OCR (B) Biology GCSE

Topic B7: Ideas about Science

Notes

(Paragraphs in **bold** are higher tier only)

What needs to be considered when investigating a phenomenon scientifically?

Scientific explanations are based on data which must be carefully **collected** and **analysed**. There are many stages to scientific investigations.

Hypotheses and Predictions

Before any data can be collected and analysed, a **hypothesis** must be made. A hypothesis is a **possible explanation** for something which has been observed.

After the hypothesis is in place, a **prediction** is made to test whether the hypothesis is correct. The prediction is based on the hypothesis and is stated in such a way that it can be **easily tested**. The prediction will state how the effect of a **factor** will affect the outcome.

For example, suppose someone is investigating the effect of fertiliser on plants:

Hypothesis: *'Plants need lots of nutrients to grow. Fertiliser provides nutrients to the soil, thus allowing plants to grow more.'*
Prediction: *'If I add fertiliser to the soil of some basil seedlings, but not others, then the seedlings with fertiliser will grow taller and will have more leaves than the non-fertilised seedlings.'*

The prediction is tested by carrying out **experiments**.

Experiments

Experiments are carried out to directly test the **prediction**. Before planning the experiments, it is important to identify the different variables:

- ➔ **Independent variable** - the thing that you change in the experiment
- ➔ **Dependent variable** - the thing that you measure in the experiment
- ➔ **Control variables** - things which must be kept constant throughout the experiments

Control variables are important to ensuring a **fair test**. They must be kept the same throughout the experiments, otherwise they may affect the results of the experiment, making the experiment **invalid**.

For example, if you are investigating the effect of light intensity on the rate of photosynthesis of pondweed, then the independent variable is distance of the lamp from the pondweed and the dependent variable is the rate of photosynthesis which is given by the number of bubbles produced per minute. The species of pondweed, carbon dioxide concentration, temperature and the time allowed for gas formation are all control variables since these factors will also have an affect on the rate of photosynthesis.

Generally, control variables are easy to control as it often just involves ensuring the reaction has been done for the same amount of time using a **stopwatch**. A **water bath** may be used to control the temperature of the surroundings of a reaction.

When planning an experiment, you must decide what **data** needs to be **collected** and what **measurements** will be taken. Depending on the type of investigation, this may include choosing a **sample size** or **range of values** which will be measured. When choosing a sample size or a range of values, it is important that it is big enough so that a reasonable correlation/conclusion can be taken from the results, but not too big that it will take an unnecessary amount of time for results to be collected and processed.

Once the type of data is chosen and the variables are outlined, the experiment method can be written. Within the method, **appropriate equipment** must be chosen which will make up an **apparatus list**. The equipment must be **suitable** for the job and must be chosen to ensure the data is as **precise**, **valid** and **accurate** as possible:

For example, if you need to measure 13 cm^3 of liquid, use a measuring cylinder which can measure to 1 cm^3 - not 5 or 10 cm^3.

The method must be **clear**, **concise** and **repeatable** - it is important that other people can recreate the experiment and get the same results.

Along with the method, a **risk assessment** should be carried out to identify any hazards and risks.

Hazards and Risks

A **hazard** is something which could cause **harm**. A **risk** is the **chance** that the hazard will cause harm.

Experimental hazards can involve **chemicals**, **electricity**, **fire** and **glass**. It is important to identify all possible hazards in an experiment, so that procedures can be put in place to **reduce the risk**.

Depending on the hazard, **reducing the risk** can be done by using **lower concentrations** of chemicals, putting a bunsen burner on a **heat proof mat** and **removing any glassware** which is not in use.

For example, if working with hydrogen peroxide, always wear safety glasses and gloves as it is an irritant. This will reduce the risk of the acid burning your skin and eyes.

What processes are needed to draw conclusions from data?

After carrying out an experiment to investigate a hypothesis, there is a **process** of **collecting**, **presenting** and **analysing** the data.

Processing Data

Significant Figures

Experimental measurements must all be taken to the same number of **significant figures**. In any further calculations involving the results, the answers must be rounded to the **lowest number of significant figures** given.

Nomenclature and SI units

IUPAC chemical nomenclature is the worldwide system used for naming chemical compounds. It is important that chemicals are named in this way during an investigation, as this ensures the investigation can be read worldwide.

SI units are the standard units used all over the world. SI units must always be chosen when appropriate, as this ensures the data is easily **translatable**.

Quantity	SI Base Unit
Time	Second, s
Length	Metre, m
Energy	Joule, J
Mass	Kilogram, kg

Since data comes in a high range of sizes, various **prefixes** can be used to make the size of the numbers easier to process.

Prefix	Tera (T)	Giga (G)	Mega (M)	Kilo (k)	Centi (c)	Milli (m)	Micro (μ)	Nano (n)
Comparison to the base unit	1,000,000,000,000 times bigger	1,000,000,000 times bigger	1000000 times bigger	1000 times bigger	100 times smaller	1000 times smaller	1000000 times smaller	1000000000 times smaller

Interconverting units

You need to be able to **convert between units** as some equations or formulas will require measurements in specific units.

kg → x 1000 → g
g → ÷ 1000 → kg
m^3 → x 1000 → dm^3 → x 1000 → cm^3
cm^3 → ÷ 1000 → dm^3 → ÷ 1000 → m^3

g/cm^3 → x 1000 → g/dm^3
g/dm^3 → ÷ 1000 → g/cm^3

Errors

The experimental results will always vary slightly due to **random errors**. These types of errors may occur due to changes in environmental **conditions**, a worn out measuring **instrument** or a **person** taking an incorrect measurement.

If the results are wrong by the same amount every time then there is a **systematic error**.

An **anomalous result**, is a result which does not fit the **trend** of the other results. If there is a clear reason supporting the result as an anomaly (i.e. you work out what went wrong with that measurement), then it should **not be included** in the processing of the results.

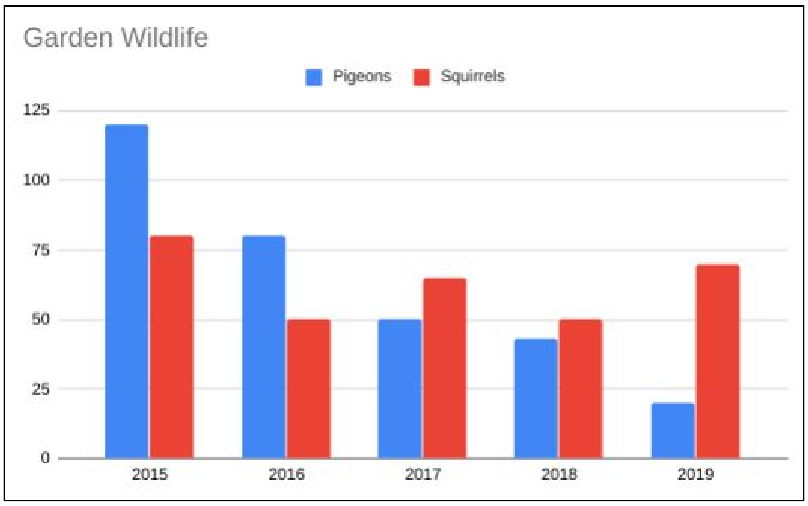
Presenting Data

Presentation of Data

Tables are commonly used to organise data. Tables must be drawn with a ruler and each column must have a **header**. The **units** must be included in the header - not in the main body of the table.

Beaker	Experiment 1 (cm^3)	Experiment 2 (cm^3)	Mean (cm^3)
A	50	32	41
B	45	29	37

If the data collected is split into **categories**, it can be presented in a **bar chart**. A bar chart allows for easy **comparison** between various categories.

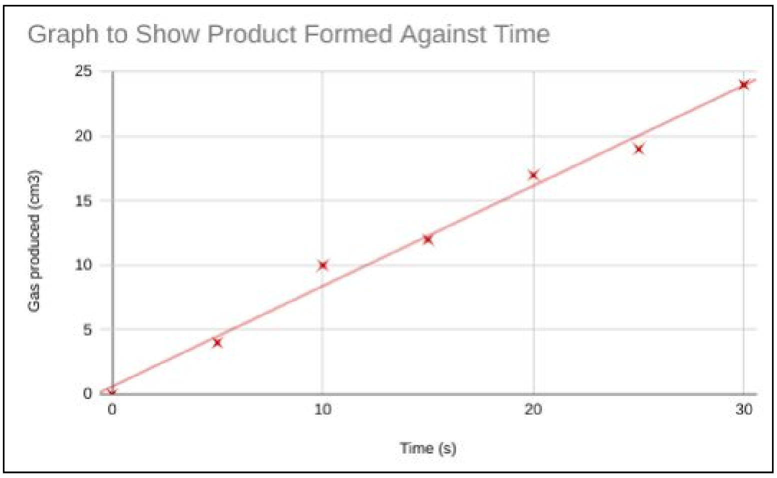


Drawing a bar chart:

1. Scale must be linear (divisions between values must be equal).
2. Label the axes and include the units.
3. Include a key to distinguish between the data.

4. Leave a gap between the various categories.

If the data is **continuous**, it can be plotted on a graph. **Continuous data** is data which can be measured and can have any value within a range.


Graph to Show Product Formed Against Time

Plotting a graph:

1. Draw a sensible scale on the axes.
2. The dependent variable goes on the vertical y axis.
3. The independent variable goes on the horizontal x axis.
4. Use a sharp pencil to plot data points, mark them as crosses.
5. Draw a line/curve of best fit through as many data points as possible. Ignore any anomalous results.

When drawing any type of graph you must use an appropriate scale as well as axes. Your graph should also take up the majority of the graph paper.

Range bars can also be drawn to indicate **uncertainty or variation** in the results that have been collected.. These are lines which are drawn at points on the graph and are parallel to one axis. A range bar indicates the highest and the lowest repeat measurements that have been taken.

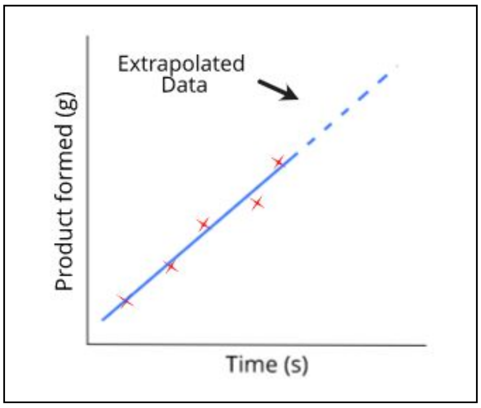
The **rate of reaction** can be calculated from the **gradient** of a graph if the amount of product formed/reactant used has been plotted against time.

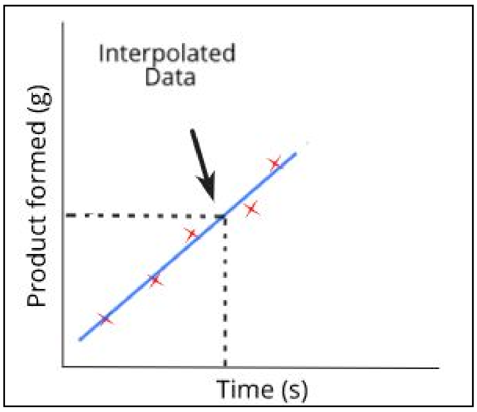
Gradient = (change in y) ÷ (change in x)

Extrapolation and **interpolation** are also techniques which can be used to obtain values from graphs.

- **Extrapolation** involves continuing the trend on further to obtain **more data points** just **outside the range**.

- **Interpolation** involves constructing **new data points within the range** of known data points. This can be done by use of a line/curve of best fit.





Statistics

Statistics such as range and mean can be calculated when processing results. This will give values which can be **easily compared** across a range of experiments. **Anomalous results** should **not be included** in these calculations.

The **range** indicates how **spread** the data is:

Range = largest number - smallest number

The **mean** should always be calculated if **repeats** of an experiment have been carried out:

Mean = (Sum of all data value) ÷ (Total number of data values)

Experiment Improvements

It is important to **evaluate** the **success** of the experiment.

- Was the method **valid**?
- Was it a **fair** test? Were all the **control variables** controlled?
- Were there any **anomalous** results?
- Was there enough evidence for a **valid conclusion** to be reached?

From these questions, you should suggest any changes to the experiment which might increase the **quality** of the results obtained.

A possible suggestion for **improving accuracy** could be to take measurements at narrower intervals.

For example, suppose you investigate the temperature at which an enzyme works best by taking measurements at 30°C, 40°C and 50°C. Furthermore, suppose the results show that *the enzyme works best at 40°C. The result could be made more accurate by repeating the experiment with more measurements taken around 40°C.*

Following on from the scientific investigation, you could also suggest **further investigations** which could be carried out.

Drawing Conclusions

In order to reach a conclusion, you must **analyse the pattern** of the data. It is important that you **only conclude what the data shows** - you should not go any further. The results must justify the conclusion and the conclusion must state whether or not the data supports the **original hypothesis** made.

For example, from the data on the right, we can conclude that enzyme A increases the rate of reaction more than enzyme B. The rate of reaction was 7.5 cm^3/s faster with enzyme A compared with enzyme B.

Enzyme	*Rate of reaction (cm^3/min)*
A	18.5
B	11.0

How are scientific explanations developed?

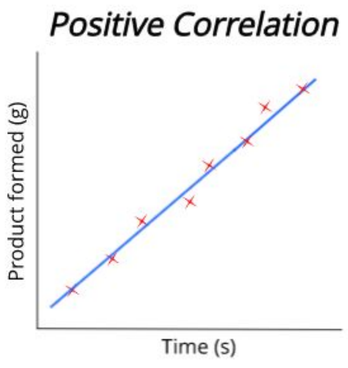
The identification of a **correlation** can lead to the identification of a **causation** which provides the basis of scientific explanations. The explanations are then developed and **modified** when **new evidence** is discovered. **'Peer review'** is also a process used to evaluate and develop scientific explanations.

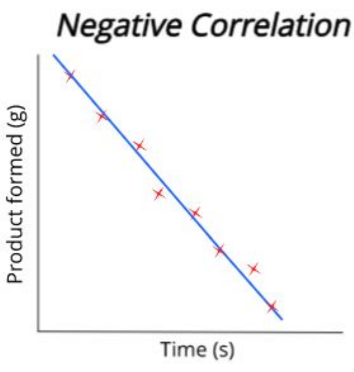
Correlation and Causation

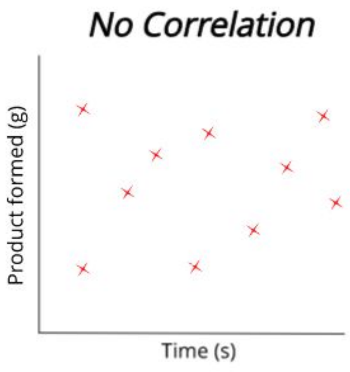
Correlation is not the same as **causation**.

A **correlation** describes the size and direction of a **relationship** between two or more variables. Importantly, a correlation between variables does not automatically mean that the change in one variable is the cause of the change in the other variable.

Correlations can be observed from **graphs** as follows:


Positive Correlation


Negative Correlation


No Correlation

Individual cases do not provide convincing evidence for or against a correlation as it is common for there to be some exceptions to a correlation.

For example, there has been shown to be a correlation between smoking and lung cancer, however there are some people who smoke but have not developed lung cancer. These individual cases are exceptions and do not disprove the correlation.

Causation, also known as **cause and effect**, indicates that one event is the **result** of the **occurrence** of the other event. Some correlations can be shown to be causations, if enough scientific evidence is provided to back up the theory.

For example, there is a correlation between carbon dioxide levels in the atmosphere and average global temperatures. This can be stated to be a causal link since the greenhouse effect explains how increasing levels of carbon dioxide in the atmosphere leads to increases in temperature on Earth.

An example of a correlation which is not a causal link is the correlation between sunglasses sales and hayfever. Clearly this is a correlation and not a causation as clearly sunglasses sales does not cause hay fever.

Modification of Scientific Theories

The biggest cause for the **modification** of scientific theories is the discovery of **new evidence.** The proposition of a scientific explanation involves **creative thinking**. An example of this is Darwin's theory of evolution by natural selection.

New evidence and data to support an explanation often relies on **technological developments**. This is why a theory often changes as the technology available becomes more advanced. Darwin's theory was not widely accepted however with the help of technology scientists have been able to prove that this theory can be applied to the development of **antibiotic-resistant bacteria such as MRSA**.

The buildup of **new evidence** can lead to a **hypothesis to be modified** and sometimes even becoming an accepted explanation or theory.

A **scientific theory** is a **general explanation** which can be applied to a large number of situations or examples whereas a **scientific explanation** is the **application** of a scientific theory to a particular situation.

Peer Review

The **'peer review'** process of developing a scientific explanation involves new scientific claims being **evaluated** by **other scientists**. It is important that new scientific findings are checked by the scientific community before being generally accepted as a scientist's personal background, experience or interests may **influence their judgements**.

Once a scientific explanation is accepted, it usually survives and remains in place (even if new evidence disagrees with it) until a better explanation is available.

Models and their Limitations

Models are used to help **explain ideas** and to **quickly test** explanations, without ethical or practical limitations.

A model represents the **main features** of a system and can be used to predict possible outcomes.

There are a wide range of different types of models.

- **Representational models** use physical analogies or spatial representations to help visualise explanations and mechanisms.

  Descriptive models are used to explain specific phenomena.

- **Mathematical models** predict behaviour by using data patterns of past events and already known scientific relationships. Computers are often used to carry out the complex calculations.

Due to the simplifications, there are **limitations** to models. For example, the limitations of the **lock-and-key** enzyme model includes the fact that it doesn't show that the active site of the enzyme actually slightly changes shape as the substrate enters.

How do science and technology impact society?

As well as advancing scientific explanations, science and technology have a significant effect on society.

Benefits of Science

Science and technology can benefit people's lives, and can improve their **quality of life**.

There are many **examples** which demonstrate the benefits of science:

- **Vaccinations** protect children from potentially life-threatening diseases
- **Monoclonal antibodies** can be used for pregnancy testing and diagnostic tests for diseases
- **Antibiotics** are used in the treatment of diseases
- **IVF** can be used to help couples with fertility problems
- **Fertilisers** supply nutrients to crops, helping them to grow better.
- **Water** can be suitably processed to be made **potable** (safe to drink)

Risks

Some applications of science can pose a risk to people's **quality of life** or to the **environment**. Scientists work to **reduce** the negative impacts of the applications. This can involve using **sustainable** resources, and carrying out processes to prevent pollutants entering the atmosphere.

Nothing is completely risk free, and everything carries a certain level of risk of **accident** or **harm**. The **size** of a risk can be estimated by analysing data. For example, you could estimate the risk of cycling accidents by recording how many people in a group of 100,000 cyclists have an accident over the period of a year.

People are generally **happier to accept** a risk if it is associated with something they **choose** to do, rather than something which is **imposed**. People will also more easily accept a risk with **short term effects**.

Higher Tier Only

People often have an idea of a perceived risk, which regularly differs from the calculated risk. A perceived risk is often an overestimate of the risk as people tend to overestimate the risk of unfamiliar things. For example, cycling is relatively high risk and flying is pretty safe, but many people would believe that flying is more high risk than cycling since it is unfamiliar. Also, people overestimate the risk of things whose effect is invisible or long-term, like ionising radiation.

Ethical Issues

Some scientific explanations can have **ethical implications**.

An example of an ethical issue is the **use of embryonic stem cells.** During this process, embryos are destroyed which leads to **controversy** as there are many **differences in opinion** as to when the embryo should be considered a person.

Another example of an ethical issue is the use of **genetic engineering**. Genetic engineering has many useful medical applications, however it is still relatively new science, and so the potential effects of the inserted gene on the body, as well as on the environment, are largely unknown.

It is generally argued that the **right decision** is the decision which leads to the **best outcome** for the **greatest number** of people.

Communicating Science

Scientists must communicate their work in a way which can be **understood** by a **range** of audiences - including the **public**, other **scientists**, and **politicians**. This allows **decisions** to be easily made based on information given about risks, benefits, costs and ethical issues.