided.
6. Place a drop of the antifungal in the centre of the agar plate.
7. Close the lid of the agar plate and tape the lid to the bottom of the agar plate with sticky tape.
8. Repeat steps 6 to 8 with the second agar plate labelled with that concentration, and the other four concentrations of the antifungal. Use separate sterile spreaders and tweezers for each agar plate.
9. Place the agar plates on the side bench and leave overnight.
10. Wash your hands and dispose of the gloves.

Ibrahim collected the following results.

Concentration of antifungal (μg/mL)	Mean diameter of fungal colony (cm)
5	3.2
10	0.8
15	1.0
20	0.2
25	0.0

Adapted from VCAA 2017 Sample Exam Section B Q11

a Name the independent and dependent variables. (2 MARKS)

b Define the term 'sterile' and explain why Ibrahim used sterile tools in this experiment. (2 MARKS)

c Identify if Ibrahim has replicated the experiment. Justify your answer. (2 MARKS)

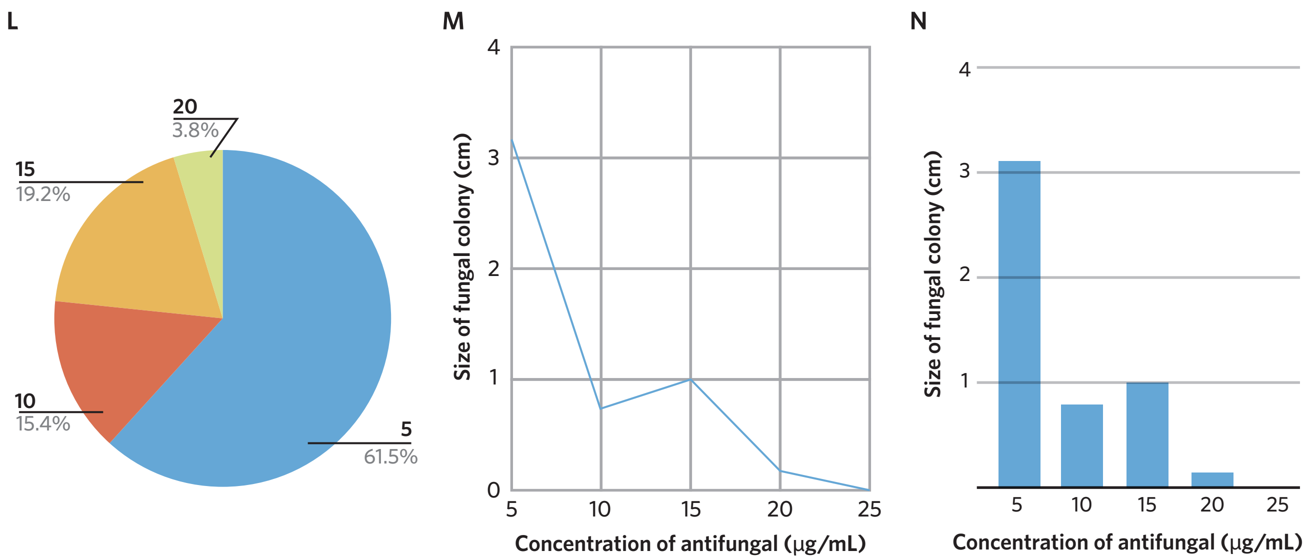
d Identify and explain one poor experimental decision in this investigation, then suggest how the experimental design could be changed to reduce the effect of this error. (3 MARKS)

e Consider Ibrahim's results.

i Describe Ibrahim's results. (1 MARK)

ii Explain whether these results would support Ibrahim's hypothesis. (3 MARKS)

iii Ibrahim tried manipulating his data in a number of ways, making the following three graphs. Which one of the graphs (L-N) is the best representation of Ibrahim's data? Justify your response. (2 MARKS)



ACTIVITY

Decoding experiments

In each of the three experiments outlined below, identify:

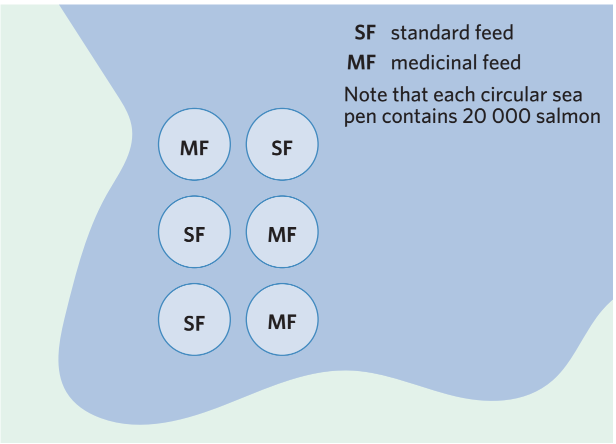
1 A hypothesis for the experiment
2 The control group/s
3 The experimental (or treatment) group/s
4 The independent variable
5 The dependent variable
6 Any constant or controlled variables described
7 Any potentially uncontrolled variables that are not described
8 A safety or ethical consideration
9 Any replication in the experiment
10 A possible improvement in the experimental design.

Experiment 1

Students wanted to determine if common home remedies for colds had antibacterial properties. To test this, 20 Petri dishes were cultured with a non-pathogenic strain of *E. coli* bacteria. Four dishes were then covered in lemon juice, another four covered in saltwater, four were covered with a steaming hot cloth, four were covered in antibiotics, and four were exposed to nothing. The Petri dishes were all exposed to the treatment for 60 minutes. Once the treatment was removed, the bacteria were incubated at 37.5 °C for 24 hours. The amount of bacterial growth on each plate was recorded.

Experiment 2

Scientists at an aquaculture research institute wanted to find out if farmed Atlantic salmon (*Salmo salar*) fed specialised feeds would be more resistant to skin parasite infestation. They designed an experiment where three groups of 20 000 salmon were fed standard industrial fish feed and another three groups of 20 000 salmon were fed the medicinal feed with an additive that helped salmon develop a thicker mucous layer around their scales. The six groups of salmon lived in sea pens in the same fjord. Every fortnight for a year, the scientists collected 20 salmon from each group and recorded the number of skin parasites.



Experiment 3

An experiment was conducted to determine the ideal amount of water and fertilizer for wheat (*T. aestivum*) germination and seedling growth over eight months. Fifteen wheat seeds were grown with no water, 15 were grown in low amounts of watering, and 15 were grown with high amounts of watering. Of the 15 grown under each condition, five were provided with no fertilizer, five were provided with a small amount of fertilizer, and five were provided with a large amount of fertilizer. The seeds were planted in the same soil, grown in the same laboratory, and the scientists ensured that light conditions were equal across treatments.

CHAPTER SUMMARY

Rotate page

Experiments must be **valid**, **reproducible**, and **repeatable**

It is NOT valid if it does not measure what it claims to be measuring. Some ways to make an experiment invalid include:
- measuring inaccurately
- not using a control for comparison
- using an inappropriate indicator for the DV (e.g. measuring the growth of a plant by counting the number of flowers produced)

It is NOT reproducible if the method and results cannot be replicated by another scientist. Some ways to make an experiment unreproducible include:
- communicating incoherently
- being imprecise and inaccurate
- designing an unethical experiment
- letting uncontrolled factors influence results

It is NOT repeatable if you cannot get the same results over and over again. Some ways to make an experiment unrepeatable include:
- not replicating experimental and control groups
- being imprecise and inaccurate
- using broken instruments
- letting uncontrolled factors influence results

So how do I make an experiment **valid**, **reproducible**, and **repeatable**?

Before the experiment

Set up scientifically
- Have an **IV** and a **DV**
  - Write a testable hypothesis that states how your IV will affect your DV
- Ensure your experiment is **safe** and **ethical**
- Include a control treatment
  - *This means you can compare the results of the control to those in experimental groups*

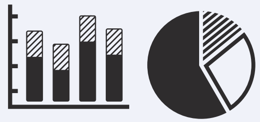
Maximise accuracy
- Ensure sample is **unbiased**
- Reduce **systematic error**
  - Calibrate instruments
  - Use sophisticated and functional instruments
- Identify & control potential **confounding factors**

Maximise precision
- Minimize **personal error**
  - Practice
  - Focus
  - Label everything correctly
  - Take detailed notes
- Minimize **random error**
  - Get a large sample size
  - Use high levels of **replication**
  - This means you can take an average and reduce the impact of **outliers**
- Use instruments with appropriate **uncertainty**

After the experiment

Analyse and present data accurately
- Choose the appropriate graph for your variables (categorical or numerical)
- Do not force a line of best fit through zero
- Do not assume correlation means causation
- Ensure your conclusions are limited to, and do not go beyond, the results you collected

Categorical variables are best depicted on bar and pie graphs



Numerical variables are best depicted on line and scatter graphs

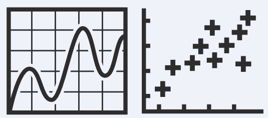


Image: graphixmania/Shutterstock.com

Communicate honestly, clearly, and concisely
- Practical reports require high level of detail and formal language
- Scientific posters require concise explanations and lots of large images and graphs to simplify key concepts
- Poster and report sections are:
  Title, introduction, abstract (optional), methodology, results, discussion, conclusion, references, and acknowledgements
- Ensure that you identify and explain anything that may have affected the accuracy, precision, and validity of your results in the discussion section
- Format your results with care, so that the main result is obvious
- Follow formatting rules for graphs e.g. Not All Caps, only use necessary gridlines, include detailed figure titles

Exam (60%)

SACs (40%)
- **Unit 3 (16%)**
  - **Outcome 1** At least two practical reports (8%)
  - **Outcome 2** One other task (8%)
- **Unit 4 (24%)**
  - **Outcome 1** A report using primary or secondary data (8%)
  - **Outcome 2** A response to an issue or practical report (8%)
  - **Outcome 3** Poster of scientific investigation (8%)

Logbook (compulsory)

CHAPTER REVIEW QUESTIONS

SECTION A (10 MARKS)

Question 1 (1 MARK)

Doctors tested a new medication, Medi-X, that controls blood pressure in pregnant women. A hundred pregnant women aged between 25 and 35 years were divided into two groups of 50 patients. The first group received a pill containing Medi-X and the second group received an identical looking pill to Medi-X but it had no active medicinal ingredients.

Each patient was given one pill per day. All pills were the same colour and of equal mass.

The dependent variable in this experiment was

A the composition of the given pill.

B the pregnant women aged 25–35 years.

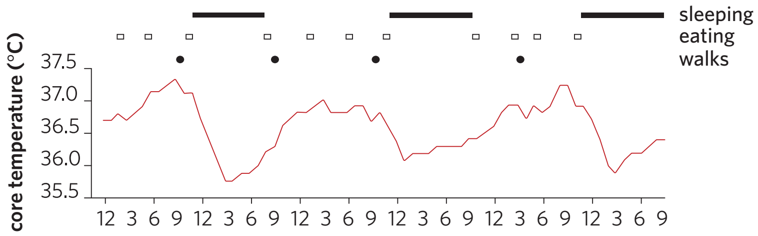
C the blood pressures of the pregnant women.

D being given a pill of the same mass each day.

Adapted from VCAA 2018 Northern Hemisphere Exam Section A Q27

Use the following information to answer Questions 2 and 3.

An experiment on the control of body temperature recorded the core temperature of one human subject, Jonah, living in one room for three days. The room temperature was kept constant at 20 °C. The results of the experiment are shown on the graph.



Question 2 (1 MARK)

The dependent variable in this experiment is

A time.

B Jonah.

C the activity of Jonah.

D the core body temperature of Jonah.

Adapted from VCAA 2012 Exam 1 Section A Q15

Question 3 (1 MARK)

From the graph, it can be concluded that

A Jonah always sleeps for the same duration each night.

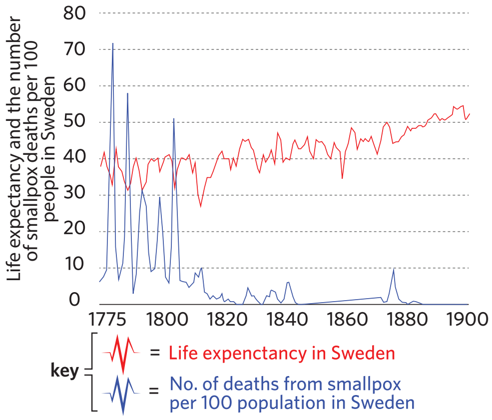
B Jonah's core body temperature decreases during sleep.

C after eating, Jonah's core body temperature reaches its highest peaks.

D core body temperature is exclusively affected by the environmental temperature.

Question 4 (1 MARK)

Smallpox is a disease caused by the variola virus. The World Health Organisation (WHO) has officially declared it has been eradicated. Data from Sweden displays the number of deaths per 100 people in the population and the life expectancy between 1775 and 1900.



Edwardes (1902), Clio-Infra until 1949: UN Population Division 1950-2015
Adapted from Ochmann and Roser 2019

It can be concluded from the data that

A in 1800, approximately 52 people died in Sweden from smallpox.

B before 1900, the greatest life expectancy for Swedish people was 55 years.

C overall life expectancy is dependent upon the number of smallpox infections.

D smallpox deaths reached its lowest point of 28 deaths per 100 people in 1807.

Adapted from VCAA 2016 Section A Q22

Use the following information to answer Questions 5 and 6.

An experiment was conducted to test the following three hypotheses about the effect of the plant growth regulator indoleacetic acid (IAA).

- Hypothesis 1 - High concentrations of IAA inhibit shoot growth and stimulate root growth.
- Hypothesis 2 - Concentrations of IAA below 0.0001 parts per million stimulate shoot and root growth.
- Hypothesis 3 - High concentrations of IAA inhibit both shoot and root growth.

In the experiment, radish seedlings were grown in different concentrations of IAA, as indicated in the table.

Concentration of IAA (parts per million)	Stimulation (+)/ inhibition (-) of shoot growth (%)	Stimulation (+)/ inhibition (-) of root growth (%)
0	0	0
0.00001	+0.10	-30
0.0001	+6	-50
0.001	-20	-70
0.01	-60	-85
1	-70	-90
10	-80	-95
100	-90	-100

Question 5 (1 MARK)

Which one of the following is a reasonable conclusion to draw from the results of the experiment?

A Only Hypothesis 1 is supported.

B Only Hypothesis 3 is supported.

C Hypotheses 2 and 3 are both supported.

D Hypotheses 1, 2, and 3 are all not supported.

Adapted from VCAA 2016 Section A Q15

Question 6 (1 MARK)

Which sample serves as the experimental control?

A 1 part per million of IAA
B 0 parts per million of IAA
C 0.1 parts per million of IAA
D 100 parts per million of IAA

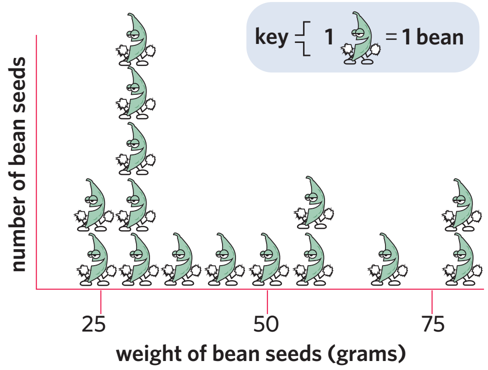
Question 7 (1 MARK)

Danielle performed an experiment on a stick of celery to see whether it needed light to grow. Each piece of celery was watered with 5 mL every day. Under these conditions, the amount of water provided to each celery is referred to as a

A control.
B controlled variable.
C dependent variable.
D independent variable.

Question 8 (1 MARK)

Farah recorded the weight of 15 bean seeds and graphically presented the data as shown.



The seeds came from bean plants grown in identical environmental conditions.

What conclusion can be drawn from these results?

A There is a spread of bean weight due to different growing conditions.
B The average bean seed weight is close to 40 grams.
C The largest bean weighed greater than 100 grams.
D The beans at 80 grams are outliers.

Adapted from VCAA 2014 Section A Q26

Question 9 (1 MARK)

Tatiana set up an experiment in her school science laboratory to test the effect of wavelength on photosynthesis. Part of the experimental method directed Tatiana to 'add a few bunches of leaves' of an aquatic plant, *Elodea*, to a number of different test tubes. *Elodea* leaves naturally vary in size.

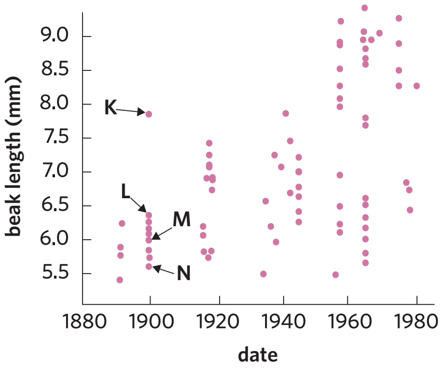
This experiment would be

A repeatable only.
B reproducible only.
C repeatable and reproducible.
D neither repeatable or reproducible.

Adapted from VCAA 2014 Section A Q26

Question 10 (1 MARK)

Scientists have measured the beak length of the soapberry bug, *Jadera haematoloma*, over time. Their results are shown in the graph.



Which of the following points is most likely considered to be an outlier?

A Point K

B Point L

C Point M

D Point N

SECTION B (30 MARKS)

Question 11 (10 MARKS)

Four groups of students carried out an experiment testing the effect of glucose concentration on the fermentation rate of yeast. Higher temperature indicates higher rates of fermentation.

Note: glucose is an input in the fermentation reaction.

a Identify the independent and dependent variable. (2 MARKS)

b Define the purpose of a control and outline a possible control for this experiment. (2 MARKS)

c Before beginning the experiment, each group practised measuring the temperature of water and checked the group's thermometer against an electronic thermometer that gave a true measure of temperature.

The following results were obtained during the practice.

Group	Thermometer readings (°C)			Electronic thermometer readings (°C)
	1st measurement	2nd measurement	3rd measurement	
1	18.0	16.5	17.5	20.1
2	19.0	18.0	18.5	20.5
3	21.0	21.0	20.5	19.9
4	20.0	19.0	21.0	20.0

i Identify which group has the most precise results. Justify your response. (2 MARKS)

ii Identify which group has the most accurate results. Justify your response. (2 MARKS)

iii Explain how testing the thermometers increases the reliability of the experimental results. (2 MARKS)

Adapted from VCAA 2018 Section A Q11

Question 12 (11 MARKS)

The effect of different concentrations of sucrose solution on the average height of groups of tomato plants was tested. Six groups containing 40 plants each were left to grow for 20 days. Each plant had an initial height of approximately 2 cm. Each group was watered daily with 5 mL of water.

a Identify the independent and dependent variables. (2 MARKS)

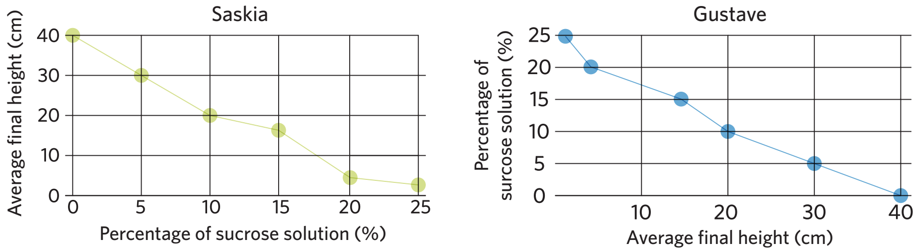
b List three variables that were controlled to ensure the experiment produced valid results. (3 MARKS)

c The concentration of sucrose solution for each group is shown in the table. The heights of the plants were measured and averaged for each group.

Plant group	Percentage of sucrose solution (%)	Average final height (cm)
A	0	40
B	5	30
C	10	20
D	15	15
E	20	5
F	25	2

i Saskia and Gustave both attempted to graph their results.

Effect of sucrose solution on the height of bean plants



Identify who has created the more correct graph. Justify your response. (2 MARKS)

ii Explain why groups of plants were used in the experiment rather than individuals and their height was averaged to form the results. (2 MARKS)

d Consider any experiment. Explain the difference between the accuracy and validity of measurements. (2 MARKS)

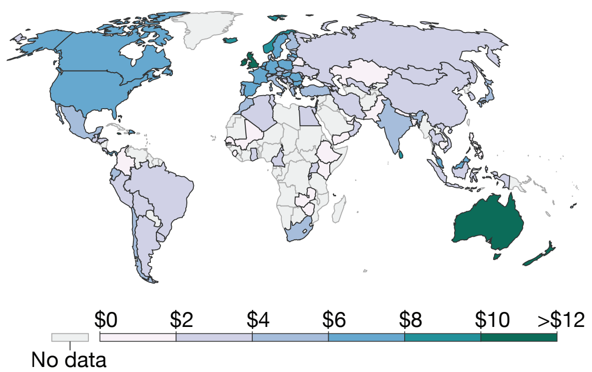
VCAA 2018 Northern Hemisphere Exam Section A Q36

Question 13 (9 MARKS)

The World Health Organisation (WHO) has released a report on the dangers of smoking tobacco. Over time, the WHO has encouraged countries to increase the price of cigarettes.

The graph displays the average price of a pack of 20 cigarettes measured in international dollars. The average price is calculated based on the prices of three brands of cigarettes known to be the most sold in the country. The average price is weighted by the market share of each of the three brands.

Average price of a pack of cigarettes, 2014



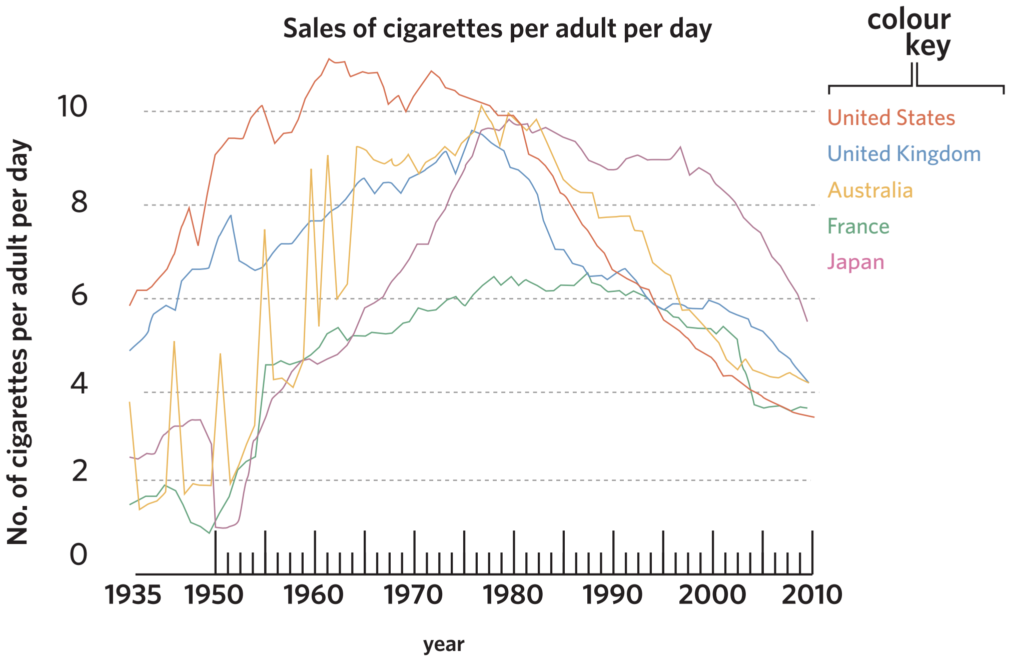
Source: World Health Organization Global Health Observatory (GHO)
Adapted from Roser and Ritchie 2019

a Identify one country that charges more than $10 for a pack of cigarettes. (1 MARK)

b Explain why the WHO would encourage countries to increase the price of cigarettes. (1 MARK)

c In 1980, it was estimated that 30.5% of the Australian population smoked daily when the population size was just under 15 million. This number decreased to 16.3% of the population in 2012 when the population was almost 23 million. Explain why these percentages were estimations rather than a true value. (2 MARKS)

d The graph displays the amount of cigarettes sold per adult per day in Australia, France, Japan, the United Kingdom, and the United States.



Source: International Smoking Statistics (2017), Adapted from Roser and Ritchie 2019

- **i** State which country had the highest average sales of cigarettes per adult per day. Identify when this occurred. (1 MARK)
- **ii** Describe the trend in the sale of cigarettes per adult per day in Australia from 1935 to 2010. Include data in your response. (2 MARKS)
- **iii** Compare the trend between Japan and France in the sale of cigarettes per adult per day from 1935 to 2010. Include data in your response. (2 MARKS)

1A What is a Key Science Skill?

Theory review questions

1 **a** Experimental group / treatment group
b Systematic error
c Valid
d Accurate
e Confounding factor/variable
f Outlier
g Control group or negative control group
h Random error
i Precise
j Reproducible
k Repeatable
l Dependent variable
m Independent variable

2 C
3 D
4 B
5 D
6 C
7 D

Exam-style questions

Key science skills

8 C
9 D
10 B
11 B
12 A
13 D

14 **a** [The independent variable is distance between GM and non-GM fields. The dependent variable is the percentage of seeds produced at various positions as a result of cross-pollination.[1]]

- I have correctly identified the independent variable and the dependent variable.[1]

b [A control group was not used in this experiment.[1]][Control groups are not exposed to the IV.[2]][An example of a control group would be setting up two fields of non-GM crops next to each other, and measuring the percentage of seeds produced at various positions as a result of cross-pollination.[3]]

Other acceptable responses include:

- A control group could be a non-GM crop set up in an isolated space e.g. a greenhouse.

- I have stated that there was no control group.[1]
- I have described the nature of control groups.[2]
- I have outlined what a control group would look like this experiment.[3]
- I have used appropriate biological terminology such as: IV, control, percentage.

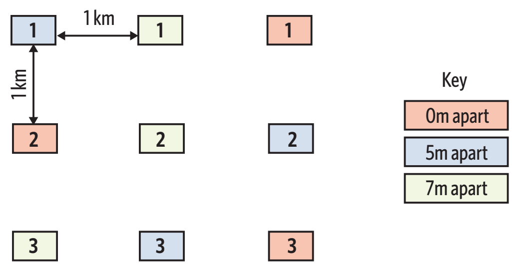
c [The general trend is that the further the distance between crops, the less cross-pollination.[1]][The most cross-pollination occurred when there was no gap between plots (10% cross-pollination at edge of crop, 2% 10m into crop).[2]][There was little difference between placing the crops 5 and 7m apart (both had 1% cross-pollination at edge of plot), except the plots 7m apart had only 0.3% cross-pollination 10m into the non-GM crop (as opposed to 0.5%).[3]]

- I have outlined the general trend of the data.[1]
- I have stated where cross-pollination was most common.[2]
- I have stated where cross-pollination was least common.[3]
- I have used data from the table to support my response.

d **i** [Replication allows you to take a mean of a group, so outliers or results influenced by random error have less impact on your results.[1]][Replication also helps scientists to understand the precision of their measurements.[2]]

- I have stated that replication reduces the impact of outliers and random error.[1]
- I have stated that replication gives a measure of precision.[2]
- I have used appropriate biological terminology such as: random error, outliers, precision.

ii [If they wished to replicate each experimental group three times, the farmers would need more plots and land.[1]][They could set up each group a great distance (e.g. 1 km) apart from each other to ensure they are not affecting each other, and plant three of each plot type.[2]]



- I have drawn and described an appropriately replicated experiment.[1]
- I have recognised that the replicates may affect each other, and attempted to overcome this issue in the design.[2]

e [By having the trials run at different times, different treatments may be exposed to different weather conditions (e.g. rain, light, temperature, wind).[1]][This could reduce the accuracy of the results[2]][and be a potential confounding factor.[3]]

- I have identified factors that may be uncontrolled over time.[1]
- I have stated this could make the results less accurate.[2]
- I have identified this problem as a confounding factor/variable.[3]

f [Farmer Y is benefitting from GM crops, but Farmer X is the individual who pays for the GM crops.[1]][The farmers should consider if this situation adheres to the ethical principle of justice.[2]]

Other acceptable responses include:

- Despite their initial agreement, Farmer Y is being forced to use GM crops. Even if she isn't too bothered by this, there may be effects on Farmer Y's crop of which she is not yet aware. The farmers should consider if this situation adheres to the ethical principle of respect.

- If Farmer Y's crop is becoming GM, then even more farms nearby may be affected. The farmers should consider the impact of their actions on others, and if the situation adheres to the ethical principles of beneficence and justice.
- Farmer Y may still be advertising her crops as non-GM. This is dishonest, and the farmers should consider if the situation adheres to the ethical principle of integrity.

I have identified one ethical issue.[1]

I have related the issue to the correct ethical principle.[2]

15 **a** [In this experiment, the IV is treatment with the drug and the DV is the number of individuals with the virus.[1]] [To begin, collect 100 mice[2]] [of the same age and genetic strain. They should be raised and kept in the same environmental conditions (e.g. temperature).[3]] [Infect all mice with the virus for which the drug has been designed, then give the drug to 50 of the mice (the experimental group). Make sure these mice are labelled/easily identified as different from the non-treated mice (the control group).[4]] [Over the coming days and weeks, the number of mice in each group with the virus should be counted.[5]] [If the number of mice in the control group with the virus is significantly greater than the number of mice with the virus in the treatment group, then the drug is most likely effective.[6]]

Other acceptable responses include:

- Give a placebo to the mice in the control group.
- Give groups of mice different concentrations of the drug to characterise its effect in more detail.

I have identified the IV and the DV.[1]

I have used a sufficiently large (e.g. >10) number of mice in the experiment.[2]

I have described the sample population as sharing a number of constant variables.[3]

I have described the control group and the experimental group, both of which are replicated.[4]

I have explained how to collect results, including the timing of collection.[5]

I have indicated what the results mean by referring to the effectiveness of the drug.[6]

I have ensured that the design does NOT involve administering the drug before the virus.

I have used appropriate biological terminology such as: control group, treatment group, significant.

b [Firstly, the welfare of the mice before and during the experiment should be considered. By ensuring the mice are fed, kept in clean and low-stress cages, stimulated socially and physically, and able to sleep, the scientists can address this issue.[1]] [Secondly, any pain or trauma experienced by the mice should be considered. This can be minimised by reducing the amount of handling and testing the drug for side effects on a smaller group prior to the experiment.[2]]

Other acceptable responses include:

- The scientists should consider what is done with the mice after the experiment. If they can be retired or used in another experiment, this is preferential to euthanasia.
- The scientists should consider how the virus affects the mice. If it causes extreme discomfort, they could use an attenuated version, or euthanise mice before they start to show severe symptoms, or not proceed with the experiment.
- The scientists should consider if there are long-lasting effects from receiving the drug. If there are severe effects, they may need to redesign the drug or halt experimentation.
- The scientists should monitor the side effects of the drug and have a plan for what happens if they occur. If the side effects are severe, they should stop administering the drug.

I have provided one ethical consideration, and suggested how it could be overcome.[1]

I have provided a second ethical consideration, and suggested how it could be overcome.[2]

I have signposted my response using terms such as: firstly, secondly.

c [The scientists should wear gloves and lab coats when handling the mice, to avoid contact with the virus.[1]] [They should also ensure the virus is kept in a well-labelled, safe, and lockable location so they can track and control its use.[2]]

Other acceptable responses include:

- They should conduct thorough research into the virus and drug prior to starting, and have processes in place if spillages or accidental infections occur.
- They should practice using syringes and other procedures before the experiment.
- They should keep the cages clean and dispose of waste appropriately to avoid disease.
- They should avoid breaking glassware, and clean it quickly and carefully if breakage occurs.
- They should wash their hands well after handling the mice, drug, and virus.
- They should use an attenuated version of the virus in their experiment, to reduce the chance of human infection.
- They should conduct the experiment in an isolated environment.

I have identified one reasonable safety precaution for this experiment.[1]

I have identified a second reasonable safety precaution for this experiment.[2]

1B Assessment of Key Science Skills

Theory review questions

1 **a** Methodology
b Independent variable
c Correlation
d Discrete data
e Continuous data
f Open inquiry
g Acknowledgements, or references
h Trendline, or line of best fit
i Categorical data
j Raw data

2 B
3 D
4 D
5 A
6 D
7 D
8 B

Exam-style questions

Key science skills

9 C
10 C
11 C
12 D
13 D

14 **a** [The independent variable is the concentration of antifungal medication,[1]][and the dependent variable is the size of the fungal colony.[2]]

Other acceptable responses include:

- The dependent variable is the diameter of the fungal colony.
- The dependent variable is the amount of fungal growth/survival.

I have identified the independent variable.[1]

I have identified the dependent variable.[2]

b [Sterile means aseptic, or free from microorganisms.[1]][Using sterile tools prevents contamination of the agar plates with environmental microorganisms or extra spores from other plates, so the results are more valid.[2]]

I have defined sterile.[1]

I have explained that sterile instruments prevent contamination.[2]

I have used appropriate biological terminology such as: microorganism, aseptic, valid, contamination.

c [Ibrahim replicated each experimental group twice.[1]][This is because he had two agar plates with the same concentration of antifungal medication.[2]]

I have stated the level of replication.[1]

I have outlined how Ibrahim replicated his experiment.[2]

I have used appropriate biological terminology such as: experimental group.

d [Ibrahim did not use a control group.[1]][This means he does not know how much fungal growth occurs without the antifungal medication, so he cannot compare his results to a baseline.[2]][If Ibrahim had two agar plates that were treated exactly the same as the other plates, but to which no antifungal medication was applied, this problem could be fixed.[3]]

Other acceptable responses include:

- Ibrahim should change gloves between each plating to reduce possible contamination/systematic error.

I have stated one poor experimental choice.[1]

I have explained why this is a potential problem for the experiment.[2]

I have suggested a modification to the experimental design to overcome the problem.[3]

e **i** [Generally, higher concentrations of antifungal medication results in lower mean diameters of fungal colonies.[1]][The mean diameter of fungal colonies is highest (3.2 cm) when treated with the 5 μg/mL fungal medication, and is lower (0.8 cm) at 10 μg/mL.[2]][Then, the mean diameter of fungal colonies actually increases slightly to 1.0 cm at 15 μg/mL,[3]][but decreases again until, at 25 μg/mL, there is zero growth.[4]]

I have stated the general impact of the IV on the DV.[1]

I have stated what occurs from 5 to 10 μg/mL.[2]

I have stated what occurs from 10 to 15 μg/mL.[3]

I have stated what occurs from 15 to 25 μg/mL.[4]

I have referred to data from the table in my response.

I have used the phrase 'mean fungal colony size' rather than just 'fungal colony size'.

ii [Ibrahim's hypothesis would have been that increasing fungal medication concentration decreases the amount of fungal growth.[1]][So, given that mean fungal growth decreases from 3.2 cm to 0 cm as concentration of antifungal medication increases, these results broadly support his hypothesis.[2]][However, the increase in fungal growth between 10 and 15 μg/mL is not in favour of his hypothesis.[3]]

I have stated what Ibrahim's hypothesis would be.[1]

I have stated how the results support Ibrahim's hypothesis.[2]

I have stated when Ibrahim's results do not support his hypothesis.[3]

iii [Graph M is the best representation of Ibrahim's data,[1]][because concentration and diameter are continuous variables.[2]]

I have stated that Graph M is the best representation.[1]

I have explained why, with reference to the type of data presented.[2]

Chapter 1 Review

SECTION A

1 C
2 D
3 B
4 B
5 B
6 B
7 B
8 B
9 D
10 A

SECTION B

11 **a** [The independent variable is glucose concentration.[1]][The dependent variable is the temperature change of yeast mixture.[2]]

- I have identified the independent variable.[1]
- I have identified the dependent variable.[2]
- I have not stated that fermentation rate is the dependent variable.

b [A control is compared with the treatment group/s, and any differences between the control and the treatment group can be attributed to the IV.[1]][A control for this experiment would be setting up a yeast mixture with no glucose added.[2]]

- I have explained the purpose of a control.[1]
- I have identified a possible control for this experiment.[2]

c i [Group 3 is the most precise[1]][as all results are within 0.5 °C of one another.[2]]

- I have identified the most precise group.[1]
- I have justified why it is the most precise.[2]

ii [Group 4 is the most accurate[1]][as all results are within 1.0 °C of the true temperature.[2]]

- I have identified the most accurate group.[1]
- I have justified why it is the most accurate.[2]

iii [Reliability refers to the degree to which results can be relied upon to be accurate.[1]][Testing the thermometers means we know if we can rely upon them to give accurate measurements, or if another tool should be used.[2]]

- I have defined what reliability refers to.[1]
- I have explained how testing the thermometers increases reliability.[2]

12 a [The independent variable is sucrose concentration.[1]][The dependent variable is the average final height of each group of plants.[2]]

- I have identified the independent variable.[1]
- I have identified the dependent variable.[2]

b [Some controlled variables include the initial height of every plant being 2 cm, the researchers watering every plant with 5 mL of water each day, and that the experiment uses the same plant species for each group.[1]]

Other acceptable responses include:

- Using 40 plants for each group.
- Having the same number of days of growth for each group.

- I have identified three controlled variables.[1]
- I have used appropriate biological terminology such as: controlled variables.

c i [Saskia's graph is more correct[1]][as she has followed standard practice by plotting the independent variable on the horizontal axis and the dependent variable on the vertical axis,[2]][unlike Gustave who has plotted the inverse.[3]]

- I have stated who has graphed the results correctly.[1]
- I have explained standard graphing practice.[2]
- I have explained why the other person is incorrect.[3]

ii [Increasing sample size makes results more reliable,[1]][because it is less likely they are affected by random outliers or an unrepresentative sample.[2]][By averaging the samples, the researchers gain a more precise result that explains what "most" plants do.[3]]

- I have outlined the effect of increased sample size on reliability.[1]
- I have explained why reliability is affected.[2]
- I have explained the effect of averaging the samples.[3]

d [Accuracy is a measure of how closely the experimentally obtained results match with the true result,[1]][whereas validity means the results measure what they claim to be measuring and exclude the effects of confounding variables.[2]]

- I have explained what is meant by the term accuracy.[1]
- I have explained what is meant by the term validity.[2]
- I have used comparative language such as: whereas.

13 a [Australia.[1]]

Other acceptable responses include:

- New Zealand.
- United Kingdom.
- Ireland.
- Singapore.
- Jamaica.

- I have identified a country that charges more than $10 for a pack of cigarettes.[1]

b [If countries increased the price of cigarettes, individuals would be deterred from buying them.[1]]

- I have stated a potential reason for the WHO's recommendation.[1]

c [These percentages were estimated as it would be unrealistic to sample the entire population.[1]][Instead a sample of individuals that is believed to be representative of the entire population would have been selected and their data used as an estimation.[2]]

- I have stated whether it is realistic to sample the entire population.[1]
- I have explained how the estimation would be calculated.[2]

d i [United States[1]][in 1961.[2]]

- I have stated the country with the highest peak.[1]

- I have identified the year in which this occurs.[2]

ii [The number of cigarettes consumed in Australia increases from 1935 to 1980[1]] [with random peaks and troughs throughout.[2]] [Reaching a maximal peak at approximately 10 cigarettes per adult per day in the late 1980's,[3]] [the results then decrease until reaching four cigarettes per adult per day in 2010.[4]]

- I have stated that the trend increases between 1935 to 1980.[1]
- I have stated there are random peaks and troughs.[2]
- I have approximated the maximal point.[3]
- I have described the final decrease.[4]
- I have used data in my response.

iii [Japan and France's graphs both share a similar shape, increasing between 1935 and 1980, before falling between 1980 and 2010.[1]] [However, the magnitude of the increase in Japan's graph is greater, reaching approximately 9.5 cigarettes per adult per day,[2]] [compared to France's peak at approximately 6.5 cigarettes per adult per day.[3]]

- I have explained how both graphs are similar.[1]
- I have stated that the magnitude of Japan's graph is greater.[2]
- I have made a comparison to France's graph.[3]
- I have used data in my response.