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INVESTIGATING SCIENCE IN FOCUS

YEAR 12

Dr Silvia Rudmann
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Bill Matchett

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Investigating Science in Focus HSC
1st Edition
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Publishing editor: Rachel Ford
Project editor: Simon Tomlin
Editor: Kate McGregor
Proofreader: Brigid Brignell
Indexer: Don Jordan, Antipodes Indexing
Cover design: Chris Starr (Watermark)
Text design: Watershed Design
Art direction: Petrina Griffin
Cover image: iStock.com/from2015
Permissions researcher: Wendy Duncan
Production controller: Karen Young
Typeset by: MPS Limited

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National Library of Australia Cataloguing-in-Publication Data
A catalogue record for this book is available from the National Library of Australia.

Cengage Learning Australia
Level 7, 80 Dorcas Street
South Melbourne, Victoria Australia 3205

Cengage Learning New Zealand
Unit 4B Rosedale Office Park
331 Rosedale Road, Albany, North Shore 0632, NZ

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Printed in China by China Translation & Printing Services.
1 2 3 4 5 6 7 22 21 20 19 18

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INTRODUCTION

Preface

Investigating Science in Focus has been written to meet the requirements of the NESA NSW Syllabus for the Australian Curriculum – Investigating Science Stage 6 Syllabus. Each page has been carefully considered to provide students with all of the information they need to meet the content and skill requirements of the new syllabus including opportunities for inquiring further.

With the introduction of the student-focused depth studies, *Investigating Science in Focus* includes scaffolds for a range of depth studies at the end of each module of work. Additional ideas for depth studies are included in the PowerPoint presentations found on NelsonNet.

About the authors

Dr Silvia Rudmann

Silvia is a passionate science teacher with classroom and executive experience. She is an experienced senior biology teacher, HSC marker and GATS program coordinator.

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An experienced author, executive and classroom teacher, Bill has also been a school certificate and HSC marker.

Review team

The following people have contributed to the review of the *Investigating Science in Focus* series: Lisa Dean, Katherine Mason and Catherine Munro.

USING *INVESTIGATING SCIENCE IN FOCUS*

At the beginning of the text

- Chapter 1 introduces students to the process of working scientifically.
- Chapter 2 guides students through the key stages when preparing for and completing a depth study.

At the beginning of each chapter

- A short chapter summary for Chapters 3–6 introduces students to the key content and skills covered.
- Inquiry questions help engage and pre-test students before introducing them to the content.
- Key content and outcomes are listed to contextualise students' learning.

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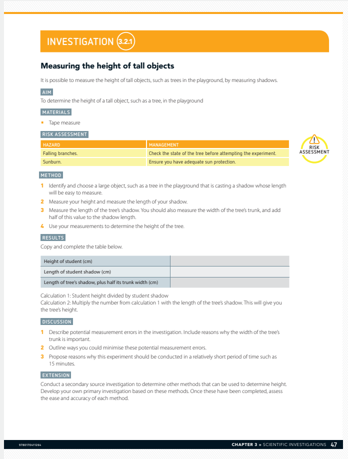
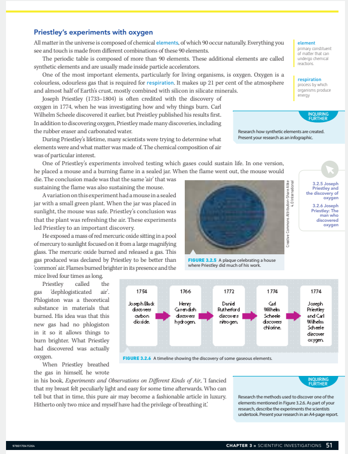
In each chapter

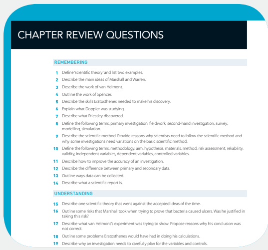
- The content in the syllabus is presented in a step-by-step approach.
- Key glossary terms are highlighted in the margin.
- Inquiring further provides opportunities for students to further investigate scientific concepts and develop scientific research skills.
- Investigations (practical experiments) contain guided instructions on the materials, method collection, analysis of results and discussion.


INVESTIGATION 3.2.1
Measuring the height of tall objects


Priestley's experiments with oxygen

At the end of each chapter

- Chapter review written in the style of Bloom's Revised Taxonomy
- Depth study scaffolds for biology, chemistry, physics and general science topics


CHAPTER REVIEW QUESTIONS

At the end of the book

- Glossary of all of the new terms introduced in the text
- Answers to section and chapter review questions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SYLLABUS REFERENCE GRID

OUTCOMES	INVESTIGATING SCIENCE IN FOCUS YEAR 12
SKILLS	
Objective: students develop skills in applying the processes of working scientifically	
Questioning and predicting	
INS11/12-1 Develops and evaluates questions and hypotheses for scientific investigation	Chapter 1, Chapter 2, Chapter 3, Chapter 4
Planning investigations	
INS11/12-2 Designs and evaluates investigations in order to obtain primary and secondary data and information	Chapter 1, Chapter 2, Chapter 4, Chapter 5
Conducting investigations	
INS11/12-3 Conducts investigations in order to obtain primary and secondary data and information	Chapter 1, Chapter 2, Chapter 3, Chapter 5
Processing data and information	
INS11/12-4 Selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media	Chapter 1, Chapter 2, Chapter 3, Chapter 4, Chapter 5
Analysing data and information	
INS11/12-5 Analyses and evaluates primary and secondary data and information	Chapter 1, Chapter 2, Chapter 6
Problem solving	
INS11/12-6 Develops and evaluates questions and hypotheses for scientific investigation	Chapter 1, Chapter 2, Chapter 6
Communicating	
INS11/12-7 Communicates scientific understanding using suitable language and terminology for a specific audience or purpose	Chapter 1, Chapter 2, Chapter 6
KNOWLEDGE AND UNDERSTANDING	
Objective: students develop knowledge and understanding of cause and effect	
INS11-8 Identifies that the collection of primary and secondary data initiates scientific investigations	Chapter 3
INS11-9 Examines the use of inferences and generalisations in scientific investigations	Chapter 4
Objective: students develop knowledge and understanding of models, theories and laws	
INS11-10 Develops, and engages with, modelling as an aid in predicting and simplifying scientific objects and processes	Chapter 5
INS11-11 Describes and assesses how scientific explanations, laws and theories have developed	Chapter 6

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1 WORKING SCIENTIFICALLY

We often work scientifically in our daily life without realising that we are applying scientific skills. For example, when we cook a new recipe, we collect the ingredients and follow a method; we take care with safety hazards and we create a delicious meal. Hence, we follow the scientific method and intuitively, we apply scientific skills. In science, we move from the intuitive aspects of our everyday life to more structured and explicit skills, to research inquiry questions and inferences that arise to understand the world around us.

In today's world, the practice and nature of science is more interconnected and less linear than it has been in previous centuries. Hypotheses and methods are redefined and modified depending on the analysis of data. Collaboration among scientists from across different scientific disciplines helps to deepen knowledge about the science behind the investigation, and consolidates the understanding of scientific concepts and processes.

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1.1 Questioning and predicting

In science, the question is more important than the answer. The first time a phenomenon is observed in the natural world, questions form in an attempt to develop an explanation for, and consequently understand, what is happening. **Inquiry questions** in science are formulated to try to explain an idea and inferences about an observed phenomenon. To create or formulate a scientific question or inquiry question, it is vital to understand that the question should be able to be investigated scientifically following the steps in the scientific method.

inquiry question
driving force of the research; can be investigated scientifically

WS 1.1.1 Questioning

A good research inquiry question has the following characteristics:

- should be able to be investigated by gathering data
- does not have a pre-set or determined answer
- is the driving force of the research
- provides structure to the research.

INQUIRING FURTHER

Imagine you are observing an eagle flying in circles on the top of grasslands. How many scientific questions can you formulate? Refer to the characteristics of a good research inquiry question above as you formulate your response.

Formulating hypotheses

Once the question is formulated, a **hypothesis** is created. A hypothesis is an educated (informed) guess that is tested through experimentation to answer a scientific question. In the hypothesis, the **independent variable** (factor that changes) and **dependent variable** (factor that is measured or tested) are related in a simple statement (Table 1.1.1).

hypothesis
educated guess tested through experimentation to answer the inquiry question; states the relationship between the independent and dependent variables

independent variable
factor deliberately changed during an investigation to obtain data

dependent variable
factor measured in the investigation (e.g. plant growth, boiling point, speed)

TABLE 1.1.1 From an idea to a hypothesis

RESEARCH IDEA	RESEARCH QUESTION	HYPOTHESIS
Television and consumer behaviour	How does the number of repetitive advertisements affect consumerism in adolescents?	Adolescents buy more products if there are more advertisements for those products on television.
Tyre pressure and speed in cycling	How does tyre pressure affect the speed of a bicycle?	The speed of the bicycle will increase when the tyre pressure increases.
Soil acidity and plant growth	How does the acidity of the soil affect the number of flowers?	Soil that is more acidic will have fewer flowers.

Writing a hypothesis

A hypothesis is a statement or assertion. In the hypothesis statement, the dependent and independent variables are related. As a general rule, to write a proper hypothesis both variables must be in the hypothesis statement. For example, writing a hypothesis that says, 'Sunlight burns leaves' is a factual statement. If the same sentence is written combining the dependent and independent variables, it would read, 'The amount of sunlight (independent variable) will affect the process of photosynthesis (dependent variable)'. The second statement shows the relationship between the two variables.

The more specific the hypothesis, the easier it will be to design the experiment.

KEY RULE

To write a hypothesis statement use the scaffold:

The … (independent variable) will affect, increase or decrease the … (dependent variable).

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WORKED EXAMPLE 1.1.1

1 A farmer is growing a new variety of lettuce and asks the following question:
How much fertiliser do I need to apply to get the most leaves from lettuces?

2 The farmer passed the question on to the local research centre where they created following hypothesis:
An increased amount of fertiliser (independent variable, what is changing) will increase the number of leaves (dependent variable, what is being measured) in lettuces.

3 In this hypothesis, the independent variable will be the different amounts of fertiliser and the dependent variable is the number of leaves in the lettuce.

Modification of questions and hypotheses

Sometimes, over the course of the data collection and analysis, new hypotheses and questions arise. This is a common consequence of the nature and practice of science, and it is not considered a problem. It is common to see scientists changing their ideas and refining their hypothesis over the course of the investigation as a result of new evidence. However, it is important to keep in mind the focus of the investigation because time and resources may be wasted if the new hypothesis is very remote from the original researched topic. For example, if the hypothesis is about how the quality of light affects photosynthesis rate and over the course of the experiments the evidence shows that light quality is not showing any difference in photosynthesis rates, a new hypothesis might arise to test the position of the plants towards the light. This revised hypothesis is a good one as it takes into account the observations while also keeping in mind the original focus (in this case, photosynthesis rates).

Data collection

Now that the hypothesis is clear, the next step will be to think about the type of **data** that needs to be collected to test that hypothesis. There are two main types of data: primary and secondary data. Primary data refers to the **empirical data** collected from experiments, and tests done in the laboratory and on field trips. The data could be as simple as a list of observations or as complex as numerical measuring data. The numerical data is organised in tables or graphs for further analysis or for application in mathematical equations. When the collection of data is coming from experiments that the scientists themselves have collected, the investigation is called a primary investigation.

data
numerical or observational facts collected together as evidence for analysis

empirical data
information collected by observations or measurements during an investigation

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FIGURE 1.1.1 Primary data is collected from primary investigations; for example, from experimental methods or field trips. Samples collected in the field are then processed in the laboratory for further analysis.

Secondary data refers to previous data published in scientific literature related to the topic that the investigation is based on. It is data that other scientists have already collected to test a similar hypothesis. Secondary sources include web pages, books and articles published in journals. The most important thing when using secondary sources for data collection is that they are **valid**. The validity of secondary data relies on the sources coming from educational, government or scientific institutions where the data is evaluated by a board of scientists before it is published. This ensures that the data and information is accurate and reliable. When the data collected comes from secondary sources, the investigation is called a secondary investigation.

valid
extent to which a report or investigation contains accurate data, inferences and conclusions

1.2 Planning investigations

Once the research inquiry question and the hypothesis have been established, the next step is to create a design or plan for the investigation and the collection of data. Starting an investigation without a plan will not only waste time and effort but is also unlikely to deliver valid results. Before beginning an investigation, you should consider the following questions.

- What kind of data do you need to collect?
- What equipment or materials do you need?
- How many variations of the independent variable will you test?
- What are the safety issues that you should consider?
- How are the results going to be recorded and analysed?
- What steps are you going to follow to test the hypothesis?

To answer those questions, you need a plan and a **log book** to keep track of the progress of your research. A log book is an important tool in research because it allows you to keep records, identify **errors** and change or improve methods if needed. It is the journal of your research. Every scientist around the world has a research log book. Log books are very valuable because if a scientist wants to repeat experiments or come back to the 'raw data' collected, all the information is recorded and readily available.

log book
journal taken during the investigation where all data, observations, results, inquiries and conclusions are registered

error
measure of the estimated difference between the observed or calculated value of a quantity and its true value

Aim

Writing an **aim** for the investigation is important. This statement, together with the hypothesis and the inquiry question, helps to keep the investigation focused.

To write the statement for an aim, start with a verb; for example, 'To investigate; To measure; To collect', then add the relationship between the variables from your hypothesis; for example, 'To investigate the effect of high levels of CO_2 (independent variable, different levels of CO_2) on the length of the leaves (dependent variable, plant growth) of grasses'.

aim
purpose of the investigation

Selection of materials, technologies and identification of safety risks

So far the question, the hypothesis and the aim should all show the relationship between what is going to be investigated and how. When these statements have been clearly written, the selection of equipment or materials to perform a primary investigation (experiments) or review secondary sources (theoretical research) can take place.

The equipment selected to be used in the experiment should accurately measure and collect data. Because **accuracy** is defined as how close a result is to the **true value**, an accurate data set will have minimal errors. Therefore, the measurements should be taken with equipment that is made and calibrated for its purpose. For example, measuring the length of a plant with a ribbon is less accurate than measuring with

accuracy
level to which a measurement, calculation, or specification conforms to the correct value or a standard

true value
measurement with no errors

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a ruler, and testing the pH (acidity) of a substance with litmus paper is less accurate than measuring with a **data logger**.

The **safety hazards** associated with an investigation must be identified before any experimentation takes place and statements explaining how to avoid those hazards are explicitly written. For example, a few safety hazards to keep in mind when designing experiments include: chemical spills, electric shocks, chemical fumes, broken glassware, allergic reactions, and eye and skin contact with chemicals. Once those hazards are identified, a **risk assessment** takes place to avoid or deal with them. For instance, taking the example of broken glassware, the risk assessment statement should say, 'Handle glassware with care. In case of broken glassware notify the teacher'. The risks in science are assessed by their likelihood and severity of consequences, as shown in Table 1.2.1. For example, a strong acid spill may be considered to have a possible likelihood of occurring with either moderate or major consequences.

data logger
electronic or digital device that records data either with a sensor or digital aid

safety hazard
expected risk during an investigation

risk assessment
evaluation of the risks of an investigation

TABLE 1.2.1 Risk assessment matrix.

	Risk matrix	Likelihood				
		Rare	Unlikely	Possible	Likely	Almost certain
Consequence	**Severe:** For example, potentially fatal or causing an injury or illness with permanent disability	MEDIUM	MEDIUM	HIGH	EXTREME	EXTREME
	Major: For example, causing a 'potential time lost' injury, but non-permanent disability	LOW	MEDIUM	MEDIUM	HIGH	EXTREME
	Moderate: For example, an injury or illness requiring moderate medical treatment but no lost time	LOW	LOW	MEDIUM	MEDIUM	HIGH
	Minor: For example, an injury potentially requiring application of first aid	LOW	LOW	LOW	MEDIUM	MEDIUM
	Minimal: For example, a hazard or near-miss that requires reporting and follow-up action	LOW	LOW	LOW	LOW	LOW

Ethical issues

Ethical issues should also be considered during the planning of the investigation. For example, if the experiment involves animals, their welfare should be kept in mind, and methods to follow should be discussed with the teacher and school authorities.

If the collection of data will involve interviewing people or they have to answer surveys, the questions should avoid bias or inappropriate comments. A valid questionnaire for interviews or surveys must be objective and with the hypothesis in mind.

INQUIRING FURTHER

More information and research about ethical issues in science can be investigated from the J. Reilly Center, University of Notre Dame, Indiana, USA.

ethical
whether what is being done conforms to good standards of behaviour

Method and variables

Method

A **method** is written in numbered, chronological steps. Each step starts with a verb followed by clear, simple instructions that indicate how to perform the experiment. The more meticulous the instructions in each step are, the easier and more repeatable the investigation is. The validity of the method relies on the clarity of the steps and ensures that the hypothesis is tested fairly. A valid method can also ensure the experiment is **reliable** because other scientists are able to repeat it, and obtain similar and comparable results.

The steps in a method are slightly different for primary and secondary investigations. In a primary investigation, the steps should specify variables but in a secondary investigation the steps are related to how the secondary resources are going to be managed.

method
experimental steps to follow to collect data and test the hypothesis of an investigation

reliability
extent to which an observation and/or measurement can be repeated under the same circumstances and produce similar results

variable measurable factor that can be changed or maintained in an experiment

treatment variation of the independent variable

control experimental set-up where the independent variable is not applied

voltage force pushing electrons around the circuit

controlled variable factor that is kept constant during the experiment

1.2.1 Virtual lab – dependent and independent variables

1.2.1 Designing investigations

Variables, control and treatments

As part of the method, the **variables** should be clearly identified to ensure the validity and reliability of the experiment. There are three types of variables: the dependent, independent and controlled variables. The identification of those variables and how they are going to be managed during the collection of data are the key to a successful experiment.

The independent variables are those factors that you change in the experiment. In the independent variable, the variations are called **treatments**. There is one treatment that does not have the independent variable which is called the **control**. The control treatment is the one that takes out the effect of the independent variable on the measurements, it is the one used to compare with the other treatments to see if the effects of the independent variable are valid. The different amounts of fertiliser, the different concentrations of chemicals reacting and the different heights that a ball is dropped are all examples of independent variables.

The dependent variables are the features or factors that are measured or tested in the experiment. For example, plant growth, density of a material or **voltage** in a conductor. The changes in the dependent variable are influenced by the different treatments (variations) of the independent variable.

The **controlled variables** are all the factors that are kept the same to reduce error in the experiment. For example, the same equipment is used to measure across all the treatments, the amount of heat, the amount of light, the temperature of the room, the amount of water or the timing of the experiment. Keeping other variables constant ensures that the changes in the dependent variable are only influenced by one independent variable. If the results of the experiment do not look as expected usually it is because there were some controlled variables that were not kept the same for the entire experimental time.

It is very important to be clear about the differences in terminology. Controlled variables are variables kept constant during the experiment and a control is a treatment without the independent variable.

WORKED EXAMPLE 1.2.1

QUESTION

Observe the images of an experiment and identify the dependent, independent and controlled variables, as well as the control and treatment.

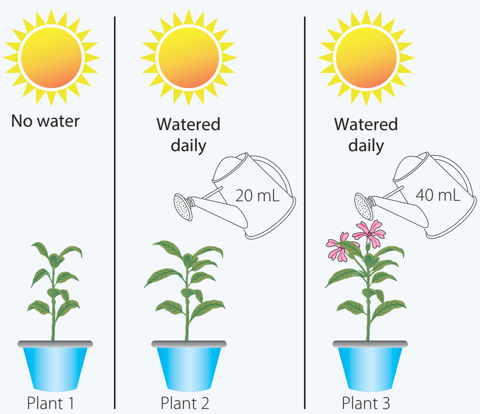

FIGURE 1.2.1 Investigating the effect of the amount of water on plant growth.

ANSWER

The experimental design can be deconstructed as follows:

- independent variable: amount of water (0, 20 and 40 mL)
- dependent variable: plant growth
- controlled variables: type of plant, room temperature, amount of sunlight, soil type, pot size, watering time
- control: Plant 1 (no water)
- treatments: Plant 2 (20 mL of water) and Plant 3 (40 mL of water).

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Sample size and replications

The reliability of the design, and consequently the results, depends on the amount of data collected and the number of replications of both the individual treatments and of the entire experiment. A large **sample size** is also important to reduce the impact of unusual results and allows for averages. For example, if testing the effect of the amount of water on plant growth, it is best to test it on many plants so that if one plant dies there are others that can be used to keep the measurements going.

sample size number of observations or replications in an experiment

The number of samples in an experiment is determined by the nature of the experiment, in some cases five samples is enough but in others more than a hundred are needed. As a rule of thumb, the bigger the sample size the better.

Replications are done in two ways: replicating each treatment and replicating the entire experiment. For example, to test the hypothesis, 'Increasing the amount of water will increase the height of plants' you will need five plants per treatment and a control. You also need to repeat the experiment three times to increase the reliability. Averages are calculated from all the data collected ensuring statistical validity.

Modifying and evaluating the investigation

An investigation is not a linear process. During the course of the collection of data, new evidence may emerge that does or does not support the hypothesis. Another issue is that the variables chosen may be difficult to measure with the technology available. Consequently, the original investigation plan is re-evaluated and a new plan is constructed.

Critical thinking is crucial to evaluate the investigation, and consultation with other researchers is important because an open collaboration helps accelerate the evaluation process and the resulting plan is more refined.

1.3 Conducting investigations

Conducting an investigation refers to the testing of your hypothesis statement by collecting data. The nature of the investigation may be primary (collecting empirical data from experiments) or secondary (collecting theoretical data from bibliographic references and previous work conducted on the researched topic by other scientists). In primary investigations, secondary sources are referenced as a way to compare the empirical results with previous findings by other researchers.

The data and results must be methodically recorded in the log book for later analysis. Safety procedures and risk assessments are followed to ensure a safe work practice. It is important to keep the inquiry question and hypothesis in mind so that no unnecessary data is collected and no time is wasted. Accuracy and reliability of the conducted investigation are ensured by using appropriate technologies and replications.

The work in the investigation may be done individually or in teams. This will depend on the nature of the work. However, it is very important to work collaboratively and share the information gathered from the investigation. This allows for a better review of the methods, and analysis of data and evidence that support the hypothesis.

Safe work practices

Safety is the first and most important consideration in conducting any investigation. The management of chemicals, equipment and practices done in the laboratory or in the field must follow safety procedures and risk assessments to ensure a safe environment for everyone.

Personal protective equipment

Personal protective equipment (PPE) must be used at all times when dealing with experimental practices. Some examples of PPE include: safety glasses or goggles, enclosed-toe safety shoes, disposable gloves, disposable apron or lab coat, hard gloves, long pants and a mask.

Assessing risks

Risk assessments are used to identify, assess, reduce and control safety hazards when conducting investigations. Risk assessments are completed for every investigation. To start writing a risk assessment, the following questions are answered:

- What are the hazards in this experiment that can cause injury?
  For example, chemicals, heat, broken glass, poison, animals in the field and tripping over things.
- What are the risks to consider for the environment, people or animals involved in the investigation?
- How serious are the risks and how likely are those risks?
  A risk assessment matrix should be created in the log book for further reference (see Figure 1.2.1 on page 6).

Chemical safety

Chemicals used in investigations can be harmful, corrosive, irritants, poisonous or flammable. Those hazards are identified on the bottle of the chemical with a diamond symbol. Some common chemical hazard symbols are shown in Figure 1.3.1.

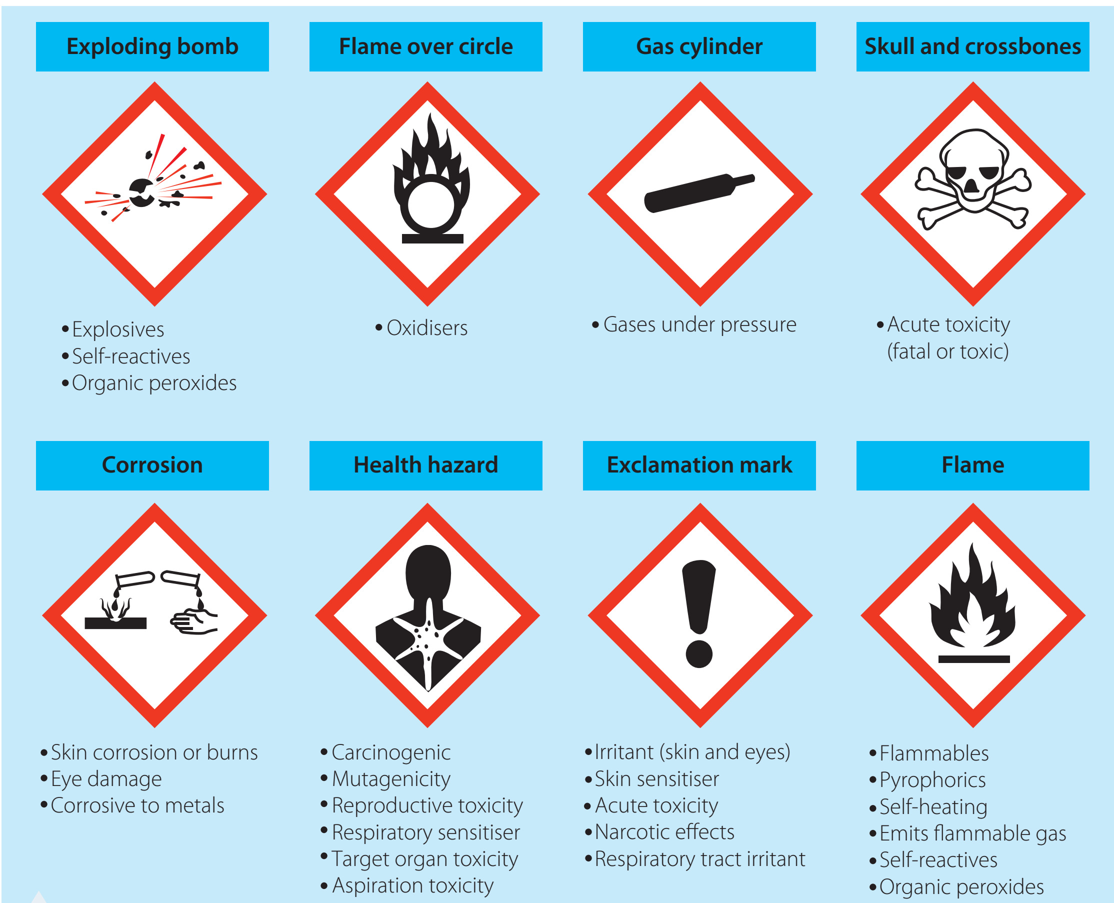

FIGURE 1.3.1 Pictograms from the Global Harmonised System used to label chemicals at school.

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Each chemical has a material safety data sheet (MSDS) in which important information about the chemical is described; for example:

- chemical and generic name of all the ingredients in the substance
- chemical and/or physical properties of the substance
- health hazard information
- safe handling of the substance
- manufacturer's name and contact details
- first aid information
- storage conditions.

1.3.1 Model code of practice: preparation of safety data sheets for hazardous chemicals

Always consult with the teacher and/or laboratory assistant before using the chemicals in your investigation and always read the labels.

Safe use and disposal of living samples

Hazards and risks when dealing with living samples are avoided by using protective gloves and masks. For example, wear gloves and a mask when handling pollen to reduce the risk of an allergic reaction. Dissections should be conducted with care. Scalpels and glass slides to observe tissue samples under the microscopes must be handled with care. Cultures in agar plates should never be open when bacteria or contaminated samples are used in the investigation as the bacterial cultures may be pathogenic.

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FIGURE 1.3.2 Observe that the researcher is wearing gloves when handling the agar culture.

To avoid contamination of a cell culture, a laminar flow cabinet can be used and all the surfaces must be cleaned with ethanol 80%. Flaming the inoculation loops on the Bunsen burner kills all the bacteria, while the hot flame creates an updraft and also kills the surrounding airborne contaminants.

After the work with living samples is finished, they should be autoclaved and then disposed. This reduces the risk of environmental contamination. All equipment used in dissections of animal and plant tissues must be cleaned thoroughly before storage.

If the investigation involves the handling of animals, the welfare of vertebrates and invertebrates is protected by state and federal laws, and they must be treated respectfully. Collection of live specimens from the field needs to follow the specific regulations for that area to protect native **species**. Be aware of the laws in the local area and consider if an alternative type of investigation can be conducted instead of using living samples.

species
group of living organisms with similar characteristics that can interbreed

Technologies and accuracy

Different technologies and equipment are used to collect data when conducting an investigation. The type of equipment and the technologies to measure and collect data depends on the nature of the investigation. The aim in selecting and choosing different equipment is focused on how well that equipment or technology will ensure accuracy in the investigation.

The selection of an appropriate technology to measure or carry out the experiment accurately, and therefore collect valid data to test the hypothesis, is very important. For example, if the experiment requires a measurement of pH, it is better to use a pH data logger probe connected to a computer than litmus paper. This is because the data logger collects specific numerical data of pH, whereas the litmus paper changes colour to give an estimation of pH. However, if a data logger is not available, the measurements can be done with a universal indicator and comments can be made in the discussion of the investigation about how to improve the measurements using more accurate technologies.

Information from secondary sources

During the design, carrying out and analysis of the investigation, secondary sources are consulted to gather theoretical data and information about the researched topic. The selected and extracted information is reliable when the secondary sources are published by scientific, government and educational institutions where the information has been assessed and evaluated by scientists and experts before being made available to the public. Table 1.3.1 compares some of the different types of secondary sources.

TABLE 1.3.1 Comparison of secondary sources

VALID AND RELIABLE SECONDARY SOURCES	
ARE ✓	ARE NOT ×
Educational textbooks	General fiction books
Educational and government institution web pages	Non-educational web pages
Scientific journals and articles	Articles in popular magazines
Encyclopaedias	Discussion blogs in social media

Once the secondary sources are selected and information is extracted, they have to be cited correctly in alphabetical order in a reference list or bibliography. It is good practice to cite them as soon as they are used to avoid misplacing information and data. Creating a reference section in the log book is a handy idea.

There are different formats to cite secondary sources. Each educational institution follows specific formats which depend on the type of secondary source used: such as web pages, books, articles or journals. But as a general example, a good secondary citation follows the following format.

KEY FORMULA

Author/s surname, initial of first name. (published year). Title of the book section or web page section. *Name of the book*, *scientific journal* or *web page*. City: Publisher name (for a book)/volume and page numbers (for a journal)/URL (for a web page). It can also be helpful to say when you accessed the webpage.

For example:

- **Book**

  Diamond, J. (2000). *Guns, Germs and Steel: A Short History of Everybody for the Last 13 000 Years.* London: Vintage Publishing.

- **Article from a scientific journal**

  Brack, A., & Eliazer, S. (2016). Stem cells: Cause and consequence in aged-muscle decline. *Nature*, Vol. 540, 349–350.

WS
1.3.1 Microsoft Word referencing

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- **Web page**

  Howard, J. (2016). *Seven Ways Astronauts Improve Sleep May Help You Snooze Better on Earth*. Retrieved from International Space Station NASA: https://www.nasa.gov/mission_pages/station/research/astronauts_improve_sleep. Accessed 30 January 2018.

1.4 Processing data and information

There are two types of data that can be collected in an investigation: qualitative and quantitative data. **Qualitative data** refers to non-numerical data and **quantitative data** are data that can be quantified or numerically collected and recorded (Figure 1.4.1).

The way that data are organised, displayed and represented helps in the interpretation and analysis of the results. Organising data aids scientists to observe trends and patterns, and to reach conclusions about the hypothesis being investigated.

qualitative data descriptive data collected as evidence during an investigation (e.g. images, observational sentences)

quantitative data numerical values collected as evidence during an investigation (e.g. calculations are usually part of the analysis, not data collection, measurements)

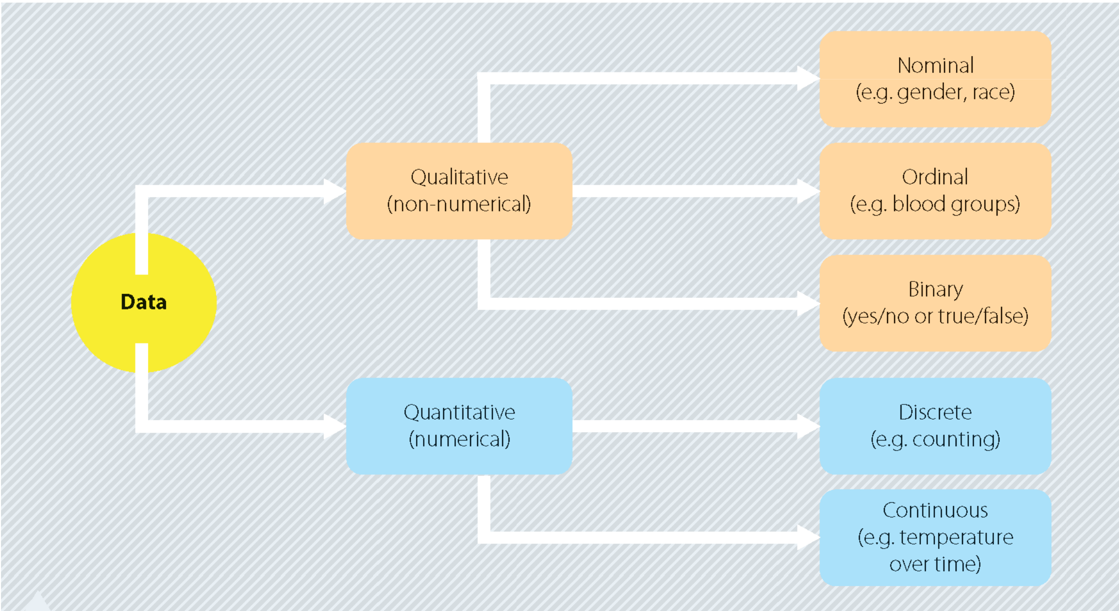

FIGURE 1.4.1 Classification of the types of data that can be collected during an investigation.

To represent and organise the data, different types of tools can be used: tables, graphs, infographics, diagrams, flow charts or digital media. The type of tool used depends on whether the type of data collected is qualitative or quantitative. The selection of how data will be represented is essential because from that representation inferences can be made and errors can be identified.

Representing quantitative data

Tables are the best representation for numerical data. All the information collected in the experiment can be organised in tables where the relationship between the independent and dependent variable can be observed clearly. In tables, any unusual results can be identified, and inferences about the method used to collect that data or how other variables were not controlled properly can be made. A table consists of rows and columns, with appropriate headings and units of measurement in each heading (Figure 1.4.2)

Table 1. Title of table

Headings with units →

Data →

TIME (MIN)	TEMPERATURE (°C)
0	25
1	38

Independent variable ↑ *Dependent variable* ↑

FIGURE 1.4.2 Example of how to construct a table.

Graphs are visual representations of data and show the relationship between the independent and dependent variables. Graphs help to identify patterns and trends that may not be noticeable from a table. It is a common rule to represent the average of the results in a graph and always calculate an equation of the **line of best fit** to see what plotted data is 'out' from the common pattern or trend. Data outside the line of best fit helps to identify mistakes in measurements or equipment for that particular investigation.

line of best fit
trendline that best fits the plotted data, it goes through the centre of the plotted data

The rules to follow in order to construct a graph can be remembered by using the acronym TALS (Figure 1.4.3).

T – Title	A – Axis	L – Labels	S – Scales
Choose a relevant title for your graph.	On the *y* axis (vertical), plot the dependent variable. On the *x* axis (horizontal), plot the independent variable.	Label each axis with the name of each variable and write the units of measurement for each variable (if appropriate).	The scales refer to the consecutive numbers written in each axis from 0 to the highest number in your recorded data.

FIGURE 1.4.3 TALS, an acronym to remember how to draw a graph.

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Types of graphs for quantitative data

Quantitative data can be separated into two categories: discrete and continuous. The type of graph used to represent these categories is different (Figure 1.4.4). Line graphs are better suited to represent continuous quantitative data such as temperature over time, speed over time or reaction rate over temperature. However, for discrete quantitative data, pie charts and column graphs represent the measured points better.

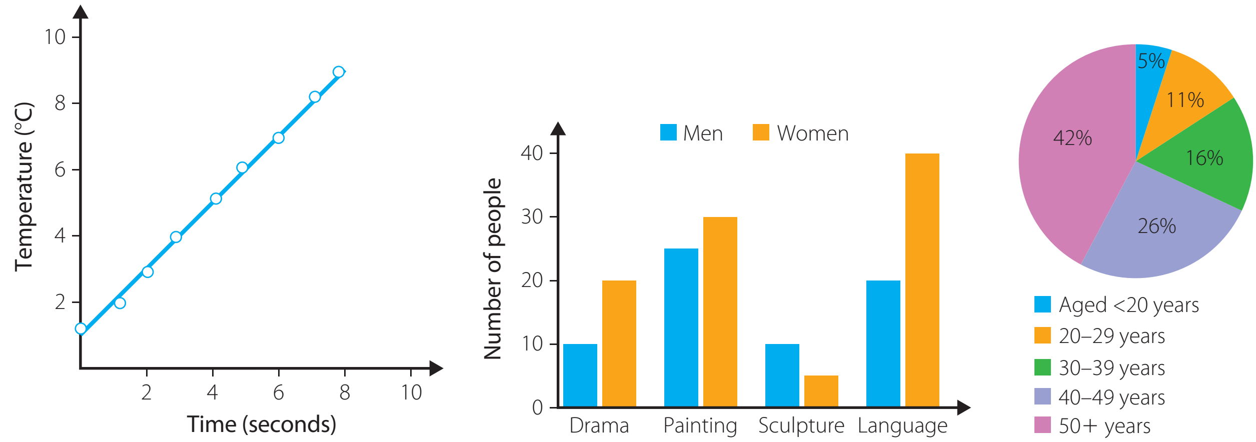


FIGURE 1.4.4 Different types of graphs to represent continuous (line graph) or discrete (pie and column graphs) quantitative data.

Representing qualitative data

Qualitative data is represented in different formats from quantitative data because the data collected is not numerical. The most suitable formats are lists, tables, flow charts and diagrams. Digital technologies, such as video clips, animations and PowerPoints, can also be useful methods to present the data collected.

In qualitative data, the non-numerical data may be represented as numerical data. This is done by assigning a numerical representation to each observed response in the investigation. For example, if the data collected is coming from a survey, each response can have a numerical value and in this way the analysis of the responses becomes easier from a statistical point of view. Representing qualitative data as numerical data also makes it easier to represent data in a graph to observe patterns and trends.

WS
1.4.1 Graphing skills

Evaluate and improve the quality of data

Data collected during an investigation is evaluated for its quality. This uncovers data defects such as errors related to the technology used, sampling techniques or sample size. To improve the quality of data, the sample size should be big enough so that there is sufficient statistical data to manipulate and reduce the error.

The identification of unusual data (i.e. data that is very different from the average calculated value) is important to reduce the statistical error and improve the consistency of the results. Taking out the unusual data from the data pool allows a much better picture of patterns and trends in the data analysis.

Sometimes, measurements will need to be taken again to improve the quality of the data because a new technology has emerged or an existing technology has been improved or the technology used was not calibrated properly for the particular data collected.

1.5 Analysing data and information

A more thorough analysis of the data collected in an investigation is needed to ensure that the hypothesis was tested fairly and is supported by the results of the research. The examination of patterns, trends and relationships from the information gathered during the investigation, the identification of error, uncertainty and limitations in data, and the evaluation of relevance, accuracy, validity and reliability of the primary and secondary data collected is crucial for the analysis of the investigation.

uncertainty interval (±) around the measured value compared to the true value

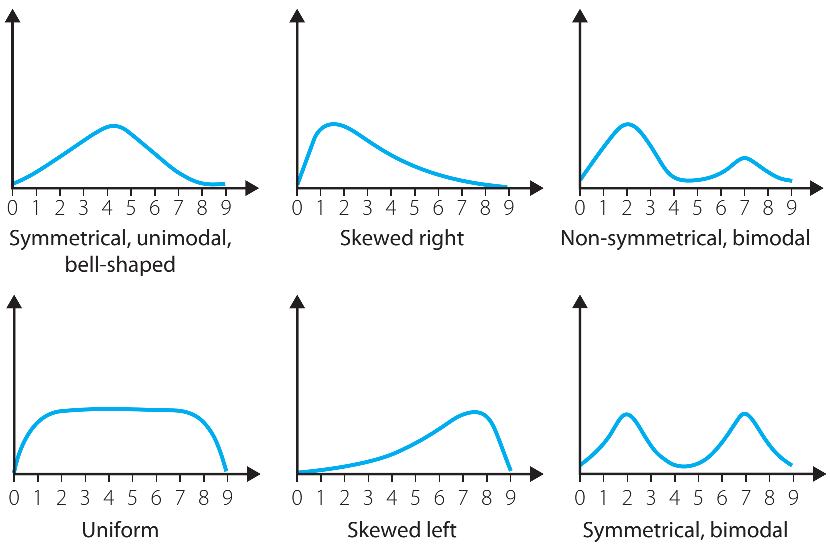
Derive patterns, trends and relationships

The best way to interpret data is to plot it. The visual representation of the line in the graph will indicate the patterns and trends between the dependent and the independent variable and therefore their relationship.

Patterns

A pattern from a graph is represented by the 'shape of the curve' or the distribution of the data. For example, the distribution can be bell-shaped, symmetrical, spread, centred or repetitive (with 'up and down' points). The pattern can be uniform if all the dots are spread evenly across the graph or skewed if the dots have an uneven distribution across the graph (more dots to one side or peaks at different levels). Figure 1.5.1 shows the different possible patterns observed from graphs.

FIGURE 1.5.1 Patterns in graphs



Sometimes, there are plotted data points that are 'out of the pattern'. These data points might be related to a mistake in the collection of data, or due to an unseen or uncontrolled variable.

Trends

A trend in a graph is the direction or the tendency of the line created by the plotted dots. Once the data is plotted, the line of best fit is traced over the dots to see the trend in the data. The trend can be ascending (increasing), descending (decreasing), stable or variable (Figure 1.5.2). All of the measured points that fit between the minimum and the maximum values plotted can be interpolated.

interpolation estimating new data points within the range of data points

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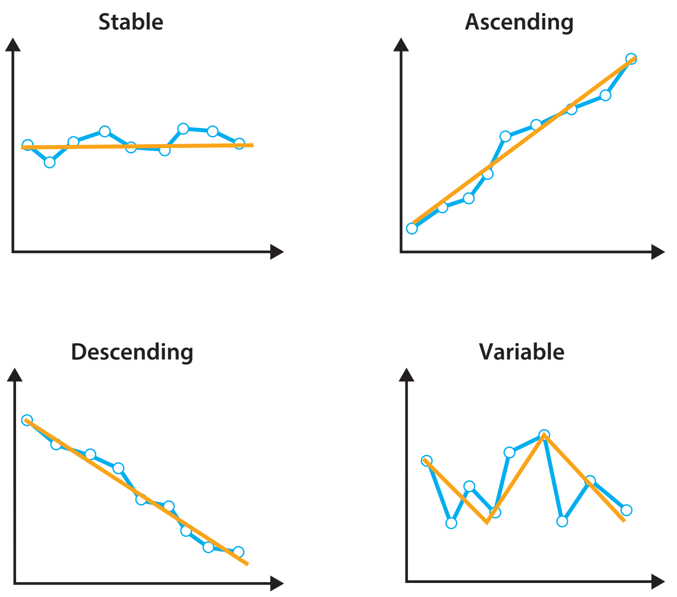

FIGURE 1.5.2 Trends in data. The orange lines are the lines of best fit for each plotted data set. The lines of best fit represent ascending, descending, variable and stable data trends.

For example, if your data measurements are 25, 38 and 45 g, the numbers between those measured numbers can be identified using the graph. The line of best fit can be extended beyond the measured points in the graph; this is called **extrapolation**. However, inter- and extrapolations should be used cautiously because you cannot be certain that the experimental system behaves in the same way at that point as for the other measured points.

extrapolation extension from a range of plotted data to infer new values from the known ones

Relationships between variables

The relationship between the dependent and the independent variable is represented by the patterns and trends. The relationship can be:

- positive – for every increasing value of the independent variable, the dependent variable increases. For example, the higher the amount of fertiliser the higher the plant growth is.
- negative – for every increasing value of the independent variable, the dependent variable decreases. For example, as the environmental temperature increases the number of hot chocolates sold decreases.
- no relationship – the values of the independent and dependent variable are scattered across the graph showing no pattern or trend. For example, the amount of time listening to music does not affect the science test marks.

Error, uncertainty and limitations in data

Error

Identifying errors, uncertainty and limitations in the experimental data collected aids in ensuring the validity of the results. There are two main types of error in experiments: systematic and random. A systematic error is a mistake when taking the measurements and usually relates to the technology or equipment not being calibrated properly for the purpose of the measurement, or that the equipment is not suitable for those measurements. Systematic errors are difficult to identify because the data seems to have a pattern and trend but usually the hypothesis is not supported by those results. A random error is easy to identify because it is an unpredictable fluctuation in the measurements due to malfunction of the equipment at the moment the data was collected for that point. Repetitions of the measurements will show if the error is systematic or random.

Another type of error is related to the acceptance of the hypothesis being investigated. Those errors are called type I and type II errors. A type I error refers to rejecting a hypothesis when the hypothesis is true (such as telling a woman that she is not pregnant when in reality she is pregnant). A type II error refers to accepting a hypothesis when the actual hypothesis is wrong (such as telling a man that he is pregnant). Table 1.5.1 compares the differences between these two types of errors.

TABLE 1.5.1 Difference between type I and type II errors.

		REALITY OF HYPOTHESIS	
		TRUE	**FALSE**
Results or findings from the research	**TRUE**	Acceptance of a true hypothesis	Type II error Acceptance of a hypothesis that is false (false negative)
	FALSE	Type I error Reject a hypothesis that is true	Rejecting a wrong hypothesis

Uncertainty

1.5.1 Statistics in science

No physical or chemical quantity can be measured with perfect certainty so there is always some uncertainty in the measurement. The uncertainty is the best estimate of how far an experimental quantity might be from the 'true value'. For example, a measurement of 7.05 g ± 0.02 g means that the experimenter is confident that the actual value for the quantity being measured lies between 7.03 and 7.07 g.

Uncertainty is reduced when the entire experiment is repeated following a valid method and using suitable equipment. The more repetitions of the entire experiment, the less the uncertainty in the results. At this point, it is important to distinguish between standard deviation and standard error. Standard deviation is how 'spread' a measurement is from the average of measurements. A standard error is how 'spread' the average of the repetitions of the entire experiment is; therefore, the standard error is a statistical measurement of uncertainty.

KEY FORMULA

Measurement = best estimate ± uncertainty

where

Measurement refers to the type of data collected (e.g. height, distance)

Best estimate refers to the numerical measurement taken

± **uncertainty** is the distance around the estimated value

Limitations in data

Data collected can have limitations due to the nature of the experiment, equipment used or unforeseen variables when the experiment has taken place. In primary investigations, the limitations in data are usually related to the type of equipment used or the environmental conditions where the experiments have taken place. For example, the equipment can take measurements to a certain value and some data cannot be collected below or above that value, or if the experiment is carried out in the field the weather conditions cannot be predicted or controlled.

In secondary investigations the limitations are related to the type of tool used to collect data; for example, a survey, focus groups, interviews or secondary sources of information. In this case, there is not much control over the responses from individuals and there can be bias.

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Relevance, accuracy, validity and reliability in data

In primary or secondary sourced data, the relevance, accuracy, validity and reliability are important aspects to consider ensuring that the data can support the hypothesis being tested. Table 1.5.2 shows the differences between those parameters.

WS 1.5.1 Analysing

TABLE 1.5.2 Evaluation of primary and secondary data in terms of relevance, accuracy, validity and reliability.

PARAMETERS EVALUATED	PRIMARY DATA	SECONDARY DATA
Relevance: data shows how close it is to the tested hypothesis	Data tested the hypothesis to be investigated	Data shows a close relationship with the topic investigated and tested the hypothesis
Accuracy: data is close to the 'true value' of the measurements	Data shows little error	Data from different secondary sources shows little variation in information
Validity: data is collected using a valid method and suitable equipment	Methods and equipment used did not limit the data collected and tested the hypothesis	Data comes from valid sources (educational, government and scientific institutions publications)
Reliability: data collected is similar for each repeated measure	Data shows little uncertainty	Small variation of information across secondary sources used in the investigation

1.6 Problem solving

Scientific research can be very challenging because unexpected problems may arise at any time. Problems in conducting investigations can be related to the equipment, technologies, environmental hazards or variables that cannot be controlled or managed. To solve these problems different strategies can be applied, such as to create a model, apply a mathematical calculation, re-create the experiment, change equipment or improve the method. Identifying the cause-and-effect relationship in the problem can also help to contextualise the problem and therefore allow a solution to be found (Figure 1.6.1). Critical thinking and creativity are additional important processes when trying to understand a problem, and in designing the steps to overcome the issue and solve it.

Sometimes reaching a solution from a scientific problem is difficult. In this case, predictions are made using explanations based on scientific theories and principles that support the evidence for the investigation.

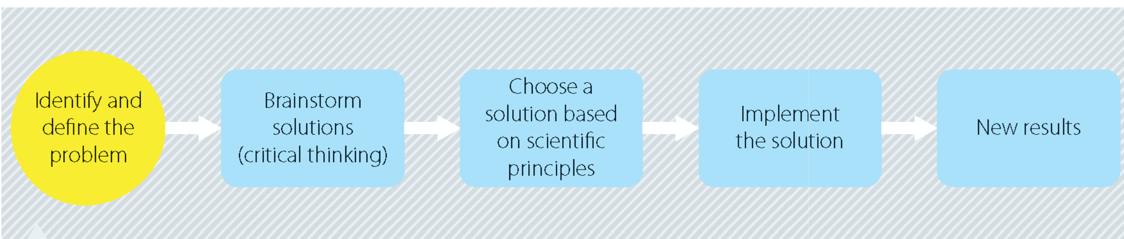


FIGURE 1.6.1 Steps in problem solving. The first step is to identify and define clearly the problem. This is followed by critical thinking to brainstorm solutions which are chosen based on scientific principles. When the solution is implemented, new results are achieved.

Models in solving problems

model
two- or three-dimensional representation or description of a process, system or idea

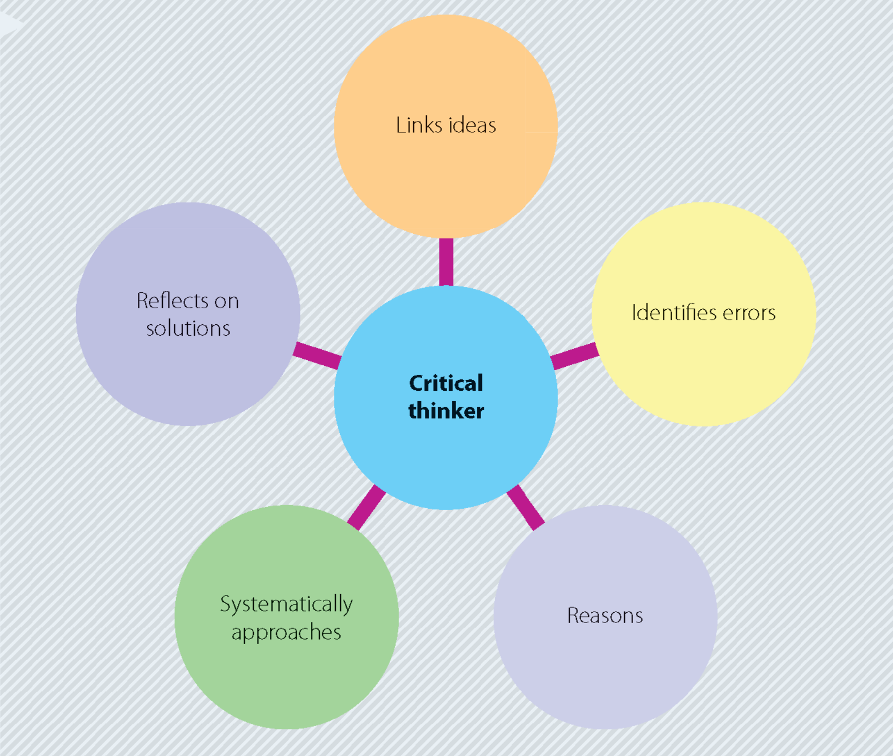
Models can be used to simplify and solve complicated scientific problems such as molecular structures, complex biochemical processes or large-scale phenomena. A model can be a mathematical equation, a two- or three-dimensional representation or come in a digital computerised form. Models have limitations because sometimes they are too simple and detailed information is not represented, but they are a good strategy to make predictions and analyse solutions in a simple way.

Critical thinking skills to solve problems

WS
1.6.1 Solving problems

Critical thinking is often used to solve problems and reach conclusions about the world around us. Critical thinking is not the simple, straightforward idea that comes to mind when someone tries to understand and solve a problem. Critical thinking refers to the more complex process of reasoning to merge ideas and concepts from different disciplines to form a comprehensive solution to the problem encountered. A good critical thinker solves the problem using systematic collection of information rather than using intuition. Consequently, solving problems arising in scientific investigation requires critical thinking to select the best change in the investigation and reach the most effective outcome.

FIGURE 1.6.2 Characteristics of a critical thinker that allows problem solving using a holistic approach of ideas.



1.7 Communicating

A scientific investigation is completed when it is published and other scientists are learning from it. A written report is usually the most common form of communication but is not the only one. Table 1.7.1 shows the components of a scientific report and how to write them. It is important that concepts are expressed succinctly and that the report follows a flow of ideas from the inquiry question to the final conclusion, making it is easy to read and understand.

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TABLE 1.7.1 Definition and features of research report sections. The features of each section are not limited to those listed here; more or less information can be added in each section depending of the nature of the research.

REPORT SECTION	DEFINITION	FEATURES
Abstract	A summary of the entire investigation.	▪ Includes the inquiry question and hypothesis, brief description of the method, results and conclusion.
Introduction	Background information that was used to research the inquiry question.	▪ Description of what and why the research was taken. ▪ Includes explanation of scientific theories and principles used in the research to answer the inquiry question. ▪ Summary of similar investigations supporting the research.
Method	Detailed procedures followed in the investigation.	▪ The method followed is written in chronological, numbered steps starting with a verb. ▪ Statements are as clear as possible so other scientists can understand and repeat the experiments. ▪ Diagrams and mathematical calculations are included. ▪ Variables and treatments are specified.
Results	Findings of the investigation.	▪ Results are represented in tables, graphs and diagrams. ▪ Observations are written as lists or descriptions.
Analysis and discussion	Analysis of data and arguments that support the hypothesis.	▪ Explanation of the meaning of the results and data collected, related to the hypothesis and inquiry questions. ▪ Relate to secondary sources which support the research. ▪ Difficulties encountered during the investigations and improvements are discussed. ▪ Future research inquiry questions are suggested.
Conclusion	Summary of results and judgement about the hypothesis.	▪ Brief summary of the meaning of the results and aim. ▪ State if the results support the hypothesis and/or inquiry question.
Acknowledgements	Recognition to the people who collaborated in the research.	▪ Thanking all the people who contributed to the research, from the equipment suppliers to the people who shared their ideas and personal support.
References	Secondary sources used in the research.	▪ Alphabetical list of all the secondary sources consulted for the research. ▪ Include references from the introduction and discussion. ▪ References are cited following a particular reference format or style.
Appendix	Supplementary section to the written research.	▪ Additional information about raw data. ▪ Calculations or list of mathematical formulae. ▪ Extra diagrams or photographs of the experimental site. ▪ Any relevant information that can help the reader to understand the research.

Other ways of communicating the findings from an investigation can be in the form of a poster or presentation at a conference, or an article published in a scientific journal or website. These ways of communication often limit the amount of the research that can be presented about the topic. However, in today's society scientists choose to present their investigations in different formats to reach the majority of audiences and promote their passion for science.

Whatever method is used to communicate research it is important to keep in mind the type of audience who is going to read it so that the work is understood, and it can be critiqued fairly and constructively for future improvements.

1.7.1 The importance of science communication

Peer review

One reason for communicating the findings of an investigation is the feedback received by other researchers. Peer review helps to improve the current investigation, to further pursue new areas to investigate and for self-evaluation.

The feedback can be done verbally or in a written form, with the objective being to evaluate the argument discussed in the conclusion of the investigation. Feedback should be constructed using evidence-based statements.

peer review
process in which experts review and critique the work and research of others in the same field

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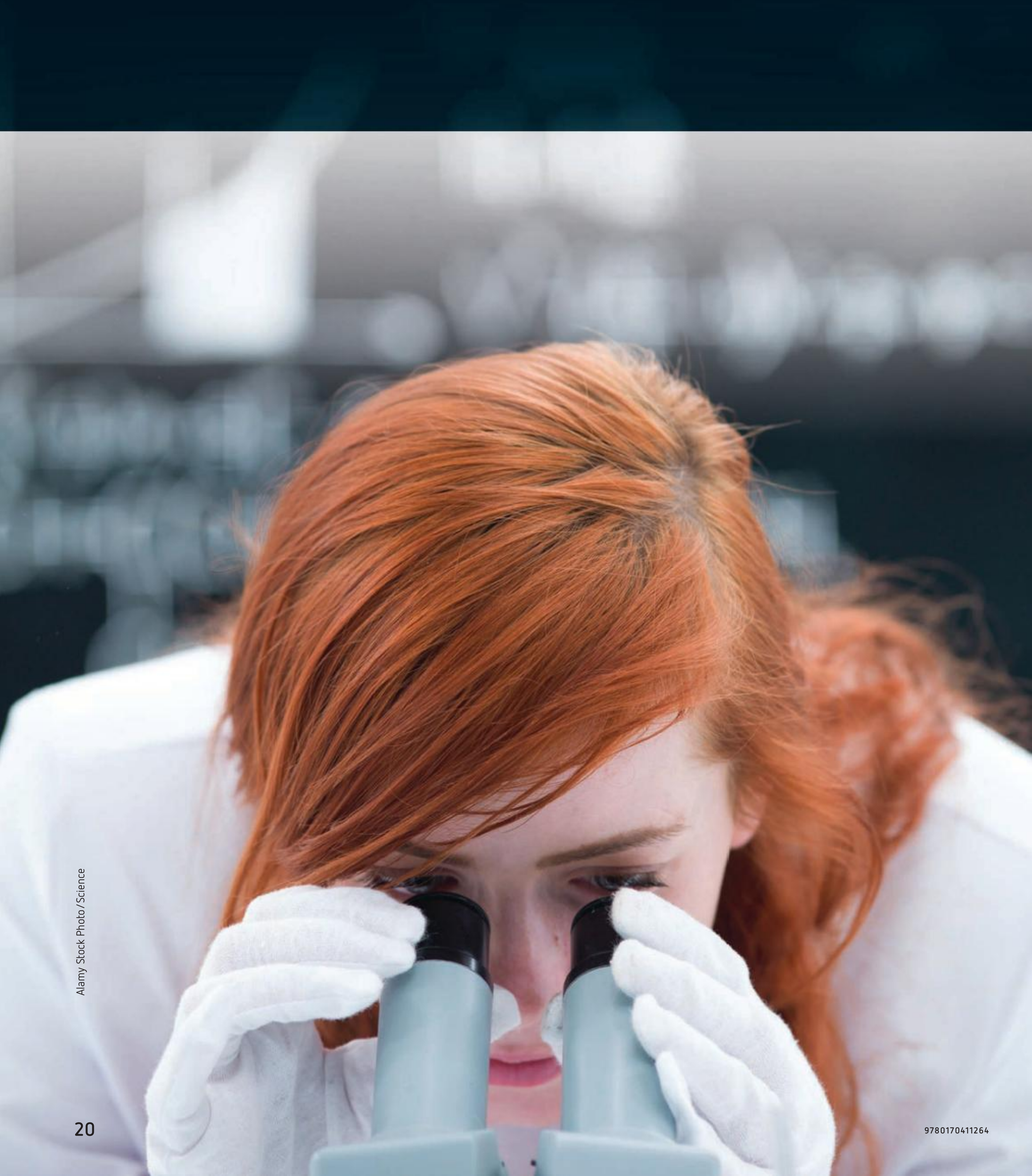
2 PREPARING FOR A DEPTH STUDY



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2.1 Devising and conducting investigations

Before you conduct an investigation you need to carefully plan what you are going to do. You must ensure that your investigation will be a fair and **valid** test. That is, one that tests your **hypothesis** and can easily be reproduced.

For an investigation to be **reliable** you must have repeated your investigation a number of times, and received consistent results. This doesn't mean you get the same result every time, but rather, that your results do not vary by a significant degree.

If the results do vary by a great degree, then there may be parts of your investigation that are flawed. You may need to go back and think of ways of improving your investigation. For example, an investigation to test the claims of stain removers would only be valid if it tested how much of the stain was removed compared to other products tested under the same test conditions.

valid
extent to which a report or investigation contains accurate data, inferences and conclusions

hypothesis
educated guess tested through experimentation to answer the inquiry question; states the relationship between the independent and dependent variables

reliable
extent to which an observation and/or measurement can be repeated under the same circumstances and produce similar results

Controls and variables

A fair test should only test one variable, which is the only factor that is deliberately changed in your investigation. This is called the **independent variable**, and in the example given previously, the independent variable is the different types of stain remover.

You should also endeavour to measure one variable: the **dependent variable**. In the previous example of the stain remover, the dependent variable is the amount of stain that is removed. While some investigations might measure more than one variable, most of the time it is just one variable being tested.

All other aspects of the investigation should remain constant, such as the size and type of the original stain, the size and type of the material, the length of time the stain remover is left on the stain and the length of the wash cycle. These constants are the **controlled variables**, and they are the parts of an investigation that must be kept the same for each of the independent variables and during any replications of the investigation. For example, if testing the effect that the different stain removers might have on the stain, the stain remover should be the only factor changed. If you change the amount of water used in each sample, or change the type of material that it is tested on, it can be difficult to eliminate these as potential causes of the results.


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FIGURE 2.1.1 Investigations are an important part of the scientific process of testing a hypothesis.

2.2 Testing a claim or device

Many commercial products, machines and devices will make claims about their performance to appeal to consumers. Often the claims are full of language designed to evoke emotions. Many of these claims are hard to prove without buying all of the available products and making your own comparisons. For example, a washing powder may claim that it makes clothes 100% brighter than other powders, while a washing machine may claim that it makes clothes 100% cleaner than another machine. Assessing these claims and finding secondary sources can be very difficult as there are many variables that need to be considered; for example, the type of soiling/staining on clothes, the type of material being washed, the length of the wash cycle, the quality of available water and the temperature of the water.

independent variable
factor deliberately changed during an investigation to obtain data

dependent variable
factor measured in the investigation

controlled variable
factor that is kept constant during the investigation

To successfully test a claim or device it is important to identify:

- what you want to learn from testing the claim or device
- what you already know about the topic
- the research that already exists (secondary sources)
- the dependent and independent variables
- what you think will happen in the test
- how you will record the data
- how you can repeat the test to ensure it is fair and valid.

2.3 Making documentaries and reports

WS
2.3.1 Making documentaries and reports

bias
when personal opinion affects how a person weighs the validity of evidence

2.3.1 Making documentaries step-by-step
2.3.2 How to make a documentary part 1
2.3.3 How to make a documentary part 2
2.3.4 How to make a documentary part 3
2.3.5 Simple mistakes documentary filmmakers make

peer review
process in which experts review and critique the work and research of others in the same field

Documentaries

A documentary film is factually based and usually reflects an area of interest of the film maker. A good documentary will critically evaluate the evidence for a concept and make a judgement. It might show examples of how a particular concept works, including positive and negative aspects, and make an overall judgement. Documentaries may be subject to criticism, so it is important to present the information factually and without **bias**. Any bias may negatively impact the perception of the documentary and a lack of facts will lead to the documentary lacking credibility.

When creating a documentary it is a good idea to complete the following steps:

- identify an area of interest
- complete an extensive secondary source study that investigates the subject broadly and deeply
- create an outline for the documentary including a storyboard and a draft script
- identify and rectify any legal, ethical and copyright issues
- revise the script
- film the documentary
- edit the documentary
- show the first edit to others for **peer review**
- refine the documentary based on feedback
- present the final documentary.

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FIGURE 2.3.1 A documentary can be used to present data about a topic or attempt to highlight an important issue.

INQUIRING FURTHER

- View some YouTube documentaries and TED presentations related to a topic of your interest.
- Assess whether the documentaries and presentations are factual or have bias. Present a report to your class on what you have found.

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Reports

A report can be written, verbal or visual and aims to provide the intended audience with information on a particular topic. As with a documentary, it is helpful if the person writing the report is interested in the topic, the report is factually based, the research is broad and deep, and the information is free from bias. A report should be written in an active voice. For example, 'We set up the equipment as shown in the diagram' and 'We repeated the procedure three times'.

Your report should include the following sections.

- Title
- Abstract (or summary)
- Introduction
- Materials
- Method
- Results
- Discussion
- References


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FIGURE 2.3.2 Many reports can be given as lectures.

2.4 Conducting a literature review

A literature review investigates scientific articles, compares their conclusions, and often evaluates the conclusions based on the validity and reliability of the investigation. A literature review is usually written in an essay format with an introduction, body, conclusion and reference section.

The introduction states your aim in writing the literature review. It answers the question, 'Why are you writing this review?' In the introduction you should describe your aim and briefly talk about the areas you are going to discuss.

Once your introduction is complete, you need to focus on the body of your review. In the body section you articulate your arguments and give evidence to support them. Each body paragraph should include the information you have researched and summarise your main ideas. For example, several paragraphs could discuss the historical background of the topic, such as in the history of ideas on **atoms**. Others could discuss further research in the area, such the development of cochlear implants. Others may discuss advantages and disadvantages of the concept being discussed, such as whether an area should consider nuclear power. Essentially this is where you are outlining your ideas.

Once you have discussed, outlined and assessed the topic in the body of your review, you will need to summarise your argument(s) and make a conclusion.

In the research phase of the literature review it is important to accurately record all of the literature you are reading either by hand, in an electronic document or using the features of your chosen software. You should include a list of all of the literature you discuss in the reference section of your review.

2.4.1 Sydney University literature review tutorial

atom
from the Greek word 'atomos' meaning cannot be divided

2.4.1 Critical evaluation of scientific articles

2.5 Developing evidence-based arguments

An evidence-based argument is a piece of writing designed to influence people's thoughts on certain topics. You start by choosing an area of interest, researching this area and then presenting a point of view. From here you develop an argument supporting your claim. Each point is supported and elaborated on with evidence from reliable sources. It is important that you cross-reference that the evidence has been checked and verified many times. It may also be appropriate to discuss opposing views and use evidence to show why your idea is correct. There may be some areas where the arguments for both sides are strong, and both have valid points. In this case, show both sides of the argument and provide evidence for why you think a point of view is correct. A process to follow when developing an evidence-based argument is to:

- identify the issue
- understand the scientific, social, ethical, environmental, economic and other important aspects of the issue
- identify, research and analyse the existing information
- evaluate the research and form an opinion/develop a position
- organise the argument
- write the first draft
- submit the draft for peer review
- revise based on the peer review and prepare the final argument
- publish or present the final argument.

For example, the following outlines how to begin an evidence-based argument concerning genetically modified (GM) crops.

1 Identify the issue.
- People should support the development and production of GM crops.

2 Show an understanding of the scientific, social, ethical, environmental, economic and other important aspects of the issue.
- GM crops produce more seed, and therefore, they can feed a higher number of people (e.g. social, ethical, economic).
- Climate change may impact food crops, thus plants need to be genetically modified to allow them to survive in harsher weather (e.g. scientific, social, environmental, economic).
- Certain GM crops are pest resistant which reduces the need for pesticides (e.g. scientific, environmental, economic).

iStock.com/-MG-

FIGURE 2.5.1 GM crops are designed to overcome difficulties such as poor soil or increases in temperature. While this may allow more crops to be grown, many people have concerns about the long-term effects of eating these foods.

2.6 Writing a journal article

Often after completing their research a scientist will publish their results. This is usually done through journal articles. The publication of journal articles is an important process in science as it allows other scientists to look at how the scientist conducted their research, whether their investigations were fair and valid, and whether the conclusions made from their investigations were valid. A journal article should methodically explain each step in detail, so that other scientists have a guide for repeating the investigations. Other journal articles may use secondary sources. However, they should follow the same methodical approach.

Before the journal article is published it should be peer reviewed. In this process other scientists assess the methodology and analysis of results, and make a judgement about the validity and reliability of the

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research. If it doesn't appear to have a solid scientific methodology then an article may be rejected for publication.

In most cases a journal article will have a structure similar to that of a standard scientific investigation.

- Question
- Background research
- Hypothesis
- Investigation method
- Analysis
- New hypothesis (if results do not align with the hypothesis)
- Conclusion

2.7 Writing an essay

An essay is a piece of writing that usually presents arguments, and assesses the reliability and validity of these arguments, which then leads to a conclusion. An essay usually takes the following structure.

The introduction gives a basic rundown of the main points of the essay and indicates the argument; in other words, the introduction summarises what the author is attempting to show in the rest of the essay.

The main body of the essay examines the evidence that the author is using to back up their argument. In most cases, each piece of evidence should have its own paragraph outlining the main points with examples.

The final paragraph will be the conclusion, where the author briefly summarises the main points, with a statement talking about the argument. This conclusion should be supported by the evidence given in the body of the essay.

An approach to writing an essay includes:

- choosing a topic
- conducting research into the topic
- scaffolding the development of the essay based on research
- writing a thesis (introductory) statement
- writing the main body of the essay
- writing the introduction and conclusion
- submitting the draft for peer review
- revising the essay
- publishing the final essay.

WS 2.7.1 Essay scaffold

2.8 Developing an environmental management plan

An environmental management plan describes how an activity, such as a new housing development, might impact on the local environment. The plan should ensure that best practice is employed during the activity, that all legislation is adhered to and assess the risks associated with the planned activity.

The management plan should be impartial and have qualified experts from a number of fields involved in its development. For example, archaeologists may be called upon to assess if there are any significant cultural or heritage risks associated with the planned activity.

There are many different types of environmental management plans, but the basic structure consists of:

- an introduction to the activity, the objectives of the plan and any environmental policies
- who is responsible for the environmental management, any licences that are required, reporting requirements and training requirements
- details on the implementation, including a risk assessment, the environmental activities/controls, the management plan, and appropriate maps and schedules
- how the plan will be monitored, audited and reviewed, and identify any corrective actions that may need to take place.

2.9 Analysing a narrative

Many movies claim to use science, or scientific concepts, as a central part of their plot. In analysing a narrative, you may look at books or movies and analyse the science used. This might involve doing background research on the 'science' in the narrative and critically analysing its accuracy. For example:

- The movie showed a volcano that was emitting a runny lava as well as a pyroclastic flow. It would be unlikely that both would occur simultaneously from the same volcanic source.
- The movie showed small spacecraft firing loud laser blasts. In space, lasers would be silent, as there is no air to carry the sound. Lasers are invisible unless passing through particles that reflect the light.
- The characters in suspended animation would most likely awake with brain damage, as brain function was stopped for a long period of time.

2.10 Creating visual representations

Conducting and presenting a secondary-source investigation involves hours of delving through information and re-writing text to present a case that appropriately addresses your research question or inquiry. To complement the written text, it is beneficial to include visual representations as an alternative way of communicating information. Visual representations can also be included in depth studies that are design-based or as a way to display the results obtained by field work or a primary investigation.

Examples of visual representations that can be used exclusively or as part of a depth study may include:

- concept maps
- labelled diagrams
- diagrams of experimental set-up
- graphs and tables
- timelines of technological advancements
- taxonomic keys
- scientific drawings of biological specimens
- design briefs for a model
- drawings of chemical structure
- phylogenetic (or evolutionary) trees
- genetic pedigrees
- cartograms.

Visual representations are a powerful scientific tool as they allow complex scientific concepts to be shown diagrammatically. Imagine this book with no images, diagrams or concept maps and you will

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soon appreciate the purpose of visual representations. By including a visual element to your depth study, the written text is strengthened with further evidence.

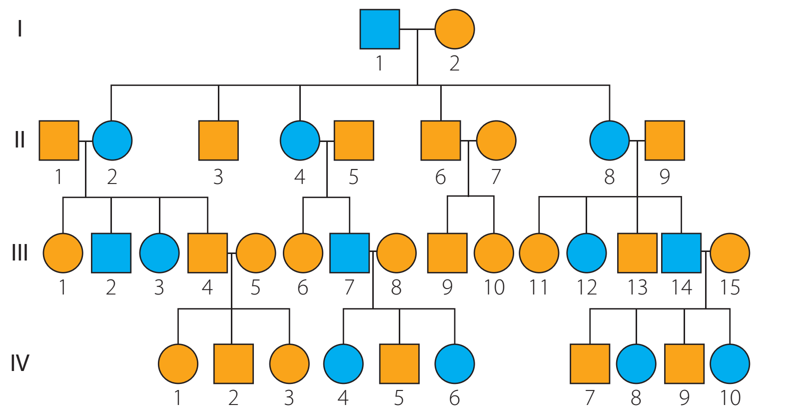

FIGURE 2.10.1 Pedigrees are an example of a visual representation that may be included in a depth study focusing on applying the conclusions of Mendelian genetics to investigate a heritable characteristic in your family.

2.11 Investigating emerging technologies

From Galileo's telescope and van Leeuwenhoek's microscope to the **Large Hadron Collider**, advances in technology are closely associated with changes in scientific thought. As new technologies are constantly emerging, a depth study is an opportunity to investigate and evaluate the potential of recent innovations.

Large Hadron Collider particle accelerator that propels subatomic particles (hadrons) at high speed

Your investigation may aim to investigate emerging scientific technologies strictly related to the work of scientists or scientific technologies affecting other target audiences such as the community, public health or even business owners. Regardless of the proposed technology, the following process can be used to initiate your investigation:

- choose an area of science that interests you
- research new or emerging technologies in that area
- relate the technology to an outcome in the *Investigating Science* syllabus
- determine your target audience/s
- evaluate the technology in terms of the target audience selected
- discuss the benefits and limitations of the technology
- include visual representations of the technology.

As there is a constant turnover in new technological products, the ability to assess and evaluate the potential of new scientific equipment or medical technology is an invaluable skill. By selecting this form of depth study, you will develop your ability to analyse a product beyond its face value to make a holistic judgement on its quality and ability to contribute to the industry it claims to benefit.

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FIGURE 2.11.1 Food scanners are an emerging technology that have recently been the subject of discussion. The scanner claims to analyse the ingredients and additives in certain foods and is being pitched as an essential device for those with life-threatening allergies, as well as a tool for those seeking to make better health choices.

2.12 Designing and inventing

Those with interests in engineering may wish to design their own invention or improve an existing one. The design element of the invention may be a proposal that encompasses visual representations of the invention or it could be a prototype for the invention itself.

If you choose to create an invention, you must consider the following issues:

- time to complete the task
- availability and cost of the materials to make your invention
- appropriateness of the invention in an educational setting (must not be offensive or associated with violence)
- expertise required to construct the invention
- whether your proposed invention has already been patented.

This choice of depth study provides the ultimate platform to apply scientific inquiry. For those who are always thinking of new ideas, this is an opportunity to finally transform your vision into something more concrete. Of course, if you are considering this form of depth study, it is important to consult your teacher and complete a lot of background research to ensure that it is plausible.

Getty Images/Michel Porro

Getty Images/REMKO DE WAAL/Stringer

FIGURE 2.12.1 Nineteen-year-old Boyan Slat invented a device to clean up plastic waste floating in the ocean while allowing marine life to pass through unharmed.

2.13 Creating a working model

Modelling is used extensively across the disciplines of science to illustrate a concept or process, or as a representation of complex scientific equipment. Additionally, if a proposed invention is not feasible due to lack of time or resources, then you can construct a model that depicts your idea.

All models do not have to be physically built; they can also be mathematical, diagrammatic, computer-generated or abstract. However, if you wish to construct a model as your depth study, it must be a working model. That is, it must include some degree of interaction in which it actively demonstrates a process.

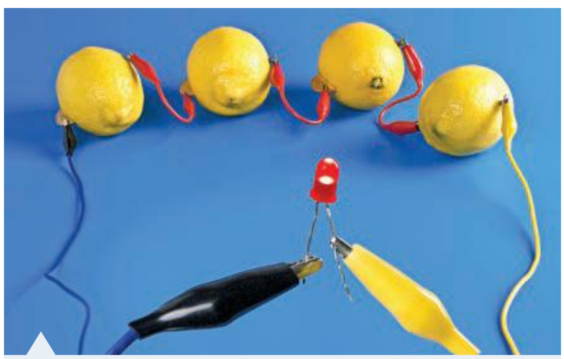
A simplified example to demonstrate the difference between a model and a working model may be demonstrated through a model of the planets in the Solar System. In this instance, the model is considered a working model when it demonstrates not only the relative size and order of each planet but also the orbital properties of the moons and planets in relation to the Sun. Figure 2.13.1 also demonstrates an example of a working model.

In order to construct a scientific model, you should ensure that you:

- conduct a lot of background research on the chosen phenomenon
- draw a draft of your model that includes the dimensions to scale
- complete a detailed risk assessment if chemicals or electricity are involved
- select materials that are appropriate for what is being modelled
- consider the cost of those materials.

Models are an important scientific device as they can represent phenomena that are difficult to observe, including those that:

- are too large or small to see
- occur too slow or too fast to observe



Science Photo Library/MARTYN F. CHILLMAID

FIGURE 2.13.1 The 'lemon battery' electrical circuit is an example of a working model that may be used to demonstrate how the electrolytes found in fruit can facilitate electron movement.

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- no longer exist or happened in the past
- have not yet been invented (prototypes).

Models simplify complex processes, and by doing so, they are likely to increase your understanding of difficult concepts. Creating a model allows you to put theory into practice and is a perfect choice of depth study for those who prefer the practical, more tactile elements of the course.

2.14 Creating a portfolio

A portfolio is compilation of work that aims to provide multimodal evidence for a particular purpose. In this case, a portfolio may be used to compile all the elements of an investigation, whether it is a primary or secondary one.

The portfolio can be used to compile:

- research
- reflective journal entries
- drawings, diagrams and photographs
- timelines
- maps
- tables and graphs
- spreadsheets
- responses from survey questionnaires
- transcripts from interviews with experts
- the primary investigation itself (i.e. research question, aim, hypothesis, materials, risk assessment, method, results, discussion and conclusion)
- conclusions drawn from related investigations.

Your portfolio should be presented in a folder with a table of contents at the beginning outlining the type of evidence included and with the associated page number/s labelled (Figure 2.14.1).

Table of contents

Investigating the impact of coral bleaching on biodiversity in the Great Barrier Reef since 2010

	Page/s
Background information on coral bleaching	1–3
Awareness of coral bleaching: Survey results	4–5
Distribution graphs	6–8
Statistical analysis	9
Interview transcript: Marine biologist	10–11
Photographs over time	12–13
Conclusions	14

FIGURE 2.14.1 A portfolio should include a table of contents at the beginning.

2.15 In the field

fieldwork investigation conducted outside the laboratory

The general process of **fieldwork** refers to observations that are collected and recorded in a natural environment, as opposed to a relatively controlled environment such as a laboratory. Fieldwork is essential in many areas of science. For example, in trying to gain an understanding of some ecological relationships such as those between biotic and abiotic factors in a natural setting.

iStock.com/RainervonBrandis

FIGURE 2.15.1 Specialised technology has allowed scientists to conduct fieldwork in the ocean, such as this scientist researching coral bleaching.

Primary scientific investigations comprising fieldwork not only increase our understanding of the world around us, they also have great economic importance. An example is soil testing, which includes the collection and analysis of a sample of soil for nutrients, pH, salinity, organic matter and contaminants such as heavy metals. In testing these factors, environmental scientists can provide farmers and other land users with feedback on how to increase the efficiency of their soil. These programs are essential in the agricultural industry in order to maintain healthy and fertile soils that encourage the rapid growth of crops.

In terms of the depth study, fieldwork does not always have to consist of an entire field study; it can also include designing field trips, conducting surveys and interviewing experts.

If you choose the main component of your depth study to be based in the field, you may either plan and perform your own field study, or design a field trip that aims to educate selected members of the public.

Considering your local environment

Local environments such as bushland, river banks or tidal zones are the most appropriate location to conduct a field study. Whether you are conducting the field study yourself or planning a field trip to a location, local areas are familiar and relevant to your life.

iStock.com/istock80

FIGURE 2.15.2 Rock platforms in tidal zones, such as this one at Bateau Bay on the New South Wales Central Coast, are an example of an environment you could use for your field study.

If you wish to design a field trip, an example may be to educate students from your local primary school about the aspects of a local ecosystem such as an area of bushland, river bank or tidal zone. Alternatively, if you reside in a heavily urbanised area, there may be museums close by that could be used as the basis of a field trip.

Once you have an idea of the types of environments or facilities you might be able to use, you need to reflect on what it is you want students to learn during this field trip. At each step of planning your field trip, it is important that what the students will learn is at the forefront of your plan.

You might talk to your teacher about areas of the year 7 curriculum that could be used to introduce primary school students to the concepts they will be learning when they go to high school. In doing so, the field trip is relevant to the students.

2.15.1 Guideline for the preparation of an environmental management plan

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Planning a field trip

Many facilities such as museums will require school groups to book into the centre, even if it is free to enter, to ensure the centre is not overcrowded when you visit.

Once the venue has been decided, it is important that you visit there to get an idea of how your field trip will progress. If you are entering an ecosystem you will need to ensure that it is easy for the students you intend to take there to move around, take rest breaks and have access to a toilet. For example, a bush track with steep inclines may not be suitable for younger students.

Another crucial step in planning any field trip is completing a risk assessment. A risk assessment allows you to foresee any potential problems before they happen. The following describes the different components of a field trip risk assessment.

- Identify: What is potentially going to be a problem?
- Assess: Is it a low risk, a medium risk, or a high risk?
- Control: How can you minimise the degree of risk?

If you complete the risk assessment and think there is a high risk of an incident occurring, then you should reconsider the suitability of your field trip.

Planning a field study

If you wish to examine a local environment yourself, then you may plan and perform your own field study. A field study is a research project carried out in the natural environment and looks at the many interacting factors of an ecosystem.

An example may be to examine the abiotic and biotic interactions within a rock platform ecosystem. A field study of this nature may include:

- assessing water quality, turbidity, salinity and pH
- listing the abiotic factors influencing the ecosystem
- identifying **species** and constructing a food web of the ecosystem
- using quadrats and line transects to determine the distribution and abundance of particular organisms
- examining the human impacts on the ecosystem.

Information collected in a field study may be presented in a portfolio with related research and data or could act as evidence for an environmental management plan.

WS
2.15.1 Field study of an ecosystem

species
group of living organisms with similar characteristics that can interbreed

2.16 Engaging with experts

Conducting fieldwork can also involve seeking opinions and expertise from those who specialise in the area of your investigation.

Engaging with experts may take place through informal conversations, structured interviews, local tours, email correspondence, scientific forums or social media. Interviewing is a useful way to obtain information from experts. When planning and conducting an interview, it is beneficial to:

- conduct the interview in a public place such as a library conference room or university
- carefully plan the questions before the meeting and have them written down
- ensure most of your questions are open-ended; that is, they encourage explanations rather than yes/no answers
- bring a voice recorder and transcribe the interview later
- ask the expert if there is anything else they would like to add.

CROSS-CURRICULUM

If your chosen depth study focuses on Indigenous perspectives of a scientific concept, such as natural medicine, Aboriginal education officers and community groups may be able to put you in contact with local elders in the community.

Meeting face-to-face with an expert in close proximity to your local area may be difficult, especially if your chosen field is a niche market. To overcome this, you may choose to conduct interviews or contact local agencies via email.

If you live close to a university, you may also be able to collaborate with scientists who are working in areas that you are interested in. Additionally, you may be able to use programs such as Scientists in Schools, run by the CSIRO.


Alamy Stock Photo/Bjorn Svensson

FIGURE 2.16.1 Local elders are knowledgeable sources of information, particularly in regards to your local area.

2.17 Analysis

Irrespective of your chosen depth study, you will have to undertake some form of analysis. Analysis is a detailed examination of the components in your investigation. You may undertake data analysis if you have chosen to perform a primary scientific investigation that also involves constructing tables and graphs to determine any relationships in your data. If you have selected to do a secondary investigation, the analysis may involve examining current research published in your area of study for its reliability and relevance to your aim.

Data analysis

Data analysis is also referred to as the 'discussion' in a primary scientific investigation. It is the component of your investigation where you link the results to the hypothesis and aim.

Data analysis can involve:

- identifying trends and relationships
- comparing results to similar research
- commenting on reliability and validity in relation to the variables of the investigation
- recognising any limitations in your investigation
- accounting for any discrepancies in your data
- suggesting how your findings can be used in future investigations.

Completing data analysis and including it as a reflection of your investigation allows those who are reading your research to evaluate its purpose and determine if it effectively addresses the aim. It also provides an opportunity for you to explain your findings and account for any problems that may have occurred throughout the investigation.

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2.18 Constructing graphs and tables

Tables and graphs are usually included in the results section of a primary investigation as a simple and effective way to organise and display the data collected. Once the data from tables are transformed into the most appropriate graph type, any trends or relationships can be identified and explanations proposed.

Tables

Tables are used to systematically record and manage data. If you intend to submit a primary investigation for your depth study, displaying your results in a table provides readers with a snapshot of the outcome to your investigation. There are many ways in which a table can be constructed and there are slight differences depending on the type of data you are collecting. Figures 2.18.1 and 2.18.2 can be used as scaffolds to display the results from investigations that collect **qualitative data** and **quantitative data**, respectively.

qualitative data descriptive data collected as evidence during an investigation (e.g. images, observational sentences)

quantitative data numerical values collected as evidence during an investigation (e.g. measurements)

When collating quantitative data, make the columns your dependent variable and ensure the units of measurement are in brackets

Trials improve reliability as they depict consistency

When collating quantitative data, make the rows your independent variable

Reporting on an average from multiple trials makes the data more reliable

Table 1. Heart rate following 15 minutes of exercise

	Heart rate (BPM)			
	Trial			
Participant	1	2	3	Average

FIGURE 2.18.1 A table scaffold for recording quantitative data.

Collating data from different groups addresses consistency and improves reliability

The independent variable is addressed in the rows

Table 2. Product of chemical reaction with unknown chemicals

	Group					
	1		2		3	
Chemical reaction	Colour	Precipitate (Y/N)	Colour	Precipitate (Y/N)	Colour	Precipitate (Y/N)
Chemical 1 + Chemical 2						
Chemical 2 + Chemical 3						
Chemical 1 + Chemical 3						

When collecting qualitative data, columns show the dependent variable/s

FIGURE 2.18.2 A table scaffold for recording qualitative data.

Graphs

You may be able to identify a relationship from simply looking at numbers in a table but the best way to determine the strength of that relationship is to plot a graph. As is explained in Chapter 3 and summarised in Figure 2.18.3, there are many types of graphs and each has a specific purpose.

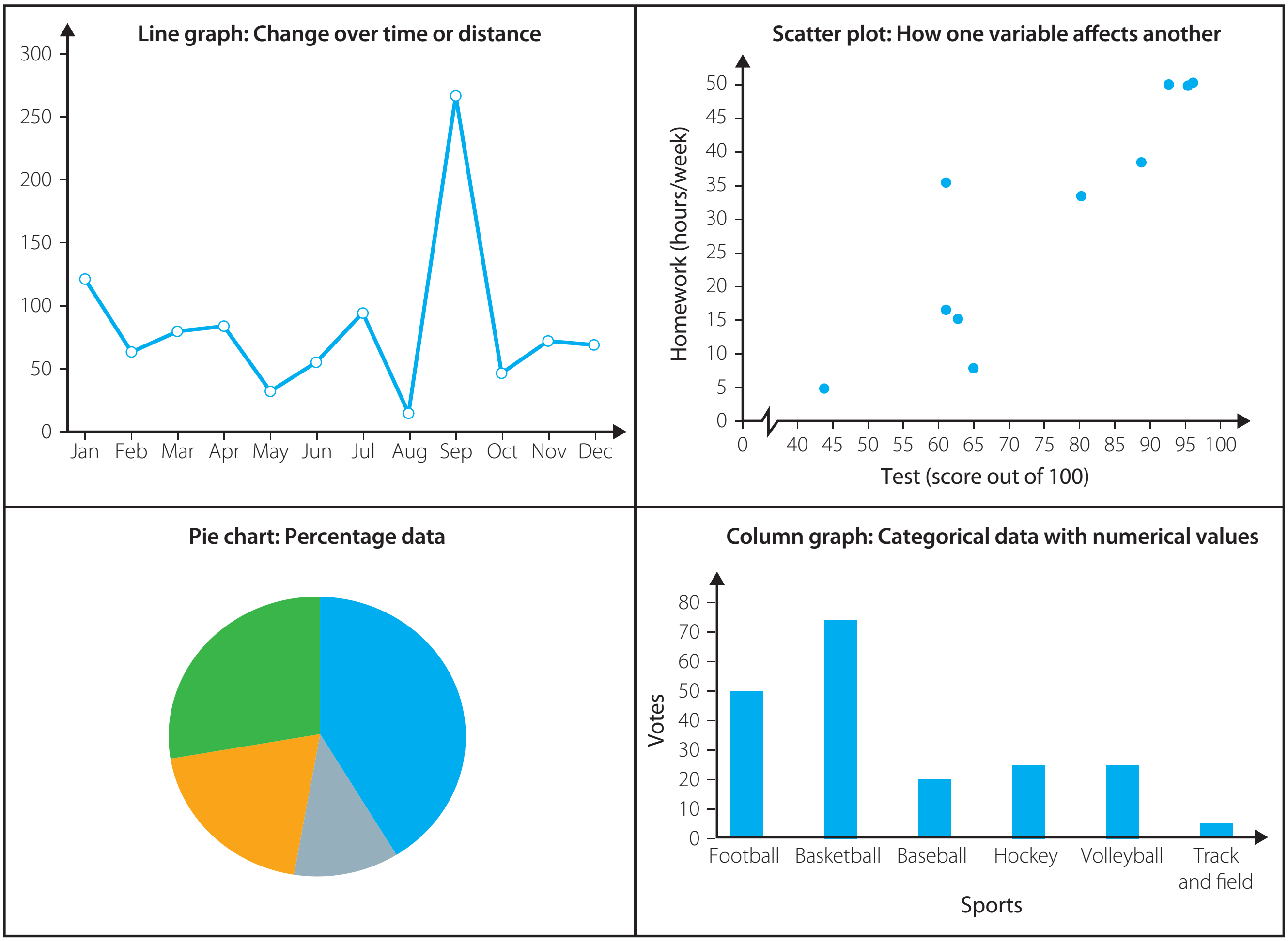

FIGURE 2.18.3 Each type of graph has a specific purpose. This figure shows how the most appropriate graph type to include in your analyses is determined by the manner in which your data is collected.

When constructing a graph, consider the following points.

- All graphs should be large and clear with a scale so that the data takes up most of the plot area.
- The independent variable is usually placed on the *x* axis and the dependent variable on the *y* axis.
- Axes must be labelled with the names of the variables and their units (if appropriate).
- The title of a graph should include the name of the independent and dependent variables.
- Scatter plot points should not be joined together but can include a line of best fit.

If your depth study includes primary research then it is beneficial to include a graph depicting your findings. In doing so, the results are succinctly presented and accessible to all readers, and can also be used as a reference point in your discussion (analysis).

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Identifying trends

Line graphs and scatter plots are constructed to determine whether a trend (or correlation) in the data exists.

To describe a trend, describe the behaviour of the dependent variable as the independent variable changes. In Figure 2.18.4 the trend would be written as follows: the data collected from this investigation shows that the more hours students spent studying, the higher their test score.

When identifying trends, it is important to keep in mind that correlation does not always equal causation. You may identify a relationship between the variables, but this does not always imply that one causes the other. For example, Figure 2.18.4 shows a positive correlation between hours spent on homework and the scores in a test, but this does not mean that homework is the only cause for increased test scores.

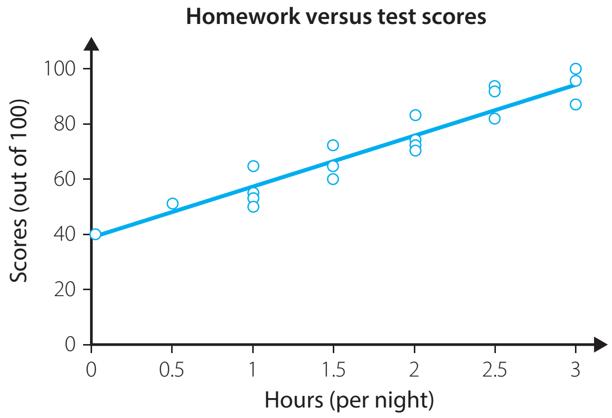

FIGURE 2.18.4 This graph shows a positive correlation between the amount of hours spent completing homework and scores on a test.

2.19 Analysing a variety of sources

Similar to a literature review, analysing a variety of sources allows a scientist to examine current texts and research to discuss conflicting ideas or gather evidence for your hypothesised theory.

Analysing secondary sources

Secondary sources are those that are published by any individual who did not personally participate in the event or research being examined. Analysing secondary sources may include examining the information contained within:

- textbooks
- magazines
- websites
- videos
- newspapers.

These sources can provide background information and context to your investigation, form the foundations for evidence-based arguments, and act as an inspiration for creative tasks.

WS
2.19.1 Secondary investigation scaffold
2.19.2 Primary investigation scaffold

Analysing research

Primary sources are those that are published by an individual who was actively involved in the study or research. The most reliable form of primary scientific research is peer-reviewed articles. When research becomes subject to peer review, it means that it has been evaluated by several academics in the specific area of research. Peer-reviewed articles have been affirmed as being of exceptional quality and in adherence to the standards of the scientific journal in which it has been published.

Analysing peer-reviewed articles demonstrates a sophisticated ability to select and evaluate relevant scientific sources, and adds complexity to your study.

3

MODULE 5 SCIENTIFIC INVESTIGATIONS

Scientific investigations follow a process. An observer ponders a question about a phenomenon or event and then creates a hypothesis. To answer the question and prove the hypothesis, investigators collect evidence as primary and/or secondary data and then report their analysis and conclusions for peer review and further analysis of the findings. The scientific investigation does not follow a formal protocol, it is a cycle of findings, refining the hypothesis and questioning and analysing the data. However, the final report of the investigation has a structured format that the scientific community understands as a common language.

A misconception about science is that its history is a steady progression, where scientists collect knowledge in an orderly manner, sequentially and deliberately building upon existing ideas and theories. However, scientific history is littered with examples of where the prevailing dogma, ideas thought to be true for hundreds or thousands of years, has been overturned by brand-new ideas. These new ideas were backed up by investigations confirming that they were correct.

Einstein's theory of special relativity was a complete departure from the prevailing ideas of the nature of light and electromagnetic radiation. However, despite its apparent weirdness, the theory has been repeatedly tested and confirmed to be accurate.

There are many examples of scientific discoveries made by accident, or by methods that are well outside the normal scope of the scientific method taught in early science lessons. In this section, we will examine a few of these discoveries.

INQUIRY QUESTIONS

- What initiates an investigation?
- What type of methodology best suits a scientific investigation?
- How can we judge the integrity of a scientific investigation?
- What is the structure of an investigative report?

CONTENT

Students investigate:

- practical investigations to obtain primary data
- different types of scientific investigations
- reliability and validity
- reporting.

OUTCOMES

A student:

- develops and evaluates questions and hypotheses for scientific investigations INS11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information INS 11/12-2
- conducts investigations to collect valid and reliable primary and secondary data and information INS 11/12-3
- develops and evaluates the process of undertaking scientific investigations. INS12-12

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Getty Images/Hero Images

3.1 Practical investigations to obtain primary data

scientific investigation
an organised approach to solving a scientific question

scientific theory
an explanation of an aspect of the world that can be tested

At the centre of most science is the **scientific investigation**. An investigation is any deliberate, organised process to try to answer a scientific question, from which new **scientific theories** may emerge.

An investigation can be instigated in many ways. It could be as straightforward as asking a simple question, such as 'Why is the sky blue?'. Some scientists may be inspired by 'eureka moments', where a sudden flash of inspiration pushes them into new ways of thinking about a problem, such as the famous story of Archimedes trying to work out if a crown was made of pure gold.

Many discoveries come from taking the ideas and discoveries made in the past and exploring new aspects of these ideas. Scientists can often develop these new ideas when technological advances allow more accurate or fresh observations.

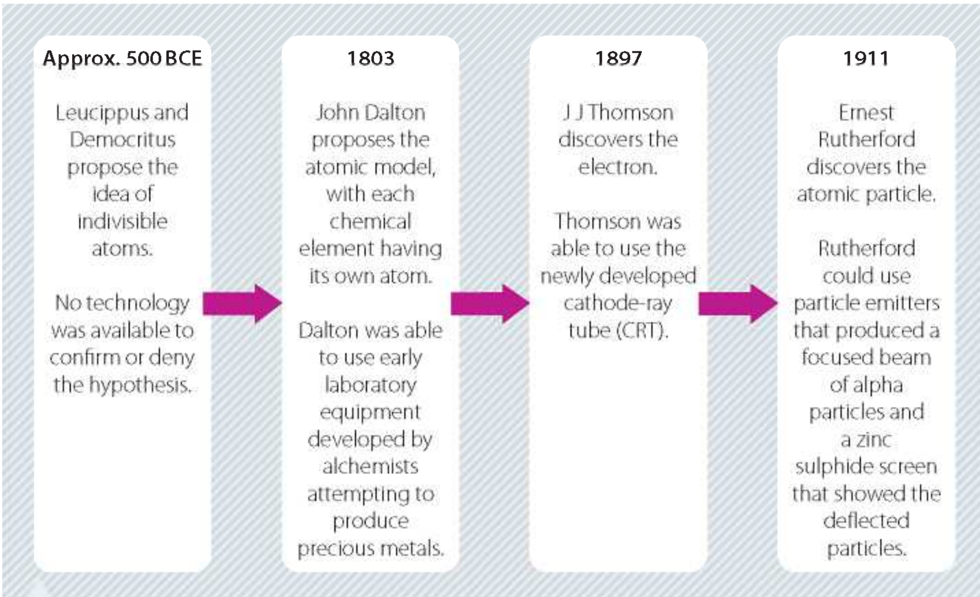

FIGURE 3.1.1 This timeline shows how advances in technology helped with the development of atomic theory.

chronic
an illness that continually re-appears or is experienced for a long time

peptic ulcer
a break in the tissue of the digestive system, mainly in the stomach, that causes pain, among other symptoms

gastrointestinal tract
organ system from the mouth to the anus which is involved in digestion of nutrients and excretion of waste products

INQUIRING FURTHER

Research a scientific discovery inspired by a eureka moment, such as that of Archimedes in his bath. Present your research as a five-minute presentation. As part of this presentation, discuss what the scientific thinking was before the discovery, and how the discovery affected scientific thinking and society.

For example, with atomic theory, each development came about because new technology was able to show an aspect of the structure of the atom that could not previously be observed, as shown in Figure 3.1.1.

In this section, we show how some discoveries come from sparks of intuition or genius, as well as some of the risks scientists sometimes take.

Peptic ulcers – Marshall and Warren

abdominal
part of the body containing the stomach and intestines

A **chronic** problem in western civilisation in the 20th century was a condition affecting the stomach – **peptic ulcers**. A peptic ulcer is a break in the tissue of the **gastrointestinal tract**, which can cause great discomfort and pain in the chest and **abdominal** area. Other symptoms include vomiting, severe flatulence, nausea and fatigue.

What led to the discovery?

Many doctors assumed that ulcers were caused by spicy food, stress, smoking and heavy drinking, all of which increase the acid levels in the stomach. It was thought that if the acid level built up too much, the

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acid would eat away at the mucous that lined the stomach, and then attack the stomach lining itself, causing the ulcers to form. This conventional thinking would be overturned by two scientists from Western Australia.

In Perth, Barry Marshall and Robin Warren (Figure 3.1.2) were studying gastrointestinal diseases. When looking at **biopsies** from patients with severe ulcers, they discovered a bacterium, *Helicobacter pylori (H. pylori)*.

Doctors thought it was impossible for any bacteria to survive in the highly acidic environment of the stomach, and the notion went against every medical idea at the time. Warren had first seen these bacteria in 1979 in patient biopsies he had been studying. This piqued his interest, as he thought there might be a connection between the bacteria and the ulcers; however, there was much resistance to the idea. In 1981, he met Marshall and they investigated these strange bacteria in detail.

AAP/AP Photo/Bernd Kammerer

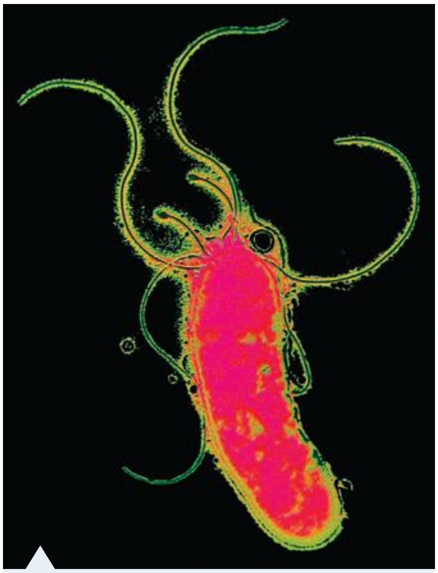
FIGURE 3.1.2 Barry Marshall and Robin Warren received the Nobel Prize for Medicine in 2005 for their work on peptic ulcers.

biopsy
taking samples of tissue from a patient and testing these samples in a laboratory; this technique is commonly used to test if cells are cancerous

Relationships and patterns

Warren and Marshall tried to grow the bacterium in the laboratory. It proved to be a difficult task, as all the **tissue cultures** they attempted to grow failed. It wasn't until a culture was left over an Easter long weekend that they were finally able to grow a successful bacterial sample.

The reason they had trouble was due to the procedures in the lab where they worked. A laboratory technician would check the sample after two days, see no growth, and, assuming the culture had failed, they would throw the sample out. An extended shutdown over the Easter weekend gave the sample the five days it needed to start growing. Once the culture had grown, it was possible to do extensive experimentation on the bacteria, which showed Marshall and Warren that the bacteria were the likely cause of the ulcers (Figure 3.1.3).



Science Photo Library/University of Southampton/P. Hawtin

FIGURE 3.1.3 Marshall and Warren confirmed the *H. pylori* bacterium was the cause of most peptic ulcers.

tissue culture
a group of living cells grown under laboratory conditions (Figure 3.1.4, over)

Testing conclusions

By 1985, Marshall and Warren were getting frustrated that no one in the medical community took them seriously. Barry Marshall attempted to prove his hypothesis by infecting himself; he deliberately swallowed some of the tissue culture. Within a week he had developed a peptic ulcer, with the symptoms of stomach inflammation and vomiting. He subsequently took a course of antibiotics, which cured the ulcer and the symptoms.

INQUIRING FURTHER

Research an example of an extremophile bacteria – bacteria that live in extreme conditions. Present your research as an annotated visual display or interactive media presentation. Examples could include bacteria found on nuclear fuel rods, around thermal vents on the bottom of the ocean, or those that eat minerals from rocks many kilometres below the surface of Earth.

INQUIRING FURTHER

Research how tissue cultures have been used in medicine, such as in making skin grafts. Present your research in the form of a one-page factsheet.

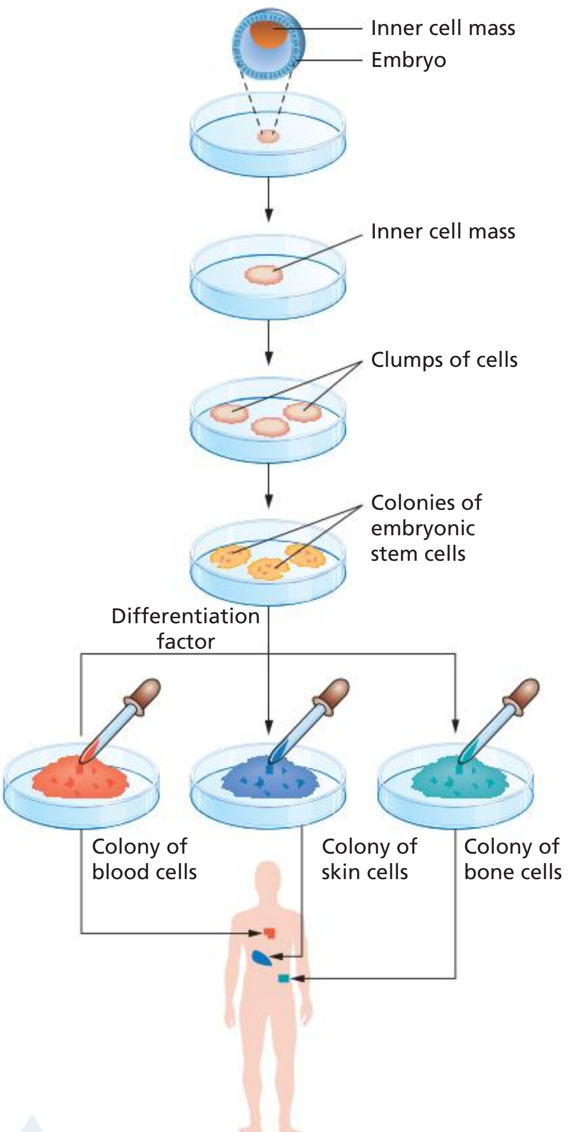


FIGURE 3.1.4 Tissue culture is a common biological tool used in research, such as for growing stem cells from human cells.

New ideas and technologies

Despite the evidence provided by Marshall testing the cure on himself, it took a decade before the findings were accepted, and antibiotics became the recommended treatment for peptic ulcers.

There was much resistance to the link between *H. pylori* and stomach ulcers. As previously stated, the accepted thinking was that peptic ulcers were caused by the stress, spicy food, smoking and heavy alcohol consumption. Drugs that reduced acid production in the stomach or neutralised stomach acid were available, and they effectively treated the condition. However, in many cases a patient required ongoing treatment to prevent the condition returning. This could be costly and inconvenient for them.

Antibiotic treatment is significantly cheaper, and has the bonus of completely removing the *H. pylori* from the body, effectively curing the sufferer, who in most cases requires no further treatment. Now, *H. pylori* can be easily detected by a breath test, meaning patients do not need internal examinations or biopsies, so they do not need to stay in hospital.

Experiments by other researchers confirmed the idea that ulcers were caused by the bacterium, and Warren and Marshall were awarded the Nobel Prize for Physiology or Medicine in 2005.

INQUIRING FURTHER

Research other Australian scientists who have won Nobel Prizes in scientific fields. Examples may include Brian Schmidt for Physics, in 2011; Elizabeth Blackburn for Physiology or Medicine, in 2009; or Sir John Comforth for Chemistry, in 1975. As part of your research, give reasons why their research was important to society. Present this as a five-minute multimodal presentation.

INVESTIGATION 3.1.1

Growing bacterial cultures

AIM

To observe the growth of bacterial cultures over several days

MATERIALS

- Agar plates
- Tape to seal the plates
- An incubator or warm space

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» **RISK ASSESSMENT**

HAZARD	MANAGEMENT
Some microbes that grow on the plates may be harmful.	Once the plates have been exposed to microbes, they should be securely sealed with several layers of tape and not opened again. The plates will need to be autoclaved once the investigation is complete.

RISK ASSESSMENT

METHOD

1 Collect your agar plate. Ensure the lid is secured to prevent early contamination.
2 Use a cotton bud to collect samples of bacteria from areas such as the laboratory bench or student chairs and tables.
3 Carefully lift the lid of the agar plate and gently rub the cotton bud across the agar surface. Take care not to dig in too far.
4 Secure the plate by wrapping adhesive tape around it to ensure you cannot separate the two sides of the plate easily.
5 Label your plates to easily identify them later. You may also want to take a 'before' photo so you can compare your results. A good technique is to include a ruler in the photo to show the scale of the growth of any microbes later on.
6 Place your plate in an incubator or a warm place. The agar medium should be at the top of the plate. This will prevent any condensation from disrupting the growth of your microbes.
7 Make observations every day if possible, taking a photo each time to compare the microbial growth.
8 After one week, dispose of all samples using an autoclave.

RESULTS

Copy and complete the table below.

DAY	NUMBER OF BACTERIAL COLONIES	ESTIMATED COVERAGE OF AGAR MEDIUM (PER CENT)
0		
1		
2		
3		
4		
5		
6		
7		

DISCUSSION

1 Outline reasons why assessing risks is important in this experiment.
2 Provide reasons why you could not conduct this experiment indefinitely.

EXTENSION

Design and conduct an experiment that either determines areas in the school that have the most microbes or assesses the cleaning claims of some hand soaps.

Growing plants

Plants are a fundamental part of any ecosystem, being the start of most food webs and a source of food. People have often wondered how plants grow. However, until a few hundred years ago, the process was a mystery. It was known that plants grew from seeds and people believed that the plants 'ate' the soil.

gas
a fluid state of matter that fill all parts of a given container because the particles move freely

3.1.1 Van Helmont's experiments

What led to the discovery?

In the early 1600s, Jan Baptist van Helmont, a Belgian doctor and chemist, was an early researcher into the way gases moved and interacted. He is credited with the first use of the term **gas**.

Van Helmont was also curious about how plants grew from seemingly nothing. He took a young willow seedling, put it in a pot with soil and let it grow. All he did was add water. Then he took careful measurements of the mass of the soil and willow plant.

At the start of his experiment, the mass of the soil was 90 kilograms, while five years later at the end of the experiment, it was still very close to 90 kilograms, weighing just 57 grams less. The willow sapling had grown into a 76-kilogram tree. Van Helmont thought that this was an insignificant amount of lost soil and therefore concluded that the growth could only be attributed to the addition of the water.

Alamy Stock Photo / Art Collection 2

FIGURE 3.1.5 Jan Baptist van Helmont was an early pioneer in the studies of chemistry and biology.

Getty Images / iStock / lamiel

FIGURE 3.1.6 A willow tree

> 'For I took an Earthen Vessel, in which I put 200 pounds of Earth that had been dried in a Furnace, which I moystened with Rain-water, and I implanted therein the Trunk or Stem of a Willow Tree, weighing five pounds: and about three ounces: But I moystened the Earthen Vessel with Rain-water, or distilled water (alwayes when there was need) and it was large, and implanted into the Earth, and leaft of the Vessel, with an Iron-Plate covered with Tin, and easily passable with many holes. I computed not the weight of the leaves that fell off in the four Autumnes. At length, I again dried the Earth of the Vessel, and there were found the same 200 pounds, wanting about two ounces. Therefore 164 pounds of Wood, Barks, and Roots, arose out of water onely.'
>
> Johannes Baptista van Helmont, *Oriatrike: Or, Physick Refined,* trans. John Chandler (1662), page 109.

Later, other researchers determined that this small loss of soil was significant, as elements found in the soil such as sulfur, nitrogen and potassium were essential for the healthy growth of the plants. The plant only needed these elements in very small amounts. Compounds such as phosphates and nitrates could also help plants grow if they were added to the soil, leading to the relatively modern idea of **fertilisers** being used in agriculture.

fertiliser
a substance added to soil to aid in plant growth

Relationships and patterns

Van Helmont tried to establish relationships between the variables that he was managing. At the end of the experiment, he dried the soil and weighed it but did not observe a significant change. However, the tree was 76 kilograms heavier. As he only used the one plant, it was difficult for him to establish any patterns or relationships. It is important to point out that van Helmont did not have enough background knowledge, as the process of photosynthesis had not yet been described; therefore, he did not know that atmospheric gases were playing a key role in the willow tree's weight gain.

While van Helmont did some early work on carbon dioxide, which he called 'gas sylvestre', it would be almost a hundred years before the idea of gaseous exchange in plants was discovered. This made it very hard for van Helmont to ascertain the correct relationship between the loss of mass in the soil, the addition of water and the growth of the plant.

INQUIRING FURTHER

Research the use of nitrogen-based fertilisers and the effect that nitrogen has on the environment and on the ozone layer. As part of your research, outline some of the ways modern farming techniques use sustainable methods. Present your research as a five-minute PowerPoint presentation or video.

Testing conclusions

Van Helmont's experiments were useful in establishing further areas for botanists to explore, even though his conclusion was wrong and not valid as a scientific experiment. In 1727, the botanist Stephan Hales built on van Helmont's research with the publication of *Vegetable Staticks*, a book in which he talked about gaseous exchange in plants through transpiration.

microwave
a form of electromagnetic radiation with wavelengths between 1 metre and 1 millimetre

New ideas and technologies

Van Helmont's ground-breaking experiment may not have solved the mystery of how plants gain mass, but it did inspire investigations by people such as Stephen Hales.

radiant heat
heat transfered by electromagnetic waves

friction
a force of resistance when two surfaces rub against each other

Microwave ovens

Microwave ovens provide a quick and convenient way to heat food. Unlike conventional electric or gas ovens that use **radiant heat** to cook food, a microwave causes water molecules in the food to vibrate. As their rate of vibration increases, they bump into each other more frequently, causing **friction** between the molecules, which generates heat. Microwave ovens are most effective in cooking foods with higher water content.

Cooking with microwaves uses less energy than conventional cooking methods. A stove or conventional oven generates a large amount of heat, which is then transferred to a pot, pan or tray, where the heat is further transferred to the food, which starts the cooking process. In each step, a good portion of the energy is lost to the environment.

With a microwave oven, the microwaves directly interact with the water molecules within the food, so there is less energy lost throughout the process.

FIGURE 3.1.7 Percy Spencer taught himself about electronics and used this knowledge to invent the microwave oven.

The invention of the microwave oven came about because of technology developed during World War II. The American physicist and inventor Percy Spencer (1894–1970) is regarded as the inventor of the microwave oven. Spencer worked for the United States military developing radar, despite the fact he was not a trained scientist. When he was young, he became very curious about electronics after learning about the use of wireless communication on the *Titanic*. When he joined the navy at the age of 18, he set about teaching himself many of the ideas behind wireless communication through textbooks he acquired.

3.1.2 Percy Spencer

3.1.3 How the microwave was invented by accident

3.1.4 The amazing true story of how the microwave was invented by accident

He eventually left the navy and joined the American Appliance Company, now known as Raytheon. The company developed large-scale electronics for the military. Spencer was well regarded, eventually becoming a member of the company's board of directors. He received many patents during his working life; however, it was his development of microwave technology that is best remembered.

radar
an acronym for RAdio Detection And Ranging (or RAdio Direction And Ranging), which is a system used to detect the presence of objects over long distances

What led to the discovery?

At the start of World War II, Spencer had become an expert in designing magnetrons. Magnetrons are vacuum tubes that generate microwaves and are the basis of how **radar** works.

INQUIRING FURTHER

Research why the radiation produced by a microwave oven is safe. As part of your research, outline how a microwave oven cooks food and describe the terms *ionising radiation* and *non-ionising radiation*. Present your research as a five-minute multimodal presentation.

While working with some of his magnetrons, he noticed that a chocolate bar in his pocket had warmed up and started melting.

Relationships and patterns, and testing conclusions

He and his colleagues began experiments exposing various foods to the microwaves, including making the world's first microwaved popcorn. The strength of the magnetron meant that the corn kernels popped almost immediately when exposed to the radiation. The experiment with cooking an egg was less successful when the egg exploded in the face of one of the engineers.

Getty Images/Science & Society Picture Library

FIGURE 3.1.8 Microwave ovens are a quick and convenient way to heat many types of food.

New ideas and technologies

Spencer eventually created a small metallic box into which the electromagnetic radiation could be directed, the first microwave oven. The first microwave oven to be sold was the *Radarrange*, which cost about $5000 in 1945. It measured about 2 metres tall and weighed 350 kilograms. It took more than 20 years for an appliance similar to a modern microwave oven to go on sale, in the late 1960s.

INQUIRING FURTHER

Science and the military – research the links between technology and military applications. Some examples might include the development of metals for swords through the bronze and iron ages, or the use of gun powders for projectile weapons. Present your research as a five-minute video or PowerPoint presentation.

INVESTIGATION 3.1.2

Measuring the wavelength in a microwave oven

AIM

To determine the wavelength of the electromagnetic radiation in a microwave oven

MATERIALS

- Microwave oven
- Microwave-safe plate
- A food that melts easily, such as chocolate or sliced cheese

RISK ASSESSMENT

HAZARD	MANAGEMENT
The food and plate will become hot.	Use tea towels or kitchen gloves to remove the plate.

»

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» METHOD

1. Take the turntable out of the microwave oven.
2. Carefully cover the plate with the food.
3. Put the plate in the microwave oven.
4. Turn the oven on for about 20 seconds. Stop and check if any of the food has melted. If it has, remove the plate; if it hasn't, heat for another 20 seconds.
5. Measure the distance between the melted spots on the food.

RESULTS

Distance between melted spots: ____________________
The distance between the dots is half the wavelength of the actual wave. Derive an expression that could be used to calculate the value of the microwave wavelength.
Expression: ____________________
Calculated wavelength: ____________________

DISCUSSION

1. Describe why the turntable had to be removed.
2. Outline what your experiment demonstrated about how a microwave oven cooks food.
3. Why should the turntable be used when cooking food?

EXTENSION

Use your experimental data to work out the speed of the microwaves using the formula below.

$$v = \lambda f$$

Where
v = the wave speed in metres per second, m/s
f = the frequency in hertz, Hz (most ovens operate at 2450 MHz)
λ (lambda) = the wavelength in metres, m

SECTION REVIEW 3.1

REMEMBERING

1. Briefly describe the work of Marshall and Warren, van Helmont and Spencer.
2. Describe the role of observation in the discoveries of Marshall and Warren, van Helmont and Spencer.
3. State a new technology that came out of two of the discoveries in this section.

UNDERSTANDING

4. Outline reasons why the medical community did not initially accept the ideas of Marshall and Warren.
5. Discuss a reason why van Helmont was unable to see the link between the slight decrease in soil mass and growth of plants.
6. Describe why Spencer is considered a scientist even though he did not have formal qualifications.

APPLYING

7. Propose the hypothesis and conclusions each scientist made in their discoveries.
8. Each of the discoveries came about through ideas that were different to the conventional thinking of the time. Propose reasons why these sorts of ideas often take a long time to be accepted.

WS 3.1 Practical investigations

3.2 Different types of scientific investigations

When scientists start an investigation, they need to carefully plan how they are going to test their ideas. Careful planning can make the impossible, possible.

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FIGURE 3.2.1 Eratosthenes used his knowledge of mathematics to determine the circumference of Earth.

circumference the distance around a circle

summer solstice longest day of the year; that is, when the most amount of sun is seen

3.2.1 Eratosthenes of Cyrene

3.2.2 Eratosthenes calculates Earth's circumference

Interesting investigations

Eratosthenes and Earth's circumference

Born in 276 BCE, Eratosthenes was an ancient Greek astronomer and mathematician, among many other pursuits. He used a number of techniques to determine Earth's **circumference**.

While working at the Library of Alexandria in Egypt, Eratosthenes devised a method to work out the circumference of Earth. Eratosthenes knew that when the **summer solstice** occurred at noon at the Egyptian city of Syene, now called Aswan, the Sun was directly overhead; there were no shadows on the ground. At the same time in Alexandria, he measured the angles of the shadows at noon, which was about 7.2°. A quick calculation of 360/7.2 gives the result that the distance between the two cities is 1/50th of the circumference of Earth.

Eratosthenes knew the distance between the two cities was about 800 km, which meant he could work out that Earth's circumference was 40 000 km, which is very close to the actual value (40 075 km). There has been some debate by scholars as to whether the measurement of the distance between the two cities was accurate; however, his methodology was correct.

INQUIRING FURTHER

In ancient times, traditional measurements such as distance and time were not standardised. Create a five-minute, multimodal presentation on two or three units of measurement used by ancient civilisations. Include reasons why we no longer use the measurements.

INQUIRING FURTHER

Ancient Greek polymaths

Many of the ancient Greek scientists read widely across a number of subjects. This kind of person is called a *polymath* which comes from the ancient Greek word meaning 'having learned much'. Eratosthenes is an example of a polymath. He was an astronomer, mathematician, poet, geographer and he ran the Library of Alexandria. Propose reasons why people such as the ancient Greeks were able to study a wide range of ideas across many disciplines. Compare the ancient Greeks to the 21st-century scientific research that is often done in teams of interdisciplinary experts.

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INVESTIGATION 3.2.1

Measuring the height of tall objects

It is possible to measure the height of tall objects, such as trees in the playground, by measuring shadows.

AIM

To determine the height of a tall object, such as a tree, in the playground

MATERIALS

- Tape measure

RISK ASSESSMENT

HAZARD	MANAGEMENT
Falling branches.	Check the state of the tree before attempting the experiment.
Sunburn.	Ensure you have adequate sun protection.

METHOD

1. Identify and choose a large object, such as a tree in the playground that is casting a shadow whose length will be easy to measure.
2. Measure your height and measure the length of your shadow.
3. Measure the length of the tree's shadow. You should also measure the width of the tree's trunk, and add half of this value to the shadow length.
4. Use your measurements to determine the height of the tree.

RESULTS

Copy and complete the table below.

Height of student (cm)	
Length of student shadow (cm)	
Length of tree's shadow, plus half its trunk width (cm)	

Calculation 1: Student height divided by student shadow.
Calculation 2: Multiply the number from calculation 1 with the length of the tree's shadow. This will give you the tree's height.

DISCUSSION

1. Describe potential measurement errors in the investigation. Include reasons why the width of the tree's trunk is important.
2. Outline ways you could minimise these potential measurement errors.
3. Propose reasons why this experiment should be conducted in a relatively short period of time such as 15 minutes.

EXTENSION

Conduct a secondary source investigation to determine other methods that can be used to determine height. Develop your own primary investigation based on these methods. Once these have been completed, assess the ease and accuracy of each method.

Alamy Stock Photo / Paul Fearn

FIGURE 3.2.2 Christian Doppler was an astronomer whose observations lead to new ideas in the way wave properties changed as the waves moved.

Doppler and the Doppler effect

One indication that an emergency vehicle is coming towards you is the noise of the sirens wailing. As the vehicle approaches, the sound appears to change, rising in **pitch** until it passes, when the pitch appears to drop drastically.

This effect is a wave phenomenon first noted by an Austrian physicist, Christian Doppler. Today, this is known as the Doppler effect. At the time of the discovery, Doppler was studying **binary stars** and the light detected from them.

At the time Doppler was working, astronomy was a laborious task. The faint images from stars were exposed to photographic plates. Once exposed, an astronomer would need to use their sight to meticulously look for changes between the plates. Often these differences were very subtle. The differences could be used to infer the relative movement of the stars, including other objects they orbited.

Doppler noticed that the light spectra coming from the binaries were influenced by the relative movement of the star. If the star was moving away from Earth it appeared to be **red shifted**. This means that the **spectral pattern** appeared to shift towards the red end of the visible light spectrum. If a star was moving towards Earth it would be **blue shifted**.

The phenomenon occurs because objects such as stars move relatively fast. When the star is moving towards Earth, it continually emits light. This emitted light becomes bunched up, increasing its frequency and shortening its wavelength, which takes it closer to the blue end of the spectrum. As the star moves away from Earth, the waves spread out more, taking the frequency closer to the red end.

This idea later allowed Edwin Hubble to use his observation of red-shifting galaxies as evidence for the idea of an expanding universe, and the development of the Big Bang theory. As the Doppler effect is a wave phenomenon, we can also observe it with sound waves.

Figure 3.2.3 shows how this works with the sound made by a fire-engine. The sound waves at the front of the fire-engine become bunched, shortening the wavelength, meaning the sound will have

pitch
a property of sound waves; high-frequency sounds have a high pitch, while a lower-frequency sound has a low pitch

binary star
a pair of stars in orbit around each other

red/blue shift
when spectral lines move towards the red or blue end of the visible spectrum

spectral pattern
when light is viewed through a spectrograph, the parts of the spectrum have distinct spectral lines that represent the various chemical elements

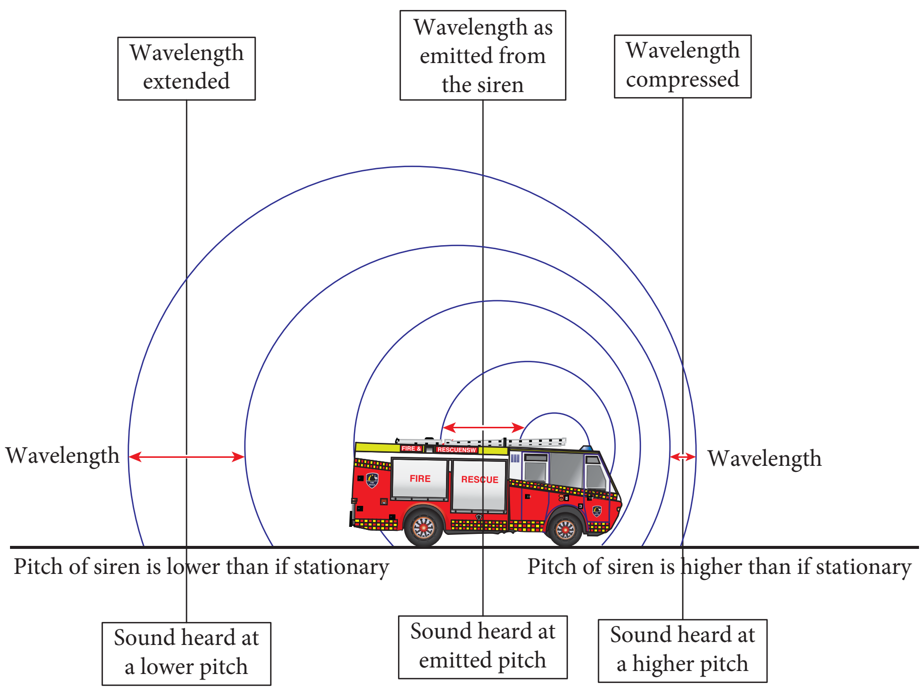

FIGURE 3.2.3 The Doppler effect is most noticeable when objects making loud noises, such as an emergency vehicle, are travelling at high speed.

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a higher pitch. Once the fire-engine moves past the observer, the waves spread out, increasing the wavelength and lowering the pitch.

Another dramatic impact of the Doppler effect comes from supersonic planes. As the plane goes beyond the speed of sound, the sound waves ahead of the plane bunch up, forming a sonic boom.

FIGURE 3.2.4 A supersonic plane breaking the sound barrier.

3.2.3 Doppler effect introduction

3.2.4 NASA: Doppler effect

INQUIRING FURTHER

The study of binary stars led to a better understanding of sound waves. Research an idea from one scientific field that had an affect on a different field. Examples could include the study of black holes leading to the development of wi-fi technology, the research of cathode-ray tubes by Wilhelm Rontgen leading to x-ray machines for medical diagnostics or the work of Russian chemist Constantin Fahlburg who discovered the artificial sweetener saccharine while doing experiments with coal tar. Present your research as a multimodal presentation.

INVESTIGATION 3.2.2

Demonstrating the Doppler effect

AIM

To demonstrate the Doppler effect

MATERIALS

- Tuning fork
- Smartphone or tablet with a frequency detector installed

RISK ASSESSMENT

HAZARD	MANAGEMENT
Pitch fork vibrations can cause damage	Do not hold near your ears.

RISK ASSESSMENT

METHOD

1. Strike the tuning fork so it vibrates. Measure its frequency.
2. Strike the tuning fork again, then rapidly move it back and forth towards your frequency measuring device.
3. Repeat for tuning forks of differing frequencies.

RESULTS

Copy and complete the table in your notebook.

	WHAT YOU HEAR	WHAT YOU MEASURED (HZ)
Tuning fork still		
Tuning fork moving		
Tuning fork still		
Tuning fork moving		
Tuning fork still		

»

»

	WHAT YOU HEAR	WHAT YOU MEASURED (HZ)
Tuning fork moving		
Tuning fork still		
Tuning fork moving		
Tuning fork still		
Tuning fork moving		

DISCUSSION

Describe whether there were any differences between the apparent strength of the Doppler effect. That is, was it easier to detect with higher or lower frequencies?

INVESTIGATION 3.2.3

Observing atomic spectra

AIM

To observe atomic spectra lines

MATERIALS

- Gas tubes (e.g. hydrogen, helium, neon, argon, mercury)
- Spectroscope

RISK ASSESSMENT

HAZARD	MANAGEMENT
Gas tubes are fragile	Handle carefully
Emitted light may be bright	Do not stare at bright lights

METHOD

1 Set up the gas tubes so that they are emitting light.
2 Use the spectroscope to split the light and observe the spectral lines.

RESULTS

Copy and complete the table.

GAS TUBE	OBSERVED COLOUR	INDICATE ANY SPECTRAL LINES OBSERVED
		red blue
		red blue
		red blue
		red blue
		red blue

DISCUSSION

1 Is there any correlation between the number and arrangement of spectral lines and the position of the element in the periodic table?
2 Discuss how a knowledge of spectral lines could be used to determine the composition of stars.

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Priestley's experiments with oxygen

All matter in the universe is composed of chemical **elements**, of which 90 occur naturally. Everything you see and touch is made from different combinations of these 90 elements.

The periodic table is composed of more than 90 elements. These additional elements are called synthetic elements and are usually made inside particle accelerators.

One of the most important elements, particularly for living organisms, is oxygen. Oxygen is a colourless, odourless gas that is required for **respiration**. It makes up 21 per cent of the atmosphere and almost half of Earth's crust, mostly combined with silicon in silicate minerals.

element
primary constituent of matter that can undergo chemical reactions.

respiration
process by which organisms produce energy

Joseph Priestley (1733–1804) is often credited with the discovery of oxygen in 1774, when he was investigating how and why things burn. Carl Wilhelm Scheele discovered it earlier, but Priestley published his results first. In addition to discovering oxygen, Priestley made many discoveries, including the rubber eraser and carbonated water.

INQUIRING FURTHER

Research how synthetic elements are created. Present your research as an infographic.

During Priestley's lifetime, many scientists were trying to determine what elements were and what matter was made of. The chemical composition of air was of particular interest.

One of Priestley's experiments involved testing which gases could sustain life. In one version, he placed a mouse and a burning flame in a sealed jar. When the flame went out, the mouse would die. The conclusion made was that the same 'air' that was sustaining the flame was also sustaining the mouse.

A variation on this experiment had a mouse in a sealed jar with a small green plant. When the jar was placed in sunlight, the mouse was safe. Priestley's conclusion was that the plant was refreshing the air. These experiments led Priestley to an important discovery.

He exposed a mass of red mercuric oxide sitting in a pool of mercury to sunlight focused on it from a large magnifying glass. The mercuric oxide burned and released a gas. This gas produced was declared by Priestley to be better than 'common' air. Flames burned brighter in its presence and the mice lived four times as long.

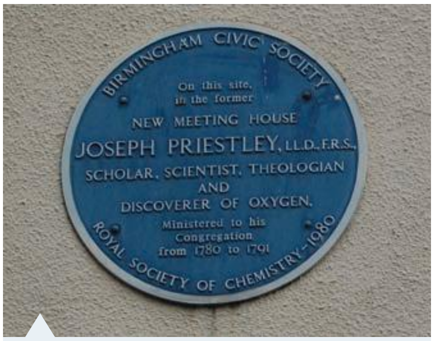

FIGURE 3.2.5 A plaque celebrating a house where Priestley did much of his work.

3.2.5 Joseph Priestley and the discovery of oxygen

3.2.6 Joseph Priestley: The man who discovered oxygen

Priestley called the gas 'dephlogisticated air'. Phlogiston was a theoretical substance in materials that burned. His idea was that this new gas had no phlogiston in it so it allows things to burn brighter. What Priestley had discovered was actually oxygen.

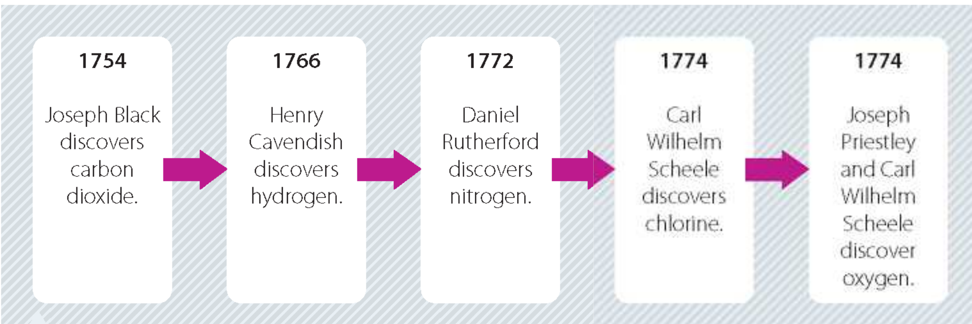

FIGURE 3.2.6 A timeline showing the discovery of some gaseous elements.

When Priestley breathed the gas in himself, he wrote in his book, *Experiments and Observations on Different Kinds of Air*, 'I fancied that my breast felt peculiarly light and easy for some time afterwards. Who can tell but that in time, this pure air may become a fashionable article in luxury. Hitherto only two mice and myself have had the privilege of breathing it.'

INQUIRING FURTHER

Research the methods used to discover one of the elements mentioned in Figure 3.2.6. As part of your research, describe the experiments the scientists undertook. Present your research in an A4-page report.

INVESTIGATION 3.2.4

Making oxygen

AIM

To make and test for oxygen

MATERIALS

- Hydrogen peroxide (3%)
- Manganese (IV) oxide
- Test tube
- Wooden splint or paddle pop stick
- Matches

RISK ASSESSMENT

HAZARD	MANAGEMENT
Manganese (IV) oxide is harmful if inhaled or swallowed	Ensure all students handle chemicals safely
Testing for oxygen increases burning	Only test small samples of oxygen

METHOD

1. Place a small amount of manganese (IV) oxide in the test tube.
2. Add about 1 mL of hydrogen peroxide.
3. Loosely place a stopper in the mouth of the test tube.
4. Light the splint, remove the stopper and carefully place the splint in the mouth of the test tube.

RESULTS

Copy and complete the table.

Observation when the two chemicals are mixed	
Observation when the lit splint is placed in the mouth of the test tube	

DISCUSSION

Outline reasons why this experiment might be best done as part of a group.

EXTENSION

1. Design and perform experiments to show properties of common gases such as hydrogen or carbon dioxide.
2. Outline other ways that oxygen can be produced.

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INVESTIGATION 3.2.5

Making a terrarium

A terrarium is a clear, sealed vessel, often a glass jar or plastic bottle, which can be used to make a small ecosystem.

AIM

To make a terrarium

MATERIALS

- Plastic drink bottle (2-litre bottles work best)
- Small amount of soil
- Some small pebbles
- Small seedlings
- Scissors

RISK ASSESSMENT

HAZARD	MANAGEMENT
Soil may contain pathogens	Wash hands after handling soil
Scissors are sharp	Use scissors carefully

RISK ASSESSMENT

METHOD

1. Cut the bottle in half
2. Place the small stones in the bottom of the bottle to a depth of about 5 cm
3. Put in about 10 cm of soil
4. Plant the seedlings in the soil
5. Water the seedlings then seal the terrarium by putting the top half of the bottle over the bottom

RESULTS

Copy and complete the table to outline the progress of your plants over a few weeks.

	HEIGHT OF PLANTS (cm)	PERCENTAGE OF GROUND COVER	GENERAL OBSERVATIONS
Week 0			
Week 1			
Week 2			
Week 3			
Week 4			
Week 5			
Week 6			
Week 7			
Week 8			
Week 9			
Week 10			

DISCUSSION

1. Describe any difficulties you encountered when preparing your terrarium.
2. The terrarium is a closed system, nothing can get in or get out. Describe how it can continue flourishing if no materials are able to get in or out.

Evaluating methodology

methodology a way of going about an investigation

There are many types of **methodologies** that scientists can undertake, such as those summarised in table 3.2.1.

TABLE 3.2.1 Scientific methodologies.

PRIMARY INVESTIGATION	An investigation done directly by a scientist. These are the types of investigations most people associate with experiments, where an individual or group conducts the investigation and directly collects and analyses the results. An example would be the investigation into peptic ulcers by Marshall and Warren.
FIELDWORK	Where a scientist makes direct observations. Unlike a primary investigation, the observer is not changing the conditions they are observing, merely observing the interactions. This is often used in ecological studies, such as the celebrated work of Jane Goodall studying chimpanzees.
LOCATING AND USING INFORMATION SOURCES	Where a scientist examines the results from another scientist's experiment. Also known as a second-hand investigation, this is commonly used in areas such as genetics, where large amounts of data can be collated and compared to work out the genes responsible for certain conditions.
SURVEYS	Collecting data from a large selection of people. Often used in medical studies to determine potential links between medical conditions and other factors in people's lives.
MODELLING	A technique whereby an object or phenomenon is represented to show how it works. Simple models include diagrams, such as diagrams of cells, while some complex models replicate the functions of the phenomenon in detail, such as a scale model of a combustion engine.
SIMULATIONS	Recreates parts of the phenomenon being studied and allows aspects to be changed. The use of simulations has become more common as computer power and speed has increased. This is a common technique used in areas such as climate modelling.

Evaluating the objective, method and data collected

Marshall and Warren

Marshall and Warren conducted primary investigations, using biopsies and tissue cultures as part of their research. The objective of their investigation was to establish if there was a link between *H. pylori* and peptic ulcers. This was based on the observation by Warren that *H. pylori* was present in the biopsy samples he was looking at.

Their methodology involved taking multiple biopsy samples, culturing the sample and testing these samples. Once the cultures were established, they could detect for the presence of the *H. pylori* bacteria.

In this case the bacterium was present, or it was not. Their data suggested that a very large portion of the patients suffering from peptic ulcers were also infected with the bacterium.

Eratosthenes

Eratosthenes used some first-hand techniques in taking his initial measurements, and second-hand sources, such as the distance between the two cities, to help calculate his result. He also observed that cities in different parts of Egypt cast shadows of differing angles at the same time.

Eratosthenes was able to use mathematics to do his calculations, based on the best measurements of distance he could get. Eratosthenes was essentially using a combination of primary data (the angles he had recorded) with secondary sources (the accepted distances between the two cities).

Doppler

Doppler was attempting to determine some of the properties of the binary stars he was observing. He came up with his conclusions by looking at spectral images made on photographic plates. This involved looking at hundreds of plates and noting the often-subtle changes.

Doppler was using first-hand data that he had collected and analysing it himself.

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Priestley

Priestley conducted many primary investigations as part of his study. From a historical perspective, most investigations were done meticulously by scientists working in isolation who would then report their findings to institutions such as the Royal Society in the UK.

Priestley was trying to determine some of the properties of air.

A summary of the investigations, **evaluations** and **justifications** is shown in Table 3.2.2.

evaluation make a judgement based on evidence

justification support an argument

TABLE 3.2.2 A summary of investigations, evaluations and justifications

INVESTIGATION	STEPS	EVALUATE AND JUSTIFY
Peptic ulcers	Objective	
	To determine a link between *H. pylori* and peptic ulcers.	This was a valid objective as they based their idea on previous observations.
	Method	
	Make tissue cultures from biopsy samples.	This was an appropriate method as it was the only way to collect evidence and show the presence of the bacterium in patients.
	Data collected	
	Primary data collection by experimentation: tissue cultures from biopsies before and after antibiotic treatment.	Examining tissue cultures was an effective way to collect primary data, and was used to establish a causal link between the bacterium and the development of peptic ulcers.
Circumference of Earth	Objective	
	To determine the circumference of Earth.	This was important in learning more about distances on Earth and to aid in navigation.
	Method	
	Used a mixture of primary data: his own observations at Syene; and second-hand data: the distance between Syene and Alexandria.	Eratosthenes couldn't be in two places at once, so to conduct this investigation he had to collect primary and secondary data.
	Data collected	
	The angles of shadows in wells.	This was directly observed by Eratosthenes and the many repetitions and averages he took made this a valid measurement.
	The distance between Syene and Alexandria.	The distance was known by the traders who often travelled the busy trade route.
Doppler effect	Objective	
	To explain the apparent change in the spectral lines of binary star system.	This was important in understanding the composition and motion of the stars being studied.
	Method	
	Primary data collected by careful examination of the photographic plates.	This was the only available technique applied to collect evidence on spectral data on stars at that time.
	Data collected	
	Primary data: spectral lines	These lines are the evidence to determine some properties of stars from Earth.
Existence and properties of oxygen	Objective	
	To determine the properties of the gas.	Study of gases led to fundamental knowledge of chemistry.
	Method	
	Burning objects in the presence of oxygen.	This had enhanced the understanding of the properties of the gas oxygen.
	Seeing the effect of oxygen on mice trapped in a jar.	This helped establish a link and provided empirical evidence that oxygen is required for respiration.
	Data collected	
	Primary data by experimentation: direct observations of the effect on mice. Priestley inhaling the gas himself.	Each observation led to an understanding of the physiological aspects of oxygen.

SECTION REVIEW 3.2

REMEMBERING

1 Describe the types of experiments that were conducted by Marshall and Warren, Eratosthenes, Doppler and Priestley.

2 Give a brief example of a scientific experiment that could be done for each of these types of investigations: experimental testing, fieldwork, locating and using information sources, conducting surveys and using modelling and simulations.

UNDERSTANDING

3 Propose reasons why tissue culturing is an important biological tool.

4 Outline reasons why Eratosthenes may have had difficulties with his measurements.

5 Describe some of the difficulties Doppler might have had with his study of binary stars.

APPLYING

6 Discuss reasons why the experiments of Priestley and his contemporaries would not be allowed in the modern world.

7 Select an experiment not studied in this chapter section; for example, the work of Galileo, Pasteur or Bohr. Identify the methodology used and evaluate why the scientist chose that methodology. As part of your evaluation, identify the type of data collected, why they were collected the way they were and how the investigation was reviewed by the scientist's peers.

WS 3.2.1 Different types of scientific investigations

3.3 Student investigation

Your own investigation

In the previous section, we looked at different examples of scientists who solved problems in a variety of ways. In this section, you will apply a vigorous scientific methodology to a problem you choose. Remember you need to:

1 develop a method that is appropriate

2 justify the use of this method to test the hypothesis.

Below are some examples of questions that could be tested or you could develop your own question.

Possible questions

- Biology: Which types of fruits have the highest percentage of water?
- Chemistry: How is iron extracted from raw materials?
- Physics: At what rate do radioactive materials decay?
- Psychology: What are the characteristics of people who play videogames more than 10 hours each week?

These questions will be scaffolded to help you develop your investigation using the tables on the following pages. Under your teacher's guidance, you may consider using this section to help complete your depth study.

Scientific method

The scientific method refers to any process undertaken to answer or explain a question.

1 Make an observation

2 Develop a question

3 Make a hypothesis

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4 Design your experiment
5 Perform your experiment
6 Accept or reject the hypothesis

Develop a method that could be used to test your idea. Copy and complete the table below to help to scaffold your investigation, or copy one of those provided for the example experiments.

PLANNING	
What is your question?	
What is your methodology?	
What is your aim?	
What is your hypothesis?	
What materials will you need?	
What steps do you think your method will have?	

DESIGNING YOUR EXPERIMENT – PLANNING FOR TESTING FRUITS	
What is your question?	Which types of fruits have the highest percentage of water?
What is your methodology?	Primary investigation
What is your aim?	To determine the percentage of water in different types of fruits
What is your hypothesis?	Fruits used in commercially made juices, such as orange and apple, will have the highest percentage of water.
What materials will you need?	Different fruits: oranges, apples, strawberries, bananas and so on
What steps do you think your method will have?	▪ Measure the masses of fruit samples ▪ Use a method to remove water from the fruit, such as a food dehydrator ▪ Calculate the difference in mass and determine the percentage of mass lost

DESIGNING YOUR EXPERIMENT – PLANNING FOR INVESTIGATING IRON	
What is your question?	How is iron extracted from raw materials?
What is your methodology?	Locating and using information sources (second-hand investigation)
What is your aim?	To research the processes involved in producing iron
What is your hypothesis?	Producing iron on an industrial scale is a complex and expensive process
What materials will you need?	Internet access, chemistry textbooks
What steps do you think your method will have?	Research the process using primary and secondary sources

DESIGNING YOUR EXPERIMENT – PLANNING TO STUDY RADIOACTIVE DECAY	
What is your question?	At what rate do radioactive materials decay?
What is your methodology?	Use a simulation to model the rate at which radioactive substances decay
What is your aim?	To demonstrate the rate at which radioactive materials decay
What is your hypothesis?	The decay will occur exponentially
What materials will you need?	Internet access
What steps do you think your method will have?	Run the simulation and record all data

DESIGNING YOUR EXPERIMENT – PLANNING TO SURVEY VIDEO GAME PLAYERS	
What is your question?	What type of people play video games more than 10 hours each week?
What is your methodology?	Conduct a survey
What is your aim?	To determine the type of people who play video games
What is your hypothesis?	Teenage boys will play videos games more than other groups
What materials will you need?	▪ A large and diverse group of people ▪ A survey about gaming habits
What steps do you think your method will have?	Survey students using either a written survey or an online tool such as Survey Monkey or Google Forms Collate the survey data using a spreadsheet

INQUIRING FURTHER

Compare the way the scientific method is applied in different areas of science. For example, compare the field techniques used in biology and earth science with lab techniques in chemistry and physics. Present your information as a poster.

SECTION REVIEW 3.3

REMEMBERING

1 State the main steps in the scientific method.

UNDERSTANDING

2 Explain why some experiments are not able to be done effectively as a primary investigation.

APPLYING

3 Outline some difficulties you might experience when designing and conducting your own experiment.

3.4 Validity and reliability

WS 3.3.1 Reliability and validity

In any experiment, scientists make sure their idea can be tested properly and that their experiments can be replicated. In most experiments, the investigation is conducted and the results will either confirm or deny the hypothesis. If the hypothesis is disproved, then the scientists should go back and rethink their hypothesis.

INQUIRING FURTHER

Create a factsheet that outlines how one area of research not mentioned in this section has been manipulated by false or misleading data. Some examples include the effect of microbeads on marine ecology; the work of Dong Pyou Han who was jailed for falsifying data in AIDS vaccine experiments; and the Piltdown Man hoax by Charles Dawson.

Unfortunately, some scientists do not follow the scientific method when conducting experiments, which can lead to false or misleading data. In some extreme cases, experimental data has been falsified to fit the original hypothesis. One example is the use of thalidomide, a drug used to reduce the effects of nausea in pregnant women. While it may have reduced nausea, it also caused debilitating birth defects. Another example was a study that tried to link the MMR vaccine with autism, which was later shown to have manipulated data.

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Variables and controls

One of the most important things you can do in an investigation is ensure that it is **valid** and reliable. Valid refers to whether the investigation is a fair test. It refers to the methodology used in the experiment and the technology selected to collect the data. This has a few aspects, such as, is your experiment actually going to test what you are trying to find? Will it test your hypothesis? For example, does the colouring of food dye affect the time it takes for water to boil?

Reliability refers to how easily an experiment can be repeated, and when it is repeated, whether the results are consistent. In terms of second-hand resources, it can refer to whether the information across many resources is consistent.

The **independent variable** is the factor of an experiment that is deliberately changed. In the example of boiling water, we are changing the colour of the food dye.

The **dependent variable** is the factor that is being measured in the experiment. In our example, this is the time taken for the water to boil.

All other factors are the **controlled variables**. These are the factors of your experiment that must be kept the same for your experiment to have validity. In our example, you should have identical equipment, the water must start at the same temperature and the same amount of heating should be used.

Controlled variables are important as they allow the scientist to focus on the hypothesis.

It is also important that a scientist is able to accurately read measurements from equipment such as thermometers. This information also has to be accurately recorded. In most experiments, this is done with a results table. Depending on the experiment these results may be put into a graph or another visual representation.

One of the most important things for a scientist to do is to repeat the experiment a number of times. This means that they will know that their results are reliable.

valid
extent to which a report or investigation contains accurate data, inferences and conclusions

reliability
whether the experiment can be repeated and give the consistent results

independent variable
the factor of an experiment that is deliberately changed

dependent variable
factor measured in the investigation

controlled variables
the factors of an experiment kept constant to ensure a valid test

TABLE 3.4.1 Definitions of scientific terms

TERM	WHAT IT IS	WAYS TO ENSURE IT HAPPENS	EXAMPLE
Validity – in a practical investigation	▪ A fair test ▪ Tests the hypothesis ▪ Relates to the method followed and the technologies used to collect data as evidence to prove or disprove the hypothesis	▪ Controlling all variables other than what is being changed ▪ Choose the appropriate technology to collect data	When investigating which balls bounce the highest, all balls were dropped from the same height and dropped onto the same surface
Reliability – in a practical investigation	Whether the results will be similar when you repeat the experiment	Conducting more trials that have consistent results to reduce error	Each ball was dropped 10 times. All the measured heights for each ball were close to each other
Validity – in secondary sources research	The research is written by an expert in the field and up-to-date	▪ Ensure the author is recognised ▪ Check whether more recent research has been done ▪ Check whether other scientists agree with what is written	▪ A post on an Internet blog without references may not be accurate ▪ Average rainfall and temperatures from 1870 to 1879 may not be useful when making rainfall predictions today
Reliability – in secondary sources research	Whether the information is consistent across all secondary sources	Ensuring the sources are reputable, such as sources from universities or government organisations	Meteorological data from the Bureau of Meteorology, at bom.gov.au
Accuracy	How precise your measurements are	Selecting equipment that is appropriate and calibrated for the intended measurements	When measuring volumes of chemicals, using a measuring cylinder with smaller graduations

Below are some examples of scaffolds you can use when testing the validity and reliability of your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – VARIABLES AND CONTROLS	
Independent variable	
Dependent variable	
Controlled variables	

DESIGNING YOUR EXPERIMENT – VARIABLES AND CONTROLS	
Biology: Which types of fruits have the highest percentage of water?	
Independent variable	The types of fruits
Dependent variable	Amount of mass lost
Controlled variables	The same method of dehydration is used

DESIGNING YOUR EXPERIMENT – VARIABLES AND CONTROLS	
Chemistry: How is iron extracted from raw materials?	
Independent variable	Not applicable
Dependent variable	Not applicable
Controlled variables	Not applicable

DESIGNING YOUR EXPERIMENT – VARIABLES AND CONTROLS	
Physics: At what rate do radioactive materials decay?	
Independent variable	The radioactive elements used in the simulation
Dependent variable	The rate of decay
Controlled variables	The same simulation is used

DESIGNING YOUR EXPERIMENT – VARIABLES AND CONTROLS	
What type of people play video games more than 10 hours each week? Is playing videos more than 10 hours a week age related?	
Independent variable	Age of people being surveyed
Dependent variable	Number of hours per week playing video games
Controlled variables	The same questionnaire is used

In the chemistry example above, the investigation is using second-hand data such as books and Internet resources, hence, there are no variables to consider.

Sampling

When considering the design of an investigation, it is important for a scientist to ask two questions. First, how much data should I collect? Second, how often should I collect the data?

Sampling is a method scientists use to collect data by gathering information from a small section of a total group.

Sampling in biology

ecological relating to the interactions of species within an environment

In many **ecological** investigations, it is essential for a scientist to understand the environment they are working in. To achieve this, scientists will try to estimate the sizes of populations.

Going through an area and counting each species is extremely time consuming and, in the case of animal species, fruitless, as most animals are reasonably mobile and will run at the first sign of a

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potential predator. Instead, scientists have developed sampling techniques that look at a section of the environment they are studying, and use these samples to estimate the wider population.

Quadrats

A **quadrat** is a frame that is used to randomly examine an area and estimate the abundance of species in that area.

Most quadrats that students will use are 1 m^2. A quadrat is randomly dropped in the area being examined, and the number of species within the quadrat are counted. This is done in a few areas and the data extrapolated from there.

For example, if a chosen location has an area of 100 m^2, then the quadrat might be placed in five random zones, as shown in the diagram below.

quadrat
a process by which a small area is examined to estimate the population of a species within a larger area

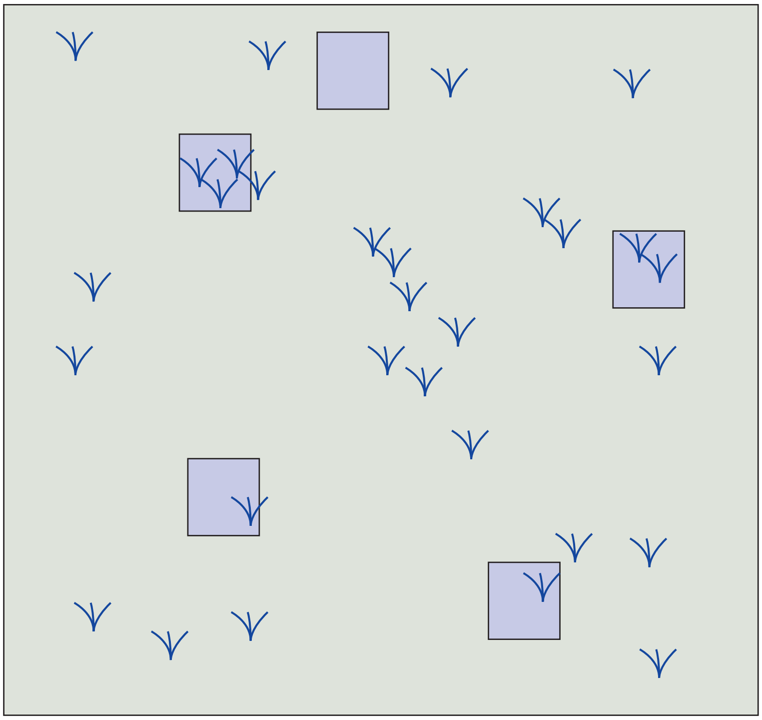

FIGURE 3.4.1 A quadrat of an area of 100 m^2, using five random zones.

TABLE 3.4.2 Sample data collected from a quadrat

QUADRAT (1 m^2)		NUMBER OF SPECIES	
1		1	
2		0	
3		3	
4		1	
5		2	
Total area	5 m^2	Total species	7

We can use the expression below to estimate the population in the entire area being studied.

$$\textit{Estimated population} = \frac{\textit{total number in quadrats}}{\textit{total number of quadrats}} \times \frac{\textit{total area studied}}{\textit{total area of quadrats}}$$

We can then complete our calculation of the population sample.

$$\begin{aligned} \textit{Estimated population} &= \frac{7}{5} \times \frac{100}{5} \\ &= \frac{7}{5} \times \frac{100}{5} \\ &= 1.4 \times 20 \\ &= 28 \end{aligned}$$

estimation
a rough calculation of the value of something

capture-recapture
a method to estimate the population size by trapping them in a small area, releasing them and then extrapolating the total population

The more quadrat samples a scientist takes, the more accurate the **estimation** will be. However, the researcher must balance this with the time it takes to undertake each sample.

Capture-recapture

Quadrat sampling works well with species such as plants, as when the quadrat is randomly dropped, the species will not run away. The **capture-recapture** method involves setting up traps for animal species. The trapped species are tagged and released.

INVESTIGATION 3.4.1

Quadrat sampling

AIM

To conduct a quadrat sample of an area within the school

MATERIALS

- A 1 m^2 quadrat
- Trundle wheel
- An area with abundant plant life
- A digital camera to take photos of each quadrat

RISK ASSESSMENT

HAZARD	MANAGEMENT
Some areas outdoors may have trip hazards	Be aware of potential trip hazards such as low branches or uneven ground
Exposure to UV radiation may burn the skin	Wear a hat and sunscreen

METHOD

1. Select an appropriate area.
2. Use the trundle wheel to measure out the dimensions of the entire sample area, then record the area's size.
3. Use the quadrat to randomly selective five areas. Where practical, these areas should be spread throughout your overall sample area.
4. Record the number of a species within each quadrat. Depending on the location, you may be looking at an individual species or a type of plant, such as a small shrub or large tree.
5. Copy the table below to record your results, then estimate the total plant population.

»

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RESULTS

Copy and complete the table.

QUADRAT	NUMBER OF SPECIES
1	
2	
3	
4	
5	
Total of all samples	

Estimate total population from the samples: ______

DISCUSSION

1 Describe any issues encountered in doing this investigation.
2 Assess the effectiveness of quadrats as a sampling technique.

EXTENSION

Resample the area using a larger number of quadrats. Compare your results and discuss issues in using the two sample sizes.

INVESTIGATION 3.4.2

Simulating capture-recapture methods

AIM

To conduct capture-recapture simulations

MATERIALS

- 40 large paperclips
- Bar magnet
- A capture-recapture simulation

METHOD

1 Use an online simulation.
2 Follow the instructions of the simulation and record your results.
3 Place the 40 paperclips in a large jar.
4 Drop a small bar magnet into the jar, gently shake the jar then remove the magnet with the paperclips attached.
5 Tag the captured paperclips by marking the ends with a marker.
6 Return the tagged paperclips to the jar and then repeat step 4.
7 Use your data to estimate the population of the paperclips.
8 Repeat your capture-recapture at least two more times.

» RESULTS

$$\text{Estimated population} = \frac{(\text{number in second sample}) \times (\text{number in first sample})}{\text{number tagged in sample 2}}$$

For example:
16 paperclips collected in first sample, tagged then released
20 paperclips were then collected in the second sample
8 of the second sample had been tagged

$$\text{estimated population} = \frac{20 \times 16}{8} = 40$$

TRIAL	SAMPLE 1	SAMPLE 2	TAGGED IN SAMPLE 2	ESTIMATED POPULATION
1				
2				
3				

DISCUSSION

1 Discuss ways this investigation could be improved.
2 Compare and contrast the use of the online simulation with the paperclip simulation.

Designing your experiment

Below are some examples of scaffolds you can use when designing the sample of data in your experiment. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – SAMPLING	
What sort of data are you collecting?	
How much data will you collect?	
How will you organise this data?	

DESIGNING YOUR EXPERIMENT – SAMPLING	
Biology: Which types of fruits have the highest percentage of water?	
What sort of data are you collecting?	Primary data
How much data will you collect?	At least three samples of each fruit
How will you organise this data?	In a results table that can be manipulated in a spreadsheet

DESIGNING YOUR EXPERIMENT – SAMPLING	
Chemistry: How is iron extracted from raw materials?	
What sort of data are you collecting?	Second-hand data
How much data will you collect?	Consistent data from at least three reliable sources
How will you organise this data?	Summary of data which will be collated into a report

»

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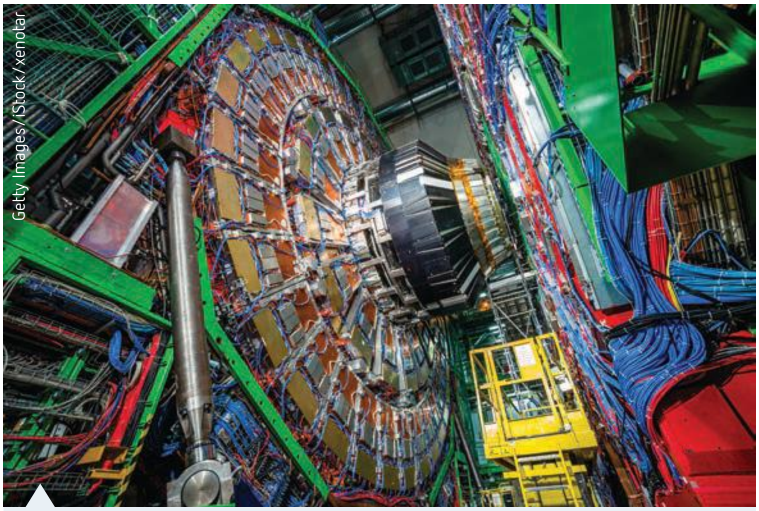
DESIGNING YOUR EXPERIMENT – SAMPLING	
Physics: At what rate do radioactive materials decay?	
What sort of data are you collecting?	Numerical data from the simulation
How much data will you collect?	At least three different data sets
How will you organise this data?	In a results table that can be manipulated in a spreadsheet

DESIGNING YOUR EXPERIMENT – SAMPLING	
What type of people play video games more than 10 hours each week?	
What sort of data are you collecting?	Numerical data based on the survey
How much data will you collect?	At least five surveys from the different age and sex ranges
How will you organise this data?	In a results table that can be manipulated in a spreadsheet

The cost of science

The biggest and most expensive piece of science equipment ever made is the Large Hadron Collider. When construction was finished in 2008, it had cost 9 billion US dollars, with running costs of about 1 billion USD per year. The costs of expensive scientific equipment such as the Large Hadron Collider lead people to question why such equipment needs to be built and what benefits it will provide society.



Getty Images/iStock/xenotar

FIGURE 3.4.2 The Large Hadron Collider is the biggest and most expensive piece of scientific equipment ever built.

INQUIRING FURTHER

Research the discoveries that led to the discovery of the Higgs boson. Use the research to create an annotated time line.

INQUIRING FURTHER

During the 'space race' in the middle of the 20th century, many people questioned why so much money was spent sending people into space and to the Moon. Research inventions that were first developed for rocket technology that are now in common use. Share your research as a five-minute presentation.

While experiments such as those done by the Large Hadron Collider are rare, cost is an important factor when planning any investigation. Some things to think about are:

1 Is the equipment you are using easily available?
2 Do you need to spend money on any equipment? If your experiment is going to cost too much money, then you might have to rethink your question.
3 Is anything in your experiment a large risk? If part of your experiment is too dangerous then you might want to rethink your question.
4 Lastly, do you know how to use the equipment you need to use for the experiment?

Below are some examples of scaffolds you can use to determine the equipment requirements and knowledge you will need for your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – USING EQUIPMENT	
Is the equipment easily available?	
Is the equipment costly?	
What is the risk of using the equipment?	
Have you used this equipment before?	

DESIGNING YOUR EXPERIMENT – USING EQUIPMENT	
Biology: Which types of fruits have the highest percentage of water?	
Is the equipment easily available?	Yes
Is the equipment costly?	No. While food dehydrators are expensive, an oven on low heat can substitute
What is the risk of using the equipment?	An oven, even on low heat, can cause burns
Have you used this equipment before?	

DESIGNING YOUR EXPERIMENT – USING EQUIPMENT	
Chemistry: How is iron extracted from raw materials?	
Is the equipment easily available?	Yes
Is the equipment costly?	No. The school library can give you free access to books and Internet resources
What is the risk of using the equipment?	None
Have you used this equipment before?	

DESIGNING YOUR EXPERIMENT – USING EQUIPMENT	
Physics: At what rate do radioactive materials decay?	
Is the equipment easily available?	Yes
Is the equipment costly?	No. Many simulations are free to use on the Internet
What is the risk of using the equipment?	None
Have you used this equipment before?	

DESIGNING YOUR EXPERIMENT – USING EQUIPMENT	
What type of people play video games more than 10 hours each week?	
Is the equipment easily available?	Yes
Is the equipment costly?	No. A survey can be done through interview or by using an online survey tool
What is the risk of using the equipment?	None
Have you used this equipment before?	

Science and ethics

The objective of science can be perceived as seeking ways to make the lives of people better. For example, improving health or making the workplace safer. Many areas of research can raise **ethical** issues. For example:

- Should embryonic stem cells be used in biological research?
- Should we genetically modify food?
- Should drugs or other materials be tested on animals?

ethical
whether what is being done conforms to good standards of behaviour

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It is important that scientists consider the ethical implications of what they are researching. Questions that scientists need to consider include:

- Will this research help people?
- Will this research cause harm?
- Is the research beneficial?

When construction had finished on the Large Hadron Collider, there was some concern that the energies produced and the unknown areas of particle physics could initiate the creation of unknown entities such as mini black holes. While the chances of something happening were infinitesimally small, some people argued that the potential harm to society was not worth the risk.

When scientists undertake research, it is important for them to consider the risks and to reflect on the ethical implications.

INQUIRING FURTHER

Research reasons why the scientific community was slow to accept the work of Marshall and Warren. In your research, inquire further into the role of human trials in the acceptance of a scientific theory. Present your research as a report.

Peptic ulcers and human trials

The work of Marshall and Warren raised many ethical issues, particularly when Marshall tested his hypothesis on himself. Even though they confirmed the link the between the *H. pylori* bacterium and chronic peptic ulcers, many of their peers took a long time to accept their research.

Priestley, oxygen and animal testing

Morals and ethics can change over time as society progresses and changes, often re-assessing religious and cultural beliefs. This is why ethical considerations are not simply an argument of good versus bad, as these ideas are often based on personal opinion.

moral
a judgement about whether what is being done is good or bad

Joseph Priestley's research involved using animals. Many mice were used to show the existence of 'dephlogisticated' air. If Priestley conducted his research today, he would be under intense pressure to ensure no undue harm came to the animals in his experiments. However, during Priestley's time it was acceptable to use animals in research and scientists rarely considered any harmful effects on their test subjects.

It wasn't long ago that products such as cosmetics were regularly tested on animals such as rabbits and monkeys. Today, most countries have abolished these practices, as they are deemed to be cruel. In Australia, this is governed by a set of rules called the 'Australian code for the care and use of animals for scientific purposes'. It outlines the ways in which scientists can use animals in their research.

Below are some examples of scaffolds you can use when considering any ethical implications. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – ETHICAL CONSIDERATIONS	
Are there any aspects of your experiment that could be deemed unethical?	

DESIGNING YOUR EXPERIMENT – ETHICAL CONSIDERATIONS	
Biology: Which types of fruits have the highest percentage of water?	
Are there any aspects of your experiment that could be deemed unethical?	No

DESIGNING YOUR EXPERIMENT – ETHICAL CONSIDERATIONS	
Chemistry: How is iron extracted from raw materials?	
Are there any aspects of your experiment that could be deemed unethical?	No

DESIGNING YOUR EXPERIMENT – ETHICAL CONSIDERATIONS	
Physics: At what rate do radioactive materials decay?	
Are there any aspects of your experiment that could be deemed unethical?	No

DESIGNING YOUR EXPERIMENT – ETHICAL CONSIDERATIONS	
What type of people play video games more than 10 hours each week?	
Are there any aspects of your experiment that could be deemed unethical?	Yes, some individuals may not feel comfortable in talking about how they spend their leisure time and it would be unethical to force them to. Ensure participants know exactly what they might be asked as part of the survey and that they can withdraw at any time.

FIGURE 3.4.3 Many areas of modern scientific research need to be monitored by ethical principles.

INQUIRING FURTHER

Investigate areas of scientific research that have been influenced by ethical considerations. Possible areas could be genetic engineering in humans, animal cloning or genetically modified plants. Present your research as a factsheet that could be used to inform people about the use, risks and benefits of the research.

INQUIRING FURTHER

View the movie *Gattaca* (or any similar film that showcases science and ethics). Assess the use of technology shown in the movie and whether it may become commonplace in the future, if it hasn't already. Share your research as a five-minute presentation.

Timeframes

An important skill for a scientist is the ability to predict how long research may take. Most of the experiments you are used to doing probably take a relatively short period, as in the time it takes for reactions to occur. However, an experiment such as Priestley's took years to complete.

You should be planning for an experiment that takes no longer than a few weeks. Below are some examples of scaffolds you can use to predict the timeframe of your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – TIMEFRAMES	
How long do you predict your investigation will take?	

DESIGNING YOUR EXPERIMENT – TIMEFRAMES	
Biology: Which types of fruits have the highest percentage of water?	
How long do you predict your investigation will take?	▪ Half a day to purchase and prepare fruit ▪ Three days for the experiment (one day for each of the three trials) ▪ One day to collate results

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DESIGNING YOUR EXPERIMENT – TIMEFRAMES	
Chemistry: How is iron extracted from raw materials?	
How long do you predict your investigation will take?	▪ One day of research at a library ▪ Two days to synthesise the research and prepare a report

DESIGNING YOUR EXPERIMENT – TIMEFRAMES	
Physics: At what rate do radioactive materials decay?	
How long do you predict your investigation will take?	▪ Half a day to construct data tables for the results ▪ Half a day to run simulations and record results ▪ One day to synthesise results and prepare a report

DESIGNING YOUR EXPERIMENT – TIMEFRAMES	
What type of people play video games more than 10 hours each week?	
How long do you predict your investigation will take?	▪ Half a day to prepare the survey ▪ Two days to find participants and survey them ▪ One day to synthesise results and prepare a report

These timeframes are just estimates and you may find that, depending on different factors, your final timings may be different. This might be due to unforeseen circumstances that require you to change or redesign parts of your investigation.

Working alone or in teams

Many of the important historical discoveries that fill textbooks were made by individuals labouring away in their workshops. Examples include scientists such Galileo, Newton and Einstein.

Alamy Stock Photo/World History Archive

Alamy Stock Photo/World History Archive

imagefolk/Mary Evans Picture Library/Weimar Archive

FIGURE 3.4.4 Three of the most famous scientists to have lived – Galileo, Newton and Einstein – mostly worked alone.

The majority of modern and contemporary science is done collaboratively. For example, while Marshall and Warren started individually, with Robin Warren noticing the *H. pylori* on tissue samples, he later started working with Barry Marshall and their teamwork allowed them to progress at a quicker rate.

One consideration for teamwork is that if you work in a group, then you can use the different skills your team possesses. Some people in your group may be adept at using and manipulating scientific apparatus, while others may be good at recording and analysing data.

Below are some examples of scaffolds you can use when determining whether to work individually or as a team. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – WORKING ALONE OR TOGETHER	
Will you need the skills of other people to complete your investigation?	

DESIGNING YOUR EXPERIMENT – WORKING ALONE OR TOGETHER	
Biology: Which types of fruits have the highest percentage of water?	
Will you need the skills of other people to complete your investigation?	Possibly. A group will spread the cost of the fruit required and may help in when collating the data.

DESIGNING YOUR EXPERIMENT – WORKING ALONE OR TOGETHER	
Chemistry: How is iron extracted from raw materials?	
Will you need the skills of other people to complete your investigation?	Possibly. The initial research could be spread among a group.

DESIGNING YOUR EXPERIMENT – WORKING ALONE OR TOGETHER	
Physics: At what rate do radioactive materials decay?	
Will you need the skills of other people to complete your investigation?	Possibly. A group could allow for more trials of the simulation.

DESIGNING YOUR EXPERIMENT – WORKING ALONE OR TOGETHER	
What type of people play video games more than 10 hours each week?	
Will you need the skills of other people to complete your investigation?	Possibly. Time taken to conduct a survey may be drastically reduced.

INQUIRING FURTHER

Research reasons why a lot of modern-day research is difficult to do on your own. Give specific examples of research that cannot be done individually, such as the work done at the Large Hadron Collider or at the Australian Nuclear Science and Technology Organisation (ANSTO). Present your research as a poster.

Primary and secondary data

When we talk about **primary data**, we are essentially talking about data you have collected yourself during an investigation. **Secondary data** are data that you collect from sources other than a primary investigation.

In general, you will be collecting one of two types of data.

1 Quantitative data – which are data that can be measured by a number, such as temperature or time.
2 Qualitative data – which are data that cannot be expressed as a number, such as what football team a person supports.

In practice, most of the data you will be collecting will be quantitative.

primary data
data you have collected yourself

secondary data
data collected by other people and published

Interpreting data

Once you have completed the investigation, it is time to see what the investigation has shown. Usually, you present your data as a table, which was filled in as the investigation progressed.

The data below is from a simple investigation where the rate of change of temperature was measured against time.

While it is possible to make conclusions from this data, in most cases the data are easier to interpret if they are converted into a graph.

When you look at Figure 3.4.5, it is easier to read and interpret the data than by only looking at Table 3.4.3. For example, the temperature only rises a little at the start, but by the third minute, the rate

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TABLE 3.4.3 Change of temperature over time for one data set.

TIME (minutes)	TEMPERATURE (°C)
0	24
1	25
2	28
3	33
4	44
5	57
6	73
7	95
8	100
9	100
10	100

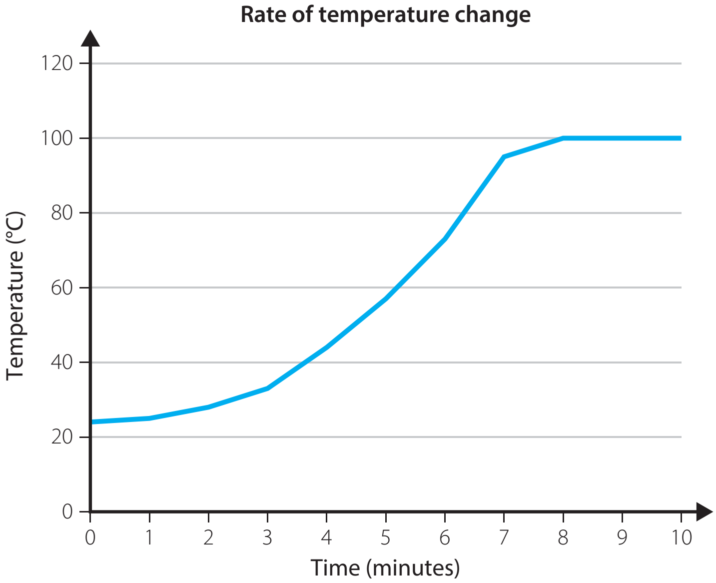


FIGURE 3.4.5 Data are easier to read and interpret on a graph

of temperature increases significantly until it levels off as the temperature approaches 100°C. Not only does the graph make it easier to see relationships, it is a useful aid in trying to explain the results to other people.

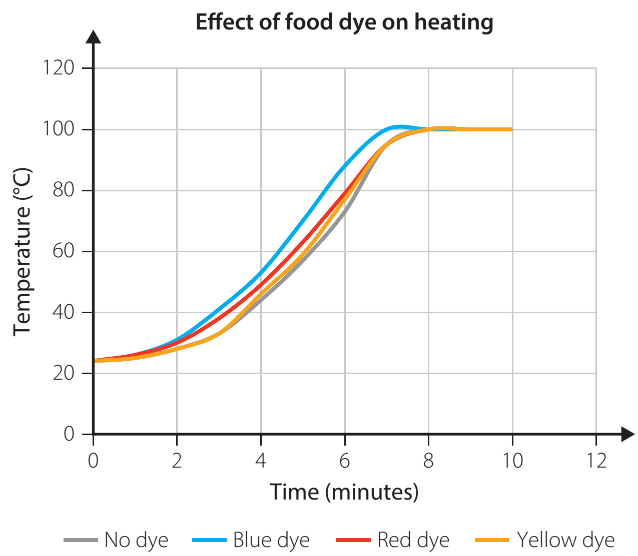
Sometimes it is also necessary to show multiple data sets on the one graph. This will allow you to easily compare dependent variables. The example below shows a set of data from the heating water with different food dyes experiment we briefly discussed earlier.

In this case, the graph (Figure 3.4.6) has all four sets of data and clearly shows that in this investigation, the water with blue food dye heated quicker.

TABLE 3.4.4 Change of temperature over time for multiple data sets.

TIME (minutes)	TEMPERATURE (°C)			
	No dye	Yellow	Red	Blue
0	24	24	24	24
1	25	25	26	26
2	28	28	30	31
3	33	33	38	41
4	44	46	49	53
5	57	59	63	70
6	73	77	79	88
7	95	95	95	100
8	100	100	100	100
9	100	100	100	100
10	100	100	100	100

FIGURE 3.4.6 Graphing data makes it easier to compare variables.



The graph clearly compares the data sets and shows that the water containing blue food dye heated faster than the others. This would have to be repeated a number of times.

Below are some examples of scaffolds you can use when interpreting the data from your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – INTERPRETING DATA	
Are your experimental data in a table?	
Can your data be graphed?	
What relationship does your graph show?	

DESIGNING YOUR EXPERIMENT – INTERPRETING DATA	
Biology: Which types of fruits have the highest percentage of water?	
Is your experimental data in a table?	Yes
Can your data be graphed?	Yes
What relationship does your graph show?	

DESIGNING YOUR EXPERIMENT – INTERPRETING DATA	
Chemistry: How is iron extracted from raw materials?	
Is your experimental data in a table?	No
Can your data be graphed?	No
What relationship does your graph show?	

DESIGNING YOUR EXPERIMENT – INTERPRETING DATA	
Physics: At what rate do radioactive materials decay?	
Is your experimental data in a table?	Yes
Can your data be graphed?	Yes
What relationship does your graph show?	

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DESIGNING YOUR EXPERIMENT – INTERPRETING DATA	
What type of people play video games more than 10 hours each week?	
Is your experimental data in a table?	Yes
Can your data be graphed?	Yes
What relationship does your graph show?	

Explaining your results

Once you have analysed the data, it is time to explain your results. Essentially you are answering the question: what did the data show?

In the food dye example above, the results showed that the food dye had an effect on the heating rate of the water. The blue food dye seemed to heat the water up more. However, as this only shows one trial, you would require more tests to confirm your results.

Once you have established what the data show, you might try to explain why this happened. In this case, a possible explanation might be that the blue food dye absorbed the heat more efficiently. Your explanations may develop as you repeat the experiment to confirm the data.

Your results may also prompt you to think of new areas of potential research. In the food dye experiment, you might want to see if different brands of food dye produce similar results.

Below are some examples of scaffolds you can use when explaining the results of your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

DESIGNING YOUR EXPERIMENT – EXPLAINING YOUR RESULTS	
What trends does your data show?	
Explain your results	

DESIGNING YOUR EXPERIMENT – EXPLAINING YOUR RESULTS	
Biology: Which types of fruits have the highest percentage of water?	
What trends does your data show?	Fruits in general have high water content
Explain your results	Fruits that appeared to be 'juicier' such as watermelon do in fact have a higher water content

DESIGNING YOUR EXPERIMENT – EXPLAINING YOUR RESULTS	
Chemistry: How is iron extracted from raw materials?	
What trends does your data show?	The data are qualitative
Explain your results	–

DESIGNING YOUR EXPERIMENT – EXPLAINING YOUR RESULTS	
Physics: At what rate do radioactive materials decay?	
What trends does your data show?	Radioactive materials decay exponentially
Explain your results	Radioactive decay is governed by the property of half-life. In a given period, half the material will decay

DESIGNING YOUR EXPERIMENT – EXPLAINING YOUR RESULTS	
What type of people play video games more than 10 hours each week?	
What trends does your data show?	People with active lifestyles play less video games
Explain your results	Athletic people spend more time outdoors

Did you test what you intended to test?

Part of the reflection of your methodology should be the basic question, did you test your hypothesis? This is important when it comes to the validity of your experiment.

Were your measurements reliable? It is also important to judge whether there were errors in your experiments, and whether these errors affected your results.

Below are some examples of scaffolds you can use when confirming the validity and reliability of your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

VALIDITY AND RELIABILITY OF RESULTS	
Was your investigation valid?	
Did you test your hypothesis?	
Were your results consistent?	
How did you reduce experimental errors?	

VALIDITY AND RELIABILITY OF RESULTS	
Biology: Which types of fruits have the highest percentage of water?	
Was your investigation valid?	Yes
Did you test your hypothesis?	Yes
Were your results consistent?	Yes
How did you reduce experimental errors?	Each trial was done under similar conditions

VALIDITY AND RELIABILITY OF RESULTS	
Chemistry: How is iron extracted from raw materials?	
Was your investigation valid?	Yes
Did you test your hypothesis?	Yes
Were your results consistent?	The information from the secondary sources was similar
How did you reduce experimental errors?	Confirmed that the information from the secondary sources was similar across many journals and websites researched

VALIDITY AND RELIABILITY OF RESULTS	
Physics: At what rate do radioactive materials decay?	
Was your investigation valid?	Yes
Did you test your hypothesis?	Yes
Were your results consistent?	Yes
How did you reduce experimental errors?	Using appropriate technology to collect data and increase the repetition of trials

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VALIDITY AND RELIABILITY OF RESULTS	
What type of people play video games more than 10 hours each week?	
Was your investigation valid?	Yes
Did you test your hypothesis?	Yes
Were your results consistent?	Yes
How did you reduce experimental errors?	Had at least five people in each survey group

Can you improve?

At this point of your investigation, it is useful to reflect on what you have done and whether you could improve your methodology. Any investigation should endeavour to collect data that are as accurate as your equipment will allow. However, there may be ways that you could modify your investigation to increase its *accuracy*, *validity* and *reliability*. This is an important step for scientists to refine their experiments and hypotheses.

Below are some examples of scaffolds you can use to try to improve your experiments. You can copy and complete the blank version, or copy one of those provided for the example experiments.

CAN YOU IMPROVE?	
What can you improve in your investigation?	

CAN YOU IMPROVE?	
Biology: Which types of fruits have the highest percentage of water?	
What can you improve in your investigation?	▪ Compare varieties of the same fruit to determine if there are differences within varieties ▪ Compare if there is a difference when a fruit is in season compared with not in season

CAN YOU IMPROVE?	
Chemistry: How is iron extracted from raw materials?	
What can you improve in your investigation?	Look at more primary sources to determine if there are variations in the data

CAN YOU IMPROVE?	
Physics: At what rate do radioactive materials decay?	
What can you improve in your investigation?	Use a range of simulations to determine if there are differences between the algorithms used in each

CAN YOU IMPROVE?	
What type of people play video games more than 10 hours each week?	
What can you improve in your investigation?	▪ Use a larger number of participants ▪ Consider other variables such as demographics

Does the investigation help humanity?

The company 3M, (formerly the Minnesota Mining and Manufacturing company), has invented many things people use every day. However, probably their most famous innovation is the Post-it Note. Little pieces of paper used for notes which will stick to most surfaces, but can easily be removed and stuck somewhere else.

Spencer Silver, a scientist working for 3M, was attempting to make an extremely strong adhesive when he developed a slightly sticky adhesive that left minimal residue instead. The slightly sticky adhesive would eventually prove to be more useful. This example shows that while not every experiment will be ground-breaking, they may still have positive implications for society.

INQUIRING FURTHER

Research a scientific discovery that had a positive impact on humanity. Examples may include Alexander Fleming's discovery of penicillin, the development of the mechanical clock or the discovery of Teflon. Share your research in a five-minute presentation.

Below are some examples of scaffolds you can use when considering whether your experiments have any implications for humanity. You can copy and complete the blank version, or copy one of those provided for the example experiments.

WHERE TO NOW?	
Does your investigation have any implications for the wider world?	

WHERE TO NOW?	
Biology: Which types of fruits have the highest percentage of water?	
Does your investigation have any implications for the wider world?	People such as athletes can now select fruits that offer better hydration

WHERE TO NOW?	
Chemistry: How is iron extracted from raw materials?	
Does your investigation have any implications for the wider world?	It may be possible to determine if some methods are more efficient than others

WHERE TO NOW?	
Physics: At what rate do radioactive materials decay?	
Does your investigation have any implications for the wider world?	Increasing our understanding in the way radioactive materials decay could help with storing radioactive waste

WHERE TO NOW?	
What type of people play video games more than 10 hours each week?	
Does your investigation have any implications for the wider world?	People may become more aware of the implications of playing video games for extended periods

After you have done your background research, you may want to test another scientist's results to confirm that they performed their research accurately. In some cases, there may have been many experiments done and most your research will involve looking at secondary source data. That is, looking at large amounts of data and using it to draw new conclusions.

Planning your own investigation

A successful investigation involves a lot of planning and thinking. The scaffold on the following pages uses the ideas from the previous discussions to help you plan an investigation. You can use this to conduct an investigation of your own. You might even use this to help frame your depth study.

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Your own investigation

PLANNING	
What is your question?	
What is your methodology?	
What is your aim?	
What is your hypothesis?	
What materials will you need?	
What steps do you think your method will have?	
VARIABLES AND CONTROLS	
Independent variable	
Dependent variable	
Controlled variables	
SAMPLING	
What sort of data are you collecting?	
How much data will you collect?	
How will you organise this data?	
USING EQUIPMENT	
Is the equipment easily available?	
Is the equipment costly?	
Are there any risks to using the equipment?	
Have you used this equipment before?	
ETHICAL CONSIDERATIONS	
Are there any aspects of your experiment that could be deemed unethical?	
TIMEFRAMES	
How long do you predict your investigation will take?	
WORKING ALONE OR TOGETHER	
Will you need the skills of other people to complete your investigation?	
INTERPRETING DATA	
Are your experimental data in a table?	
Can your data be graphed?	
What relationship does your graph show?	
EXPLAINING YOUR RESULTS	
What trends does your data show?	
Explain your results	

VALIDITY AND RELIABILITY OF RESULTS	
Was your investigation valid?	
Did you test your hypothesis?	
Were your results consistent?	
How did you reduce experimental errors?	
CAN YOU IMPROVE?	
What can you improve in your investigation?	
WHERE TO NOW?	
Does your investigation have any implications for the wider world?	

SECTION REVIEW 3.4

REMEMBERING

1 Describe what the term methodology means in relation to a scientific investigation.

2 Define the following terms: independent variable, dependent variable, controlled variable, sampling, qualitative data and quantitative data.

UNDERSTANDING

3 Explain why taking too many data samples could be a problem.

4 Discuss why it is important to organise your data into a graph.

5 Outline reasons why a risk assessment is vital to any investigation, and explain why is it important to identify, assess and control.

6 Compare and contrast working individually or in teams.

APPLYING

7 Discuss reasons why ethical considerations need to be taken into account for any investigation. As part of your discussion, include examples of experiments done in the past that would now be considered unethical.

8 Assess the impact that technologies have had on scientific investigations.

9 Outline the impact that some investigations have had on society and the environment.

3.5 Reporting

Once the experiment has been completed and all the data analysed, it is time to write a scientific report. This report should clearly give the reader all the relevant information about the experiment. It should outline the methodology used, describe the first-hand data collected and explain how this data was used. Other scientists should be able to replicate the investigation if required or clearly understand the data.

Most scientific investigations are written up as scientific papers. These papers are then peer reviewed, which is where experts in the same or similar fields review the research. One of the key parts of the peer-review process is ensuring that the data and conclusions made are valid. Once a paper has passed peer review, it can be published in a scientific journal. Some well-known scientific journals are *Nature* and *Science*.

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One way to record the information found in scientific journals is to use a scaffold, such as the one below.

Report title	Increasing Incidence of *Salmonella* in Australia, 2000–2013
Type of information	Primary data
Source of information	http://journals.plos.org/plosone/article?id=10.1371/journal.pone.0163989
Give a summary of the report	The rate of infection of salmonella during the years 2000 and 2013 has increased.
What is the purpose of the report?	To prompt health authorities to develop policies to reduce people's infection with the disease.
What measures were taken to reduce error?	Data which was missing some details such as sex and age were excluded from the data analysis.
What language style was used?	Formal scientific language
How was the report presented and structured?	Abstract (summary of results) Methodology, data and analysis explained Results in table and graphical form Discussion comparing results to other investigations References listed

This can also be done with secondary sources of information.

Report title	Assessing a Text – Global Systems – Global Issues
Type of information	Secondary data
Source of information	*Nelson iScience 10 for NSW* pages 331–334
Give a summary of the report	Greenhouse gases, such as carbon dioxide, trap thermal energy in the atmosphere, leading to an enhanced greenhouse effect. The ozone layer protects the surface of Earth from dangerous UV radiation.
What is the purpose of the report?	To convey information about the greenhouse effect and ozone.
What measures were taken to reduce error?	The information was compared against other secondary sources and government website sources.
What language style was used?	The section is written in an expository style. That is, it is written to explain information.
How was the report presented and structured?	The written information was supported with diagrams to help the reader understand the concept.

INQUIRING FURTHER

The *Public Library of Science* (PLOS) is an open-source online journal, which peer reviews articles before they are published. Search the PLOS database for an article you find interesting.

Write a small literature review on the article you have chosen. Your review should cover the following areas.

- Report title
- Type of information
- Source of information
- Give a summary of the report
- What is the purpose of the report?
- What measures were taken to reduce error?
- What language style was used?
- How was the report presented and structured?

Investigations and reports

Investigations

The two main processes that scientists usually engage in are investigations and reports. The function of the investigation is to test a hypothesis and most students of science will be familiar with the basic scientific method used.

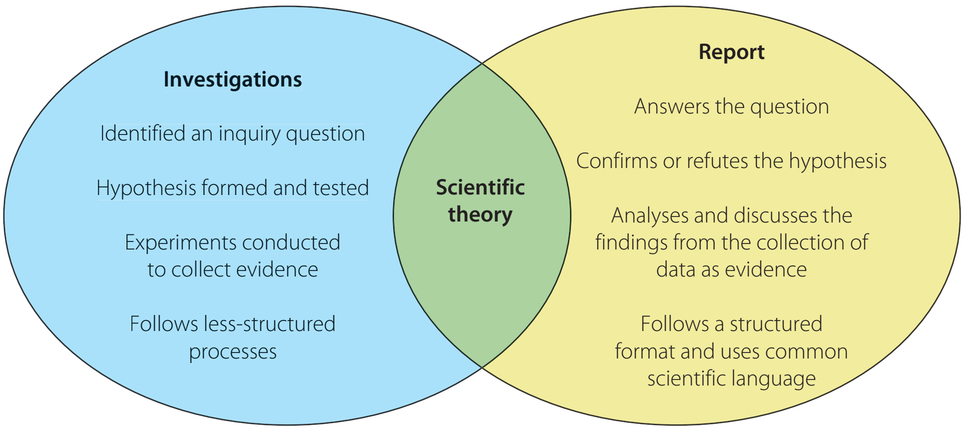
- Identify your question – what you are going to study.
- Form a hypothesis – what you think the answer to your question will be.
- Conduct your experiment – perform a valid and reliable experiment to answer your question.

Reports

The scientific report is about taking the results from the investigation and explaining what was found. The report may also discuss the background behind the investigation. How did the scientists come up with their hypothesis based on work done in the past?

- Did you answer your question?
- Did your experiment match your hypothesis?
- Thoroughly analyse how you conducted your experiment and how you know it is valid and reliable.

FIGURE 3.5.1 Ultimately, the purpose of both investigations and reports is to explain or develop a scientific concept.



Peer assessment

Once you have completed an investigation, you will need to write a scientific report, which summarises what you did and what you found. Then you and your class can assess one another's reports – your own peer assessment.

Then use the scaffold below to assess a scientific report submitted by another student or group in your class from the investigation they conducted in the previous sections. When doing this, try to be neutral in your criticism. The aim of your assessment should be to help your peers improve their scientific methodologies.

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Report title	
Source of report	
Give a summary of the report	
What is the purpose of the report?	
What measures were taken to reduce error?	
What language style was used?	
How was the report presented and structured?	

Report title	Blue food dye heats water faster
Source of report	Class investigation
Give a summary of the report	In the investigation food dye of different colours where added to 100 mL of water, which was subsequently heated over a Bunsen flame. In each trial, water with blue food dye reached 100°C in a shorter time than the other samples.
What is the purpose of the report?	To highlight the results from the investigation
What measures were taken to reduce error?	All variables, other than the dye colour, were kept consistent throughout the investigation. Electronic data loggers were used to take the measurements.
What language style was used?	Formal, scientific language
How was the report presented and structured?	The report was structured like a primary investigation conducted in class. This was a valid way of presenting the information as it showed an orderly layout and was easy for the reader to follow the ideas of the writer.

CHAPTER REVIEW QUESTIONS

REMEMBERING

1 Define 'scientific theory' and list two examples.
2 Describe the main ideas of Marshall and Warren.
3 Describe the work of van Helmont.
4 Outline the work of Spencer.
5 Describe the skills Eratosthenes needed to make his discovery.
6 Explain what Doppler was studying.
7 Describe what Priestley discovered.
8 Define the following terms: primary investigation, fieldwork, second-hand investigation, survey, modelling, simulation.
9 Describe the scientific method. Provide reasons why scientists need to follow the scientific method and why some investigations need variations on the basic scientific method.
10 Define the following terms: methodology, aim, hypothesis, materials, method, risk assessment, reliability, validity, independent variables, dependent variables, controlled variables.
11 Describe how to improve the accuracy of an investigation.
12 Describe the difference between primary and secondary data.
13 Outline ways data can be collected.
14 Describe what a scientific report is.

UNDERSTANDING

15 Describe one scientific theory that went against the accepted ideas of the time.
16 Outline some risks that Marshall took when trying to prove that bacteria caused ulcers. Was he justified in taking this risk?
17 Describe what van Helmont's experiment was trying to show. Propose reasons why his conclusion was not correct.
18 Outline some problems Eratosthenes would have had in doing his calculations.
19 Describe why an investigation needs to carefully plan for the variables and controls.
20 Describe some limitations that a scientist may have when working out their sampling method.
21 Compare and contrast doing investigations individually or in groups.
22 Describe reasons why numerical data are often converted into graphs.
23 Describe reasons why it is important for a scientific report to explain the results.
24 Outline how a scientist could show that their investigation was reliable and valid.
25 Outline reasons why a scientific report is important.

APPLYING

26 Outline an area of research, other than peptic ulcers, that uses or has used cell cultures.
27 Describe some reasons scientists such as Eratosthenes and Doppler took a long time to do their investigations and research.

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28 Assess the impact that technology has had on astronomy. Use the work of Doppler as part of your answer.

29 Outline reasons why experiments such as those done by Priestley would not be considered ethical in modern society.

30 What benefit does a literature review provide when attempting to understand an investigation?

ANALYSING

31 Assess the impact that inventions such as the microwave have had on society.

32 Much scientific progress has been made because of technological innovations such as the Large Hadron Collider. Justify the cost of 'big' science experiments and projects, using examples, such as the Manhattan Project or the development of Wi-Fi.

DEPTH STUDY
BIOLOGY

SIMULATING VAN HELMONT'S EXPERIMENT

Suggested length: 10–15 hours done over a period of 5–10 weeks.

Focus: Primary investigation

Take a small plant or seed and perform your own version of van Helmont's experiment.

3.7.1 Primary investigation scaffold

PRIMARY INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will investigate and write a summary of how you will address the outcome.

Hypothesis (if applicable)

A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.

The plant will experience significant growth just by adding water.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb; for example, 'investigate', 'measure', 'test' and so on.

To investigate aspects of van Helmont's original experiment.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references:

- BBC (2017), Bitesize – National 4 Biology – van Helmont's experiments on plant growth
- Johann Baptista van Helmont online biography by Dr Bruce Mattson.

3.7.1 van Helmont's experiments on plant growth

3.7.2 Johann Baptista van Helmont

Investigation design

Outline how you will design the final presentation (refer to Chapter 2 for further information). Make sure you include the following (where applicable):

- Variables
  - Independent
  - Dependent
  - Controlled
- Treatments/control.

Method

The procedure is written as numbered steps. Each sentence must start with a verb.

1. Weighed the mass of the soil and the plant.
2. Added 100 mL of water to the plant each week.
3. Measured the height of the plant.
4. Repeated this process over a period of 10 weeks.
5. Weighed the mass of the soil and the plant.

Results

The results may be recorded in tables or graphs, or written as observations in sentence form.

Validity and reliability

Remember that validity is related to the method and equipment used to perform your experiments, whereas reliability is associated with the repetition of the experiment obtaining similar results with minimal error.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your hypothesis, aim and inquiry question/s.

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TESTING FOR ATMOSPHERIC GASES

DEPTH STUDY
CHEMISTRY

Suggested length: 5 hours

Focus: Developing a primary investigation

Design experiments to produce and test the properties of the main gases in the atmosphere.

3.8.1 Primary investigation scaffold

3.8.1 Testing for different gases

PRIMARY INVESTIGATION SCAFFOLD
Syllabus outcome Identify the syllabus outcome you will be investigating and write a summary of how you will address the outcome.
Hypothesis (if applicable) A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.
Aim Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on. *To investigate tests used to identify the main gases found in the atmosphere.*
Secondary sources List all the sources you have used in your investigation and cite them using the correct protocols. Suggested reference: BBC (2017), GCSE Bitesize: Testing for different gases.
Investigation design Outline how you will design the final presentation (refer to Chapter 2 for further information).
Method The method is written as numbered steps. Each sentence must start with a verb.
Results The results may be recorded in tables or graphs, or written as observations in sentences.
Validity and reliability Remember that validity is related to ensuring that the sources come from educational, government or scientific websites, journals and textbooks. Reliability is associated with finding similar explanations of the concepts across many sources.
Discussion and conclusion In the discussion and conclusion, analyse your findings to answer your hypothesis and aim.

DEPTH STUDY
PHYSICS

THE DOPPLER EFFECT IN THE MODERN WORLD

Suggested length: 5 hours

Focus: Secondary-source investigation

Research ways that the Doppler effect has been used in two types of modern technology.

3.9.1 Secondary investigation scaffold

3.9.1 How the Doppler effect works

3.9.2 Using the Doppler effect

SECONDARY-SOURCE INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Hypothesis (if applicable)

A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb; for example, 'investigate', 'measure' or 'test'.

To research ways that the Doppler effect has been used in two types of modern technology.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.
See weblinks for suggested references:

- HowStuffWorks (2017), How the Doppler effect works.
- YouTube (2017), 'Physics – Waves in the Real World: Using the Doppler effect'.

Investigation design

Outline how you will design the final presentation (refer to Chapter 2 for further information).

Method

The method is written as numbered steps. Each sentence must start with a verb.

Results

The results may be recorded in tables or graphs, or written as observations in sentence form.

Validity and reliability

Remember that validity is related to ensuring that the sources come from educational, government or scientific websites, journals and textbooks. Reliability is associated with finding similar explanations of the concepts across many sources.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your hypothesis and aim.

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ANALYSING SCIENTIFIC METHODOLOGIES

Suggested length: 8 hours

Focus: Secondary-source investigation

Analyse the methodologies used by scientists not studied in this text. Examples might include:

- Jane Goodall's study of chimpanzees in Africa
- the work done by the Large Hadron Collider, particularly in relation to the discovery of the Higgs boson.

SECONDARY-SOURCE INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Hypothesis (if applicable)

A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb; for example, 'investigate', 'measure' or 'test'.

To analyse how famous scientists have used methodologies to undertake their work.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references:

- *The Guardian* (2017), 'Jane Goodall: 50 years working with chimps', Discover interview, *Science*.
- The Higgs Boson, (2017).
- Don Lincoln (2017), 'Has Stephen Hawking solved the mystery of black holes?', CNN.com.

Investigation design

Outline how you will design the final presentation (refer to Chapter 2 for further information). Make sure you include the following (if applicable):

- Variables
  - Independent
  - Dependent
  - Controlled
- Treatments/control

Method

The method is written as numbered steps. Each sentence must start with a verb.

Results

The results may be recorded in tables or graphs, or written as observations in sentence form.

Validity and reliability

Remember that validity is related to ensuring that the sources come from educational, government or scientific websites, journals and textbooks. Reliability is associated with finding similar explanations of the concepts across many sources.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your hypothesis and aim.

WS 3.10.1 Secondary investigation scaffold

3.10.1 Jane Goodall: 50 years working with chimps

3.10.2 The Higgs boson

3.10.3 Has Stephen Hawking solved the mystery of black holes?

4

MODULE 6 TECHNOLOGIES

Humans' desire to solve problems and answer questions about the world leads us to create and develop technologies to remedy our lack of understanding about phenomena. At the beginning of human existence, many technologies helped us to hunt and gather food. Over time science played an important role in developing new technologies and influencing social developments in areas such as agriculture, medicine, industry and communication.

Creating and developing technology follows a cycle. The scientific understanding of the physical, chemical and biological world enhances technological developments, while at the same time new technologies deepen the knowledge and understanding of concepts and principles that rule phenomena. For example, our understanding of how light and sound waves work has enhanced the development of communication systems, such as mobile phones and GPS. These new technologies in communication increase our understanding about how light and sound waves behave and can be manipulated further.

This interdependence between science and technology helps us to develop tools to improve the wellbeing of humans and to create a more sustainable future.

INQUIRY QUESTIONS

- How does technology enhance scientific investigation? How does technology limit it?
- How have developments in technology led to advances in scientific theories and laws?
- How have developments in science driven the need for further developments in technology?

CONTENT

Students investigate:

- Scientific investigation and technology
- A continuous cycle

OUTCOMES

A student:

- develops and evaluates questions and hypotheses for scientific investigation INS11/12-1
- designs and evaluates investigations in order to obtain primary and secondary data and information INS11/12-2
- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media INS11/12-4
- describes and explains how science drives the development of technologies INS12-13

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Getty Images/Roger Ressmeyer/Corbis/VCG

4.1 The scientific investigation and technology

technology
practically applying knowledge to create a device for practical purposes in any area of research

Research and **technology** have gone hand-in-hand since the beginnings of scientific inquiry. When we think about technologies, we usually think of computers, robotics and bionics. However, humans have been using technologies since we developed the ability to use tools. We can define technology as the application of knowledge to create a device for practical purposes in any area of research. So, a hammer, a spoon, a computer or a robot are all technologies – devices invented for practical purposes to make life easier.

The advances in technologies from the beginnings of civilisation to today increased at a steep curve after the Industrial Revolution at the end of the 19th century (Figure 4.1.1). That was related to the invention of the steam engine and electricity. Later on, the invention of computers and information technologies changed the way research was carried out. Science uses technologies to advance research but, at the same time, the knowledge and understanding of how the physical, chemical and biological world work has helped to create technologies to improve the wellbeing of humanity. For example, because humans learned how our kidneys filter blood, we were able to invent the dialysis machine to do this when the kidneys failed. At the same time, new research into materials such as cellulose-based and synthetic polymers have helped in developing new filtration systems that reinforce the current systems and help the dialysis machine avoid contamination.

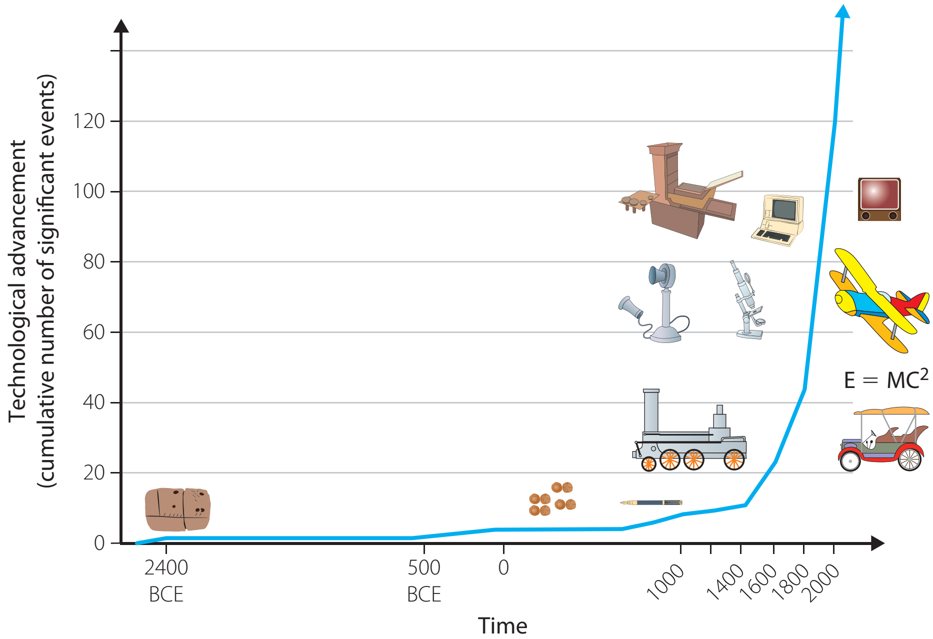

FIGURE 4.1.1 Technological advances since 2400 BCE. The Industrial Revolution in the 19th century was a key turning point, with the invention of the steam engine and electricity initiating a steep upwards curve of technological development.

Technologies can improve or limit a scientific investigation. Improvements come when the technology helps to collect accurate and valid data. Limits can come when the technology is not calibrated or appropriately chosen for the collection of information and data for that particular research. Human creativity and imagination plays an important role in creating new and more advanced technologies. As Einstein said, 'Imagination is more important than knowledge. For knowledge is limited, whereas imagination embraces the entire world, stimulating progress, giving birth to evolution'.

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Using technologies to collect data

Technologies are used to facilitate **data collection**, processing and analysis, to help measure and control the variables and to generate the statistical information to create a valid, accurate and reliable investigation. This consequently helps us to answer questions and predict future patterns and trends from the research.

In science, the technologies used for data collection refer to different types of equipment, such as analogue or digital, to measure and analyse the variables in the experiment. Thermometers, data loggers, stopwatches, computerised data analysers, spectrophotometers, chromatographers, microscopes and gas analysers are just some of the equipment used to measure and collect quantitative data.

INQUIRING FURTHER

The French Institute Research, Innovation, Society (IFRIS) has a classification system for sorting technologies into 389 categories. Research and create a mind map with the criteria to classify technologies that are listed in their five domains.

4.1.1 Classification of technologies

Uses of technologies to measure variables

The selection of the technology used to measure variables is crucial when collecting data, because it helps determine the **accuracy** and **validity** of the data for that particular research and the integrity of the investigation. For example, if the aim of the experiment is to test how the effect of temperature affects the rate of a chemical reaction, a simple thermometer would be a fair choice, but a data logger to measure temperature would be more suitable for collecting the data.

Technologies can limit data collection for independent and dependent variables if the technology is not calibrated properly, it is not appropriate for that research, or the data collected is within a range and not a specific number. For example, to measure the pH of substances to make cosmetics, different pH indicators can be used to collect data (Figure 4.1.2). Each indicator gives a colour for a range of pH but not a specific pH value. Therefore, the measurements of pH may affect the conclusion for each substance to be selected to make the cosmetic. A pH probe is a more accurate method for determining the actual pH number for that particular substance.

INQUIRING FURTHER

Over the centuries, different cultures have developed different technologies according to their needs. Research how Aboriginal Australians differ in the development of technologies for hunting between communities living in the desert and in the bushland. Create a Prezi, PowerPoint or Animoto with your research.

data collection gathering of qualitative or quantitative measurements for the purpose of statistical analysis

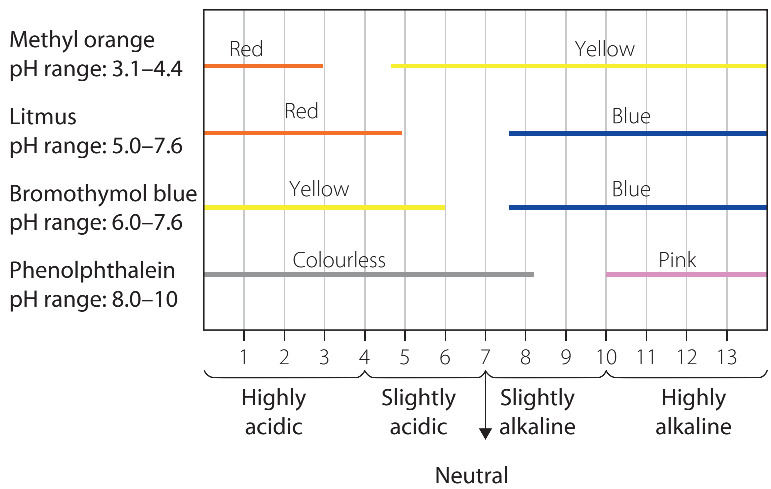

FIGURE 4.1.2 The colours shown by these indicators are over a range of pH; they do not indicate a specific pH. For example, bromothymol blue turns yellow for pH in the range 6.0-7.6. When a substance turns methyl orange to yellow, it indicates a pH between 5.5 and more than 13. These indicators are not able to be used to determine specific pH; only the range in which the pH falls.

Errors in technologies

Assessing the errors in measuring devices is an important issue in research as it helps to determine the integrity of the data collected. Errors in measurement can be random, systematic or gross. Table 4.1.1 summarises the differences between the three main types of errors in measurements.

INQUIRING FURTHER

A group of students is trying to measure the volume of gas released during photosynthesis. Research the technologies that could be used in the experiment to measure the variables. Analyse if the technologies are limited in measuring the data needed. Write a short descriptive report.

The accuracy and precision of the technology, and the operator of the technology, determine the level of error. The accuracy of the instrument is given by how close the measured value is to the true value expected or it is similar to the value recommended in the researched literature. Precision is the reproducibility of the measurement, which means that each time the measurement is taken, the same value is obtained. However, an instrument can be precise but not accurate. For example, the same value of voltage 12 V can be obtained with a digital voltmeter each time voltage is measured but the value is very distant from the true value of the measurement, which is 24 V.

TABLE 4.1.1 Type of errors in measurement, definitions, examples and how to reduce error during experimental data collection.

ERRORS		DEFINITIONS	EXAMPLE	HOW TO REDUCE THE ERROR
Gross		Caused by mistakes in using instruments or meters, calculating measurement and recording data results	A person or operator reading pressure gage wrote 1.10 N/m^2 instead of 1.01 N/m^2	Have other observers double-check the measurements
Systematic	**Instrumental**	Occur because of a fault in the measuring device	A data logger is measuring temperature in the range of 100°C instead of range of 30°C	Re-calibrate the instrument
	Environmental	Occur because of some external conditions (pressure, temperature, humidity or magnetic fields)	The humidity levels during the measurements has changed because of wind conditions	Assess environmental conditions properly before using the device
	Observational or parallax errors	Occur because of incorrect observing or reading of the instruments	Reading 35 mL from the measuring cylinder instead of 32 mL	Have another observer be a second reader of instruments
Random		Caused by the sudden change in experimental conditions	Changes in humidity, unexpected change in temperature or fluctuation in voltage	Reduced by taking the average of a large number of readings

Technologies and safety

Today's technologies often come with detailed instructions explaining the how to use them safely. Reading these safety procedures and keeping them in mind when using technologies to collect data helps to reduce errors and ensure the safety of users. In many cases, you must follow chemical safety data and the work health and safety guidelines while using technology. Operators should receive training in managing technologies and be aware of the risks in using any type of technology when collecting data during an investigation. If an accident occurs, procedures should be in place to support the operator and a new risk assessment for the technology must be done.

Chemical safety data

Chemicals used in investigations are listed in the chemical safety data manual in the laboratory. Each material safety data sheet (MSDS) is written by the manufacturer and contains the following:

- the properties of the chemical
- the chemical safety information
- first aid information in case of accidents

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- the storage and handling of the chemical
- protective personal equipment to be used when handling the chemical.

Before using any type of chemical, you must consult the MSDS to make sure the chemical is safe to use in the classroom laboratory. Many chemicals are not authorised to be used in schools because they have been assessed as high-risk.

4.1.2 Chemical safety data

Work health and safety

Workplace health and safety starts with you. You have the right to work safely, while at the same time the responsibility to keep the workplace safe for others too. In the laboratory, it is very important to manage and be aware of safety. Make sure you have proper training in using technologies, are wearing appropriate protective equipment and have an emergency plan to respond in case of accidents. For example, if you are using electrical devices to collect data for an investigation, read the risk assessment and instructions on how to use the equipment and assess the environmental conditions around it, such as water spillages or faults in cables and electrical plugs. This will help you avoid accidents and control any hazards.

4.1.3 Workplace health and safety

Analogue versus digital technologies

Over time, technologies have moved from analogue to digital. The difference between the two is how data from the wave carrying the information is recorded. In analogue technologies, the wave is recorded or used in its original form, but in digital technologies the wave is sampled at some point and turned into a combination of the numbers 0 and 1 (binary numbers) and stored in a device. Take the example of sound recording. With an analogue technology, the sound wave is recorded straight from a microphone onto a tape and then sent to a speaker. In a digital technology, the sound is transformed into a binary system of 0 and 1 and stored in a digital device (Figure 4.1.3)

INQUIRING FURTHER

Identify all the technologies that are used in your class laboratory and create a poster for your classroom indicating the safety procedures to follow when using those technologies in investigations

WS 4.1.1 Analysis of technologies: errors and safety

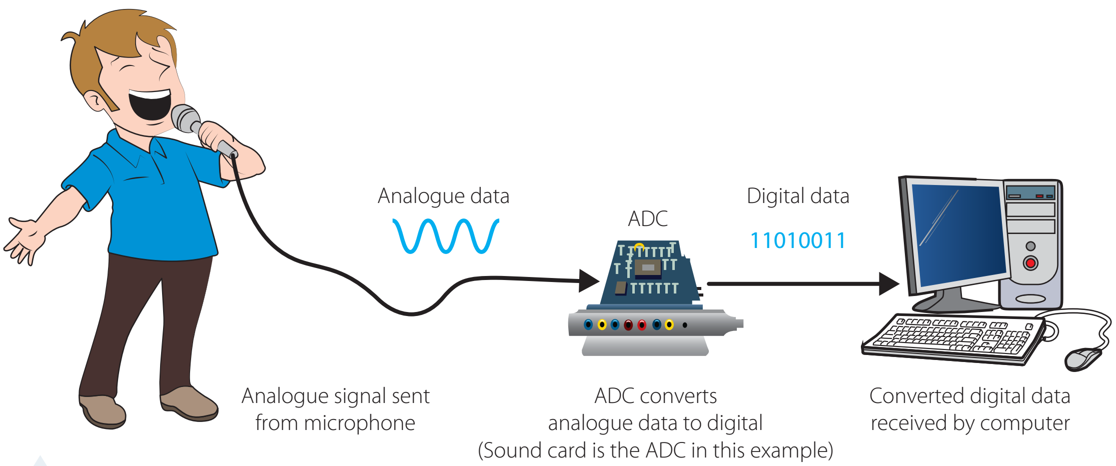

FIGURE 4.1.3 Conversion of sound from analogue to digital.

Both technologies, analogue and digital, have their advantages and disadvantages, as shown in Table 4.1.2. Both technologies can be used to measure the variables in an experiment. However, the selection of the technology to use depends on costs and nature of the experiment.

TABLE 4.1.2 Advantages and disadvantages between digital and analogue technologies.

TECHNOLOGY	DIGITAL	ANALOGUE
Advantages	▪ More precise ▪ Compatible with other digital systems ▪ Integrated networks ▪ Immediate recorded information	▪ Low cost ▪ Uses less bandwidth ▪ More accurate ▪ No need of synchronised communication systems
Disadvantages	▪ Can be expensive ▪ Sampling error ▪ Digital communications require greater bandwidth than analogue to transmit the same information ▪ The detection of digital signals requires the communications system to be synchronised	▪ The effects of random noise can make signal loss and distortion impossible to recover from ▪ Observational errors

reaction rate speed at which a chemical reaction occurs

activation energy minimum level of energy for a substance to be activated to react chemically

catalysts chemicals that increase the reaction rate by lowering the activation energy

enzymes catalysts that assist biochemical reactions in organisms

Practical investigations and technologies

The following set of experiments uses different technologies to measure both the independent and dependent variables to collect quantitative data. In each of the investigations developed below, the evaluation of the technologies used, the assessment of errors and accuracy from the data gathered using a particular technology and the considerations about the safe use of the technology are included as discussion questions.

Temperature on reaction rate

In a chemical reaction, substances react with each other, chemical bonds are broken and new substances are formed as products. The reaction rate is the speed at which the chemical reaction occurs. Temperature affects the reaction rate because it increases the collision between the particles, this is according with the collision theory. The theory states:

KEY THEORY

For a chemical reaction to occur, the particles of the reactants must collide with each other.

In a chemical reaction, a minimum level of energy is needed to start the particles colliding and consequently produce the chemical products. That energy is called activation energy. The particles must have enough energy for the collision to take place and successfully produce a reaction. The reaction rate depends on the rate (speed) of successful collisions between reactant particles. The more successful collisions there are, the faster the rate of reaction.

Increasing the temperature in the chemical reaction affects the activation energy because:

- there is more energy in the chemical system and consequently the particles have more energy
- there are more collisions between the particles
- the rate of reaction increases.

Catalysts are chemicals that increase the reaction rate by lowering the activation energy. The catalyst itself remain unchanged at the end of the reaction.

At an industrial level, catalysts are used widely to catalyse chemical reactions to create commercial products. For example, iron is used as catalyst in the reaction between nitrogen and hydrogen to produce ammonia. In the case of biochemical reactions in organisms, those catalysts are called enzymes.

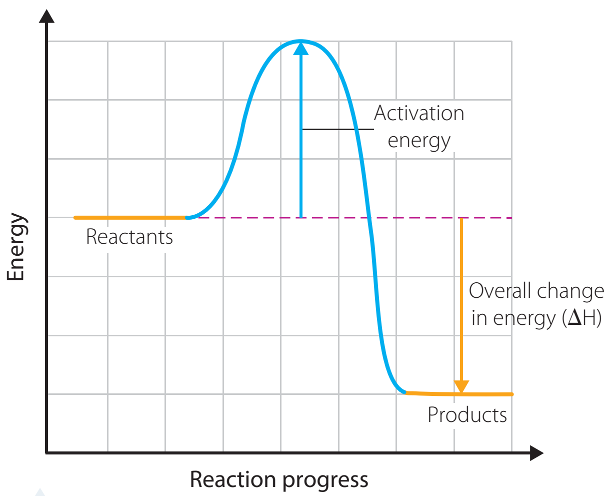

FIGURE 4.1.4 Activation energy of a chemical system.

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Enzymes have the property that they 'help' in the chemical reaction but they do not react with the products or reactants and they are not affected by the reaction. In other words, they are inert to the reaction.

Enzymes are specific for each biochemical reaction and they work in a particular range of temperatures, therefore a change in temperature affects the enzyme (it becomes **denatured**) and consequently affects the reaction rate of the biochemical reaction.

KEY RULE

$$\text{Reactant A} + \text{Reactant B} \xrightarrow{\text{Catalyst}} \text{Product A} + \text{Product B}$$

denatured
an enzyme that has been altered by heat, acidity or some other effect

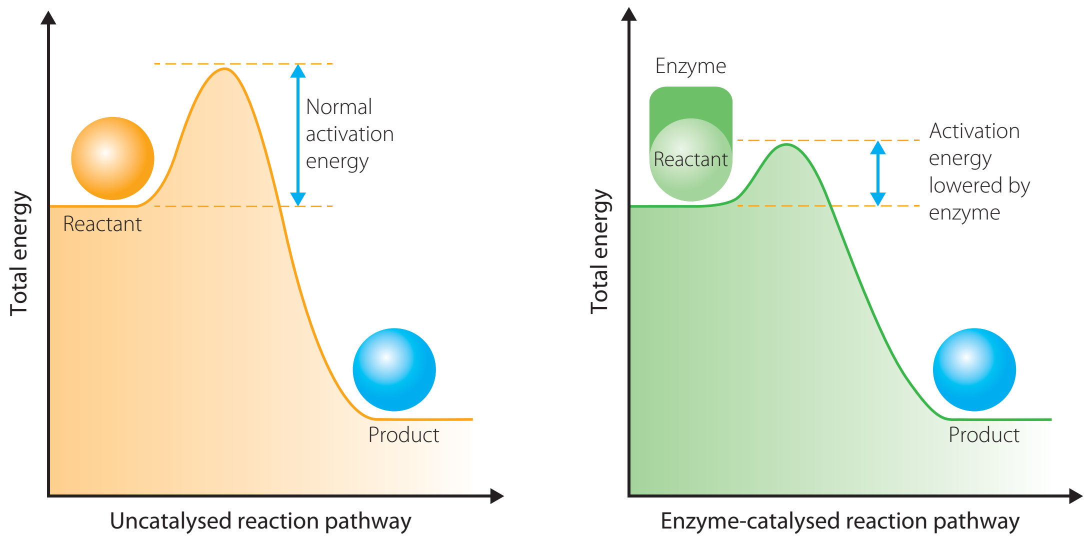


FIGURE 4.1.5 Effect of the enzyme (catalyst) on activation energy and reaction rate in a biochemical reaction. It is important to note that for every enzyme there is a specific temperature range that the enzyme works, outside that temperature range the enzyme is denatured.

4.1.4 Enzyme lab
4.1.5 Effect of temperature on enzyme kinetics
4.1.6 Enzyme-controlled reactions

Calculating reaction rates

If the rate of the reaction is faster, more reactants are used and consequently, more products are made in a given time. The reaction finishes when all the reactants are used up and no more product can be made. The reaction rate can be plotted (Figure 4.1.6) and calculated.

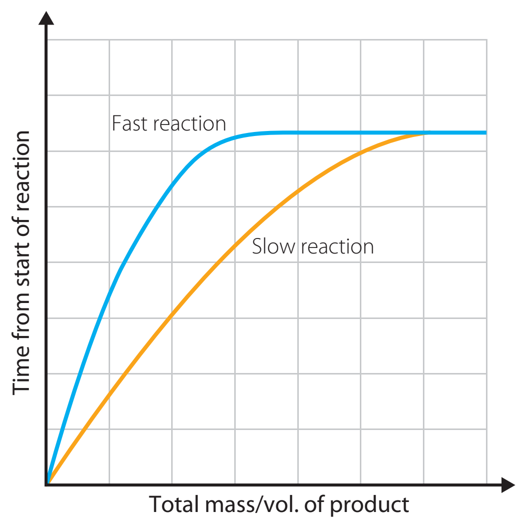


FIGURE 4.1.6 This graph shows the reaction rate as a function of the total mass or volume of the product created over the reaction time. If the reaction is fast the curve (blue) will have a steep increase and then plateau, which indicates that the reaction stops. In a slow reaction, the curve is less steep (orange).

KEY RULE

Rate of reaction

rate of reaction = total amount of reactant used or product made ÷ time taken

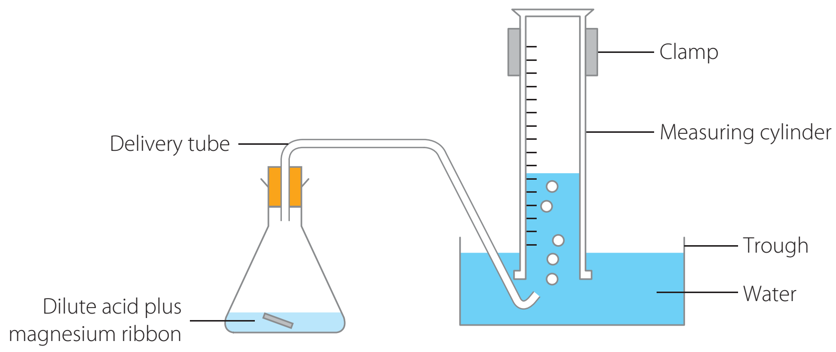
The rate of the reaction can be calculated using the equation: rate of reaction equals the total amount of reactant used or product made divided by time taken.

As an example, Rita and Fred set up the following apparatus to measure the amount of hydrogen produced when they react magnesium with hydrochloric acid. What is the reaction rate if 25 cm^3 of hydrogen is produced in 2 minutes?

4.1.7 Using the Arrhenius equation

4.1.8 Arrhenius equation

FIGURE 4.1.7 Apparatus set up by Rita and Fred to collect and measure the amount of hydrogen produced be the reaction between acid and magnesium ribbon.



INQUIRING FURTHER

An Arrhenius equation (explained in weblinks 4.1.7 and 4.1.8) can be applied to calculate the effect of temperature on reaction rates. Explore how you can apply the equation in investigations, such as Investigation 4.1.1, and include the calculations in your discussions.

The calculation is as follows:

rate of reaction = total amount of reactant used or product made ÷ time taken

rate of reaction = 25 cm^3 H_2/2 min

rate of reaction = 12.5 cm^3 H_2/min

INVESTIGATION 4.1.1

Effect of temperature changes on reaction rate

AIM

To investigate the effect of temperature changes on reaction rate

PROCEDURES

1 Choose from one of the experiments below:

Experiment 1 – effect of temperature on the reaction rate of liver enzyme catalase

Experiment 2 – effect of temperature on the reaction rate between sodium thiosulfate and hydrochloric acid

Experiment 3 – effect of temperature on the reaction rate of a glow stick

2 Design your experiment to measure the effect of temperature on the reaction rate and in your design, identify the independent, dependent and controlled variables.

3 List all the equipment necessary to carry out the experiment and identify the risks when creating a risk assessment. Refer to the MSDS of the chemicals if necessary.

4 Measure the dependent variable using both analogue and digital technology (e.g. thermometer vs data logger).

5 Ensure the validity and reliability of your experiment.

6 Record your results in tables and graphs.

4.1.9 Temperature effect on reaction rate between hydrochloric acid and thiosulfate

4.1.10 Temperature effect on reaction rate of catalyse enzyme

4.1.11 Effect of temperature on glow sticks

»

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» ANALYSIS AND DISCUSSION

1 Describe the issues encountered when measuring the independent, dependent and controlled variables in the chosen investigation.
2 Describe how validity and reliability of the results was achieved.
3 Evaluate the limitations of each of the technologies used to collect data in the chosen investigation.
4 Assess the error and accuracy of each of the devices that were used in the investigation.
5 Compare which device was more precise to make observations and collect data.
6 Assess the safety of the technologies used in the investigation.

Effect of temperature and pressure on gas volume

Gas is a state of matter in which particles move freely. Consequently, gas conforms to the shape of the container or space in which it is held, acquiring a uniform density across that space despite gravitational forces. Gas particles have a high number of collisions and gases can expand indefinitely. Gases can be grouped according to how they behave under different pressures such as compressed, liquefied or dissolved (Table 4.1.3). As can be observed from Table 4.1.3, temperature and pressure play an important role in compressing gases to make them useful for industrial purposes.

TABLE 4.1.3 Classification of gases according to how they behave under different pressures.

CLASSIFICATION	DESCRIPTION	STATE	EXAMPLE
Compressed	Packaged under pressure at –50°C	Gaseous	Carbon dioxide, propane, oxygen
Liquified (high pressure)	Packaged under pressure at temperatures between –50°C and 65°C	Liquid	Ammonia, chlorine
Liquified (low pressure)	Packaged under pressure at temperatures above 65°C	Liquid	Liquified natural gas
Dissolved	Packaged under pressure but dissolved in a liquid phase solvent	Liquid	Acetylene

Charles' law for a constant volume of gas in a sealed container, the temperature of the gas is directly proportional to its pressure

The relationship between pressure and temperature in gases was put forward by the French scientist Jacques-Alexandre-César Charles in around 1787 and is known as Charles' Law. This law can be expressed in a mathematical equation: $K = V/T$

KEY FORMULA

$K = V/T$

Where

K = constant

V = volume (mL or L)

T = temperature (Kelvin)

Note: Temperature must be in Kelvin for Charles' equation. To calculate Kelvin temperature, add 273 to the Celsius temperature.

Or:

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

Where

V_1 = initial volume (L or mL)

T_1 = initial temperature (K)

T_2 = final temperature (K)

V_2 = final volume (L or mL)

Charles' law animation

Boyle's law
the product of the volume and the pressure, for a fixed mass of a gas at constant temperature, is constant.

Applying Charles' law, we can measure the relationship between temperature and volume. But what about the relationship between volume and pressure? Particles in gases are constantly moving and colliding with the walls of the container that the gas is held in. Those collisions create the pressure of the gas; the smaller the container, the higher the pressure.

In 1660, Robert Boyle developed a law to measure the relationship between volume and pressure mathematically. **Boyle's law** is shown in the key formula, below.

KEY FORMULA

$K = P \times V$

Where

P = pressure in millimetres of mercury (mmHg)

V = volume in litres (L)

K = constant

Or:

$P_1V_1 = P_2V_2$

where

P_1 = initial pressure (atm or mmHg)

V_1 = initial volume (L or mL)

P_2 = final pressure (atm or mmHg)

V_2 = final volume (L or mL)

INVESTIGATION 4.1.2

Effect of temperature or pressure on the volume of gases: Charles' law and Boyle's law

AIMS

To investigate the effect of temperature on the volume of gas
To investigate the effect of pressure on gas volume

PROCEDURE

1 Choose from one of the experiments below:

Experiment 1 – effect of temperature changes on the volume of gas using balloons

Experiment 2 – effect of temperature changes on the volume of gas using marshmallows

Experiment 3 – effect of temperature changes on the volume of gas repeating Charles' law experiment and one of the experiments below:

Experiment 1 – effect of pressure on the volume of gas using mini-marshmallows and a syringe

Experiment 2 – effect of pressure changes on the volume of gas using balloons and a syringe

Experiment 3 – effect of pressure changes on the volume of gas by building a piston

»

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2 Design your experiment to measure the effects of temperature or pressure on the volume of gases. In your design, identify the independent, dependent and controlled variables.
3 List all the equipment necessary to carry out the experiment and, when appropriate, identify and create a risk assessment. Refer to the MSDS of any chemicals if necessary.
4 Measure your dependent variable using both analogue and digital technology (e.g. thermometer vs data logger).
5 Ensure the validity and reliability of your experiment.
6 Record your results in tables and graphs to demonstrate the application of Charles' and Boyle's laws.

ANALYSIS AND DISCUSSION

1 Describe the issues encountered when measuring the independent, dependent and controlled variables in the chosen investigation.
2 Describe how validity and reliability of the results were achieved.
3 Evaluate the limitations of each of the technologies used to collect data in the chosen investigation.
4 Assess the error and accuracy of each of the devices that were used in the investigation.
5 Compare which device was more precise when making observations and collecting data.
6 Assess the safety of the technologies used in the investigation.

Effect of changes of speed on distance travelled

Speed is a scalar quantity defined as distance travelled by a moving object over time. Therefore, if an object speeds up, more distance is covered over a particular time. Conversely, if the object slows down, it covers a smaller distance in that time. An object with no movement has zero speed. Speed is usually measured as **average speed**. This is because speed varies over any distance travelled. For example, in a trip from home to school, the bus travels at different speeds in relation to traffic lights, stops and the type of road. Therefore, the speed can change from 0 to 40 kilometres per hour or from 80 kilometres per hour back to 0. Other factors are taken into account when objects move, such as friction, angle of trajectory if the object is launched, the mass of the object, the forces applied on the object and gravitational pull.

INQUIRING FURTHER

Investigate how speed cameras work and create a flyer to inform students who are learning to drive.

average speed total distance travelled over time

KEY FORMULA

Speed, distance, time

$s = d/t$

Where

s = average speed (m/s)

d = distance (metres)

t = time (seconds)

Note: that all the measured distances and time must be converted to metres and seconds.

INQUIRING FURTHER

In freefall, gravity increases a falling object's acceleration by 9.8 metres per second (m/s) with every passing second. How does this constant acceleration affect the distance that an object travels over time? Design and perform a simple experiment to prove the statement. Present the results as a short video.

INVESTIGATION 4.1.3

Effect of speed on distance travelled

AIM

To investigate the effect of speed on distance travelled

PROCEDURE

1. Design a practical investigation to investigate the effect of speed on distance travelled.
2. Identify the dependent, independent and controlled variables of the experiment.
3. Choose different technologies (motion sensor, ticket timer, ruler, stopwatch) to measure the variables in your experiment.
4. Record your results in tables and graphs, for each technology used.
5. Analyse the patterns and trends from your graphs for each technology.

ANALYSIS AND DISCUSSION

1. Describe the issues encountered when measuring the independent, dependent and controlled variables in the chosen investigation.
2. Describe how the validity and reliability of the results were achieved.
3. Evaluate the limitations of each of the technologies used to collect data in the chosen investigation.
4. Assess the error and accuracy of each of the devices that were used in the investigation.
5. Compare the precision and accuracy of the devices used to make observations and collect data.
6. Assess the safety of the technologies used in the investigation.

SECTION REVIEW 4.1

REMEMBERING

1. Define 'technology'.
2. Using an example, describe how technology developed over time.
3. Identify the types of errors encountered when using different technologies in experiments.

UNDERSTANDING

4. Outline how temperature affects reaction rate in chemical reactions.
5. Explain Charles' law in relation to the effect of temperature and pressure on the volume of gases.
6. Explain why average speed is usually measured when objects travel over a distance.

APPLYING

7. Plants in the desert suffer extreme changes in temperature. Explain how different temperatures affect the biochemical reaction rates and how plants overcome the issue.
8. Aboriginal Australians use the boomerang as a technology to hunt. Analyse how the speed of the boomerang affects the distance travelled considering the throwing forces, air resistance and gravity.

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4.2 Technological and scientific development: a continuous cycle

As discussed, science and technology go hand-in-hand. This relationship has driven the development and growth of human society and consequently, human impact on Earth. Technological developments lead to advances in science, its theories and laws, and consequently drives new developments and creates new needs in society. For example, communications technology has advanced from simple verbal transmission of information to 'can't leave home without it' mobile phones. Mobile phone applications then help us understand new scientific knowledge; for example, there is an app that helps us understand how the orbit of the planets may behave around a black hole. So, scientific knowledge helped to create mobile phones while content accessed on mobile phones helps us to understand scientific phenomena. Today, digital technologies drive the way we live our lives and interact with each other across the world.

INQUIRING FURTHER

How have developments in technology led to advances in scientific theories and laws that, in turn, drive the need for further developments in technology? Conduct a secondary-source study and discuss the findings in class..

Thanks to the deep understanding of scientific principles, new technologies are emerging at a great rate, every day. This has created a feedback loop between science and technology as shown in Figure 4.2.1.

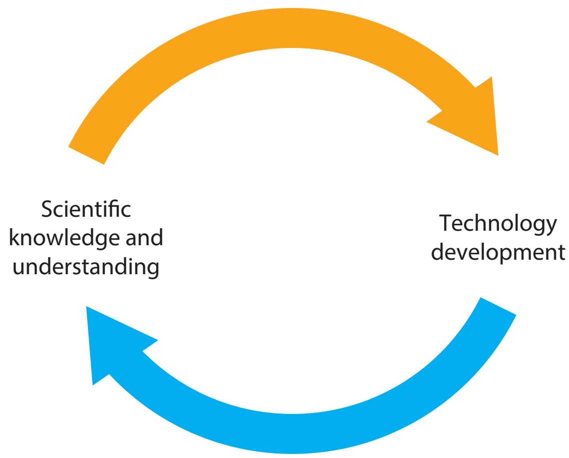


FIGURE 4.2.1 The knowledge and understanding of scientific physical and biological principles drives the development of new technologies, and technologies help to understand the science behind world phenomena.

INQUIRING FURTHER

In just one century, humanity developed the technology to replace horse-powered carriages with cars that respond to voice commands and are driven by an onboard computer. Research the development of car engines from the first prototypes to current hybrid fuel and electrical cars. Create a flow chart with the scientific principles and technologies underpinning this science–technology cycle.

INQUIRING FURTHER

Emerging technologies can enhance the wellbeing of humanity. Technologies like stem cell research, genetically modified food and robotics create discussions about their implications on ethical issues. Choose one of the technologies listed in the World Economic Forum and create a brochure to explain how to overcome the challenges with their ethical issues.

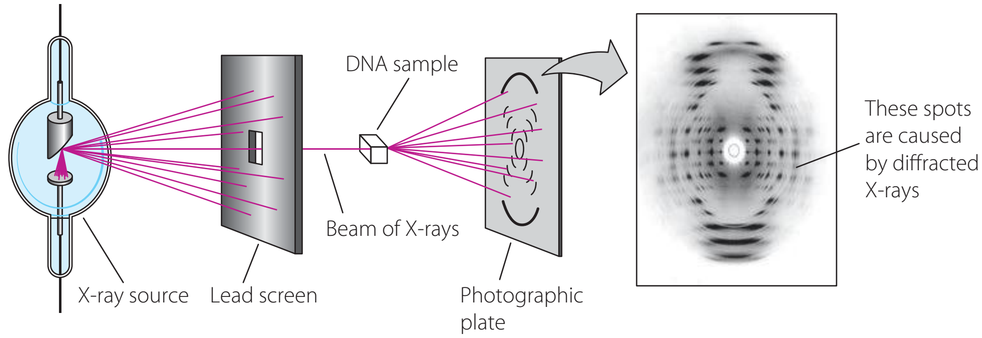
INQUIRING FURTHER

What is the Hype Cycle? Think about a technology that you want to invent to solve a problem around your house or school. Create a poster to explain its Hype Cycle.

Impact of technologies on scientific understanding

In the last few centuries, technology and science have become more interrelated and it has become difficult to separate the impact that they exert on each other. The development of a technology drives the discovery of more evidence that consolidate scientific progress. Contemporary philosophers describe the impact of technologies on scientific advances as like a symbiotic relationship, where the separation between science and technology is nearly impossible to discern. Without doubt, technological developments and their applications enhance and impact on the accumulation of evidences for scientific principles, theories and laws. For example, thanks to the use of X-ray crystallography techniques by Rosalind Franklin the structure of the deoxyribonucleic acid (DNA) was finalised by James Watson and Francis Crick (Figure 4.2.2) or because of the creation of the Large Hadron Collider, the existence of Higgs boson sub-particles, which was predicted by the Standard Model, was consolidated (Figure 4.2.3).

FIGURE 4.2.2 X-ray crystallography illuminating DNA.

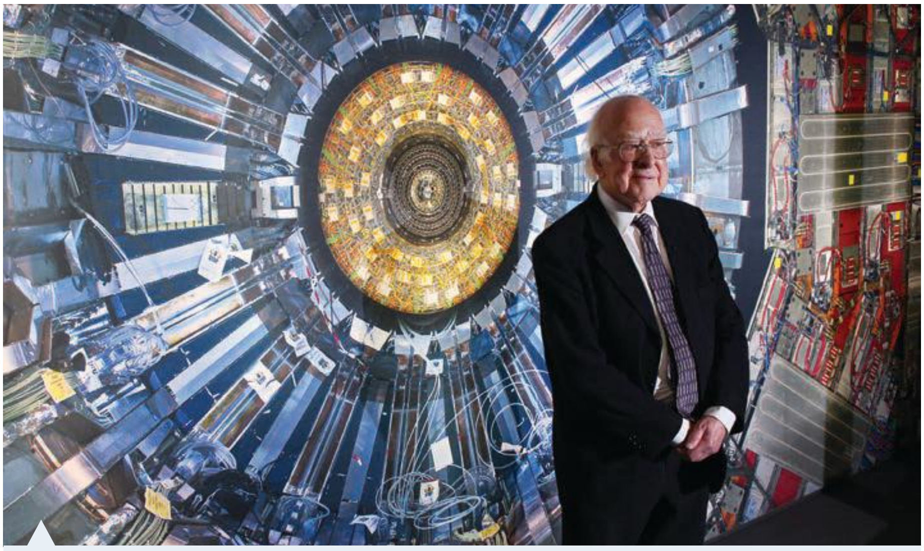


4.2.1 The Large Hadron Collider

4.2.2 The Synchrotron and the Large Hadron Collider

INQUIRING FURTHER

The Large Hadron Collider is one of the latest technologies used in quantum physics to collect evidence about subatomic particles. What are subatomic particles? What are the implications of understanding subatomic particles behaviour? What are the applications of quantum physics in society? Research those questions and create a flyer for people to understand them.



Getty Images/Peter Macdiarmid

FIGURE 4.2.3 Professor Higgs with an artist's impression of the Large Hadron Collider.

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INVESTIGATION 4.2.1

Impact of technologies on scientific developments

AIM

To assess the impact of technologies on the accumulation of evidences for scientific models, theories and laws

MATERIALS

The references listed as weblinks may be useful as secondary sources for this investigation.

PROCEDURE

1 Investigate each of the following technologies and describe the evidence collected with those technologies that support the related scientific model, theories and laws:
   - Computerised simulations and models of Earth's geological history
   - X-ray diffraction and the discovery of the structure of DNA
   - Technology to detect radioactivity and the development of atomic theory
   - The Large Hadron Collider and discovery of the Higgs boson
2 Create a table with the following headings, as a scaffold for the research:

EXAMPLE	TECHNOLOGY AND YEAR OF DISCOVERY/ APPLICATION	SCIENTIFIC MODEL, THEORY OR LAW	EVIDENCE COLLECTED (EXTENDED EXPLANATIONS RECOMMENDED)	ASSESSMENT OF IMPACT AND IMPLICATIONS OF THE TECHNOLOGY ON THE SCIENTIFIC DISCOVERY	REFERENCES
e.g. DNA molecule	*X-ray diffraction (1953)*	*DNA molecule model*	*Double helix structure*	*The DNA model helps us understand what the molecule of DNA is and how it works. Consequently, the model helps to advance further genetic research.*	

3 Cite all your references properly.
4 Create a report about each technology and assess its impact on the scientific discovery.

KEY RULE

Writing an 'assessment of impact'

To write a proper assessment about any contribution that has an impact on any scientific discovery the rule to follow is illustrated in the following flow chart.

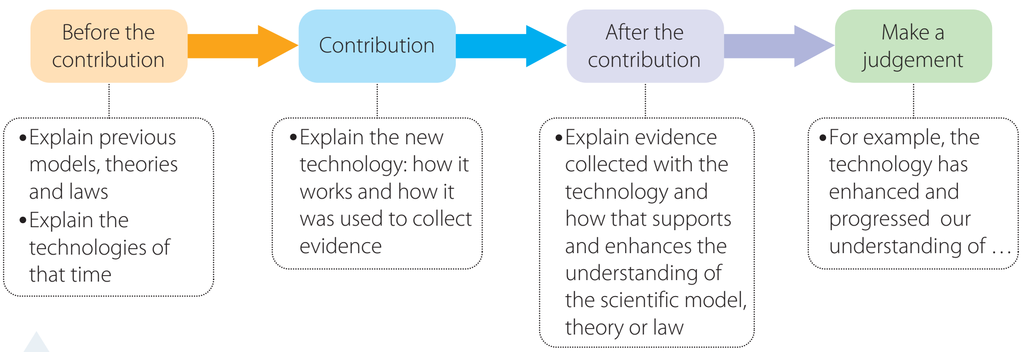

FIGURE 4.2.4 Scaffold to write an assessment of the impact of any contribution to the development of new scientific principles, models, theories and laws.

4.2.3 Plate tectonics – key to life on Earth?

4.2.4 Computer simulation sheds light on how Earth's continents were born

4.2.5 Franklin's x-ray diffraction, explanation of x-ray pattern

4.2.6 What is radioactivity?

4.2.7 German physicist Hans Geiger and the Geiger counter

4.2.8 The Higgs boson

»

» DISCUSSION

For the report and discussion about each technology, complete the following tasks.

1 Describe the scientific theory, model or law.
2 Explain the technology used to collect evidence for that model, theory or law.
3 Explain the evidence collected with the technology and how this evidence supports the scientific model, theory or law.
4 Assess the impact of the technology on the understanding of the scientific model, theory or law.

Scientific understanding and its impact on developing technologies

Scientific understanding begins from observations of the 'big picture' of the world around us and works inwards from there. The key to today's scientific models, theories and laws is that we now measure and test those initial observations until a clear answer about the phenomenon arises. Historically, scientific understanding was based on arguments and discussion. Now, knowledge and understanding of science drives the development of technologies to test and measure hypotheses or collect new evidence to prove scientific principles. For instance, the scientific knowledge in Newton's laws about forces, acceleration, mass and inertia has driven the creation of many technologies for buildings, aeronautics and the automotive and engineering industries, such as, for cars, the seatbelt and the crumple zone.

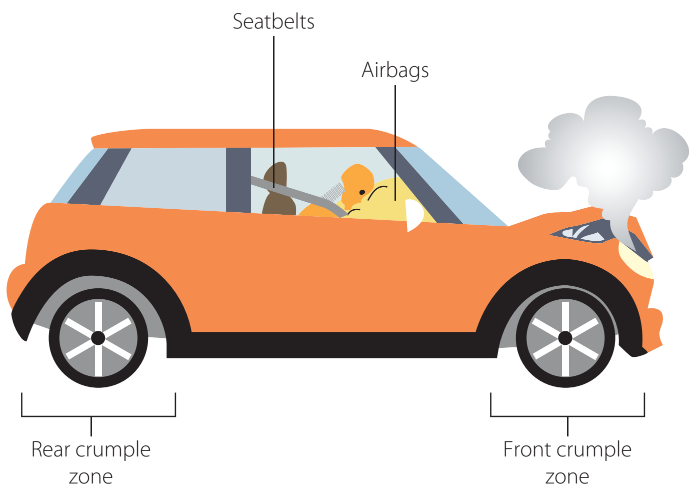

FIGURE 4.2.5 The application of Newton's laws in car safety: crumple zones, airbags and seatbelts try to counteract inertia (Newton's first law), the resultant forces between mass and acceleration of the car (Newton's second law) and the action-reaction forces in a car crash (Newton's third law).

INQUIRING FURTHER

The Petronas Twin Towers in Kuala Lumpur are a clear example of the application of Newton's laws. What forces act on the 88 floors? Why did engineers have to construct a bridge between the two towers? What scientific principles were applied in constructing the bridge? Create a 3D model of the towers and explain the applications of Newton's laws.

4.2.9 Car safety and Newton's laws

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INQUIRING FURTHER

David Unaipon is considered the Australian Leonardo da Vinci because of his inventions. Research one of his inventions and make a scientific poster explaining the scientific principles used to develop the ideas for the technology.

INQUIRING FURTHER

Indigenous cultures from China, the Middle East, Australia and North America may have scientific principles that do not follow the same testing processes as western science. Choose one of the cultures and research a scientific principle that was applied to improve their technologies. Discuss the differences in the approach to apply science on technologies and present a short PowerPoint with your findings.

INVESTIGATION 4.2.2

Impact of scientific theories, laws and models on technological developments

4.2.10 Structural principles – forces
4.2.11 Microscopes and telescopes
4.2.12 What is radioactivity?
4.2.13 Earthquake-proof buildings?

AIM

To investigate and assess the impact of scientific theories, laws and models on technological developments.

MATERIALS

The weblinks listed on the right are suggested secondary sources are relevant to use in this investigation.

PROCEDURE

1 Investigate each of the examples below.
   - The laws of refraction and reflection on the development of microscopes and telescopes
   - Radioactivity and radioactive decay on the development of radiotherapy and nuclear bombs
   - The discovery of the structure of DNA and the development of biotechnologies to genetically modify organisms
   - Newton's laws and the technology required to build buildings capable of withstanding earthquakes

2 Copy the table below as a scaffold to organise your research.

TECHNOLOGIES	SCIENTIFIC THEORY, LAW OR MODEL THE TECHNOLOGY IS BASED ON	DIAGRAM	IMPACT OF SCIENTIFIC KNOWLEDGE ON TECHNOLOGICAL DEVELOPMENT	SECONDARY SOURCES
Microscope	Law of refraction and reflection of light		The understanding of the law of reflection and refraction drove the creation of the simple light microscope and consequently has enhanced the knowledge about the microscopic biological and physical world.	

»

3 For each example:
   a Research the scientific theory, law or model that the technology is based on.
   b Explain the application of the scientific knowledge with the aid of diagrams, pictures or digital images.
   c Cite all the secondary sources used in the investigation.
   d Create a case study report.

DISCUSSION

For each case study:

1 State the scientific theory, model or law.
2 Explain how the scientific theory, model or law was applied to develop the technology.
3 Assess the impact that the scientific theory, model or law has on the development of the technology. Follow the flow chart below to write your assessment.

KEY RULE

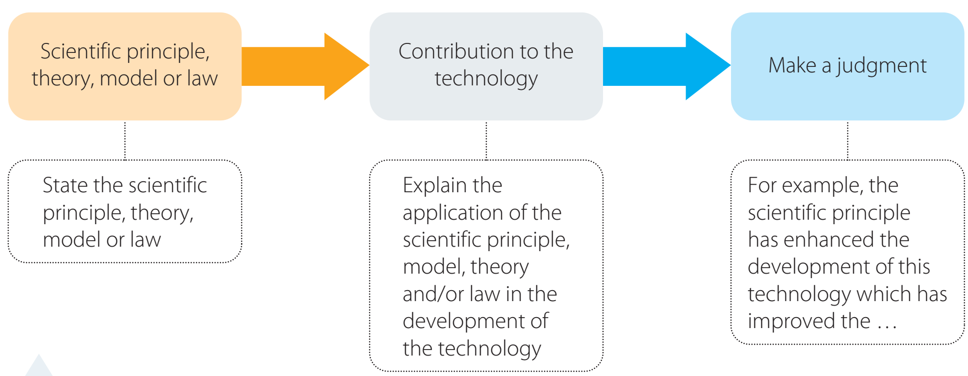

FIGURE 4.2.6 Scaffold to write your assessment of the influence of a scientific principle, model, theory and/or law on the development of technology.

Uses of native plants by Aboriginal and Torres Strait Islander people

The use of plants for materials and medicinal purposes is as old as humankind. Every culture in the world uses plants collected locally and, through many years of trial and error, each culture learned to use these plants for medicines and materials.

Aboriginal and Torres Strait Islander people have a broad knowledge of how to use native plants for medicinal and material purposes. Contemporary science has an increased awareness of the value of Aboriginal and Torres Strait Islanders' knowledge and this is helping pharmacists and physicians to respond to the challenges that have emerged in modern medicine, such as antibiotic resistance and allergies to synthetic drugs. However, a lot of information has been lost over the years since Aboriginal and Torres Strait Island culture has no written records and the traditions are passed through verbal communication, songs, dancing and ritual ceremonies that are becoming rare.

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Native plants as materials

Native plants were used to construct shelters, make clothing, ropes and baskets, and in art (paints and bark as canvases). The plants used were resistant to wear and today we can still see and appreciate the constructions, tools, utensils and pieces of art made thousands of years ago.

Aboriginal people were innovative in using weaving as a technique to make utensils and bags. Some of the bags were so tight that it could carry honey and other containers could collapse and expand, which made them easy to transport.

Alamy Stock Photo/Penny Tweedie

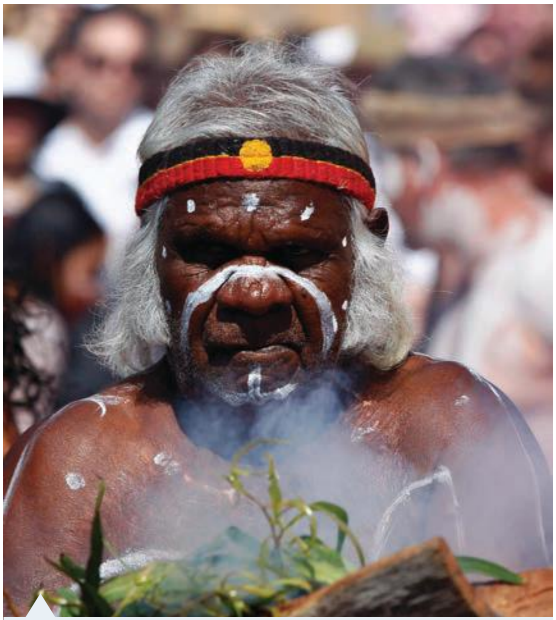
FIGURE 4.2.7 Example of weaving technique used to make baskets by Aboriginal and Torres Strait Islander communities.

INQUIRING FURTHER

Aboriginal and Torres Strait Islander communities were using woven fibres to create many objects for everyday uses, such as nets, fish traps, baskets, bags and seed sifters. Contact your local Aboriginal community to research the types of plants used and how the weaving technique was applied to make utensils to serve specific purposes. Create an audiovisual presentation to present to your school during NAIDOC week.

Native plants and medicine

Australians and Torres Strait Islander people often predict their good health because they say that 'they eat well'. However, when someone becomes ill, they drink traditionally made infusions to treat upset stomachs or body aches, and ointments and saps are placed on infected cuts and abrasions. All of those bush medicines are collected and prepared from well-known local plants to cure the ailments. Some of these **medicinal plants** are commercially available, such as tree tea oil (*Melaleuca alternifolia*) and eucalyptus oil (*Eucalyptus sp.*). Some that are not common to western medicine including the Kakadu plum (*Terminalia ferdinandiana*) and emu bush (*Eremophila sp.*), are widely used as medicines to treat and reduce the effect of illnesses by many Aboriginal Australian and Torres Strait Islander communities, as shown in Table 4.2.2.



Getty Images/Don Arnold

FIGURE 4.2.8 Smoking ceremonies are common in Aboriginal Australia. Participants burn river gum, ironwood or native cherry depending of the type of healing needed.

Alamy Stock Photo/MNS Photo

Getty Images/iStock/Amy_Lv

FIGURE 4.2.9 Tea tree oil produced as essential oil from *Melaleuca alternifolia* plants. Before its commercial production, Aboriginal Australians boiled the leaves to make infusions or crushed them to extract the oils.

4.2.14 Australian Indigenous tools and technology

4.2.15 Indigenous Australian objects

medicinal plant
a plant with pharmaceutical properties possessing an active ingredient that can be extracted for medicinal purposes

TABLE 4.2.2 Some of the Australian native plants used by Indigenous Australians as traditional medicines. Plant parts were boiled to create drinks or inhale the steam, or the infusions were mixed with beeswax to produce ointments.

NATIVE PLANT COMMON NAME	SCIENTIFIC NAME	PLANT PART USED	MEDICINAL USES
Cheese fruit	*Morinda citrifolia*	Raw fruit	Colds, coughs, flu
Bush plums	*Santalum lanceolatum*	Raw fruit	Colds, coughs, flu
Goat's foot	*Ipomoea pes-caprae*	Warm leaves and vines	Stings and bites
Ironbark	*Eucalyptus sideroxylon*	Bark	Wash sores and skin infections
Snake vines	*Tinospora smilacina*	Vine tied around the painful area	Aches, pains, headaches
Desert fuchsia	*Eremophila macdonnellii*	Water from the boiled leaves is mixed with beeswax	Applied to skin for aches and pains
Quandong	*Santalum acuminatum*	Paste made with seeds	Fever
Wild tobacco	*Solanum mauritianum*	Leaves	Burns
Lemongrass	*Cymbopogon citratus*	Boiled leaves	Body wash for skin infections, boils, scabies, colds, fevers
Coolabah tree	*Eucalyptus coolabah*	Boiled bark	Eye infections, cancer-fighting properties
Kakadu or billy goat plum	*Terminalia ferdinandiana*	Boiled fruit	Sores and skin infections
Woolly butt tree	*Eucalyptus miniata*	Boiled bark	Eye infections
Sandpaper fig	*Ficus opposita*	Boiled white inner bark	Diarrhoea and stomach upsets
Tea tree	*Melaleuca sp.*	Boiled leaves	Antiseptic
Gum trees	*Eucalyptus sp.*	Boiled leaves	Antiseptic
Apple bush	*Pteropcaulon sphacelatum*	Boiled leaves Crushed leaves	Cold, flu, antiviral, congestion

Auscape/S Wilby & C Ciantar

© Centre of Australian National Biodiversity Research

imagefolk/CSP_Fitnow

FIGURE 4.2.10 Examples of Australian native plants used for medicinal purposes: (**a**) Bush plum (*Santalum lanceolatum*), (**b**) snake vine (*Tinospora smilacina*) and (**c**) desert fuchsia (*Eremophila macdonnellii*).

There is a lot of crossover in the type of plants used by different Aboriginal communities. The same plants could be used for different illnesses in different regions of Australia. This is due to the wide spread of the communities across regions and the availability of the plants depending on seasonal fluctuations and environmental conditions. This wide range of uses creates a challenge for modern medicine and pharmacologists in narrowing down the research for a particular medicinal plant used to treat or cure a specific illness. For example, in some Indigenous communities, the 'lolly bush' (*Clerodendrum floribundum*) leaves are crushed and boiled and the infusion obtained is used as an antiseptic lotion to

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cure sore, itchy and scaly skin, while other Aboriginal groups drank the infusion as a tea to relieve headaches and severe cases of diarrhoea.

INQUIRING FURTHER

Coolabah trees grow in Far North Queensland. In 2014, scientists discovered that the tree has anti-cancer properties; however, pharmaceutical industries were reluctant to extract the active ingredient. Research the case of the Coolabah tree, its anti-cancer properties and the reasons behind its lack of use in western medicine. Prepare an audiovisual presentation to accompany your research.

Bioharvesting native plants from Country to Place

To be considered for medicinal purposes, plants must have a substance that is biologically active. The pharmaceutical industry calls this the **active ingredient**. Australian native plants are hardy plants due to the dry conditions and extreme heat in many areas. As a result, it can be difficult and sometimes expensive to extract the active ingredients from Australian plants, and therefore many native Australian plants are not used in the modern pharmaceutical industry. As Aboriginal people know how to prepare the plants to expose those active ingredients, their infusions and ointments are effective in helping to treat or avoid illnesses and infections.

active ingredient substance/s present in a plant that is biologically active and it can be extracted for medicinal purposes

Modern medicine has researched many native Australian plants that contain active ingredients, such as the northern black wattle (*Acacia auriculiformis*). This plant has alkaloids that inhibit the growth of infectious bacteria such as *Staphylococcus aureus*, *Streptococcus pyogenes* and *Escherichia coli*. The research on the active ingredient of the northern black wattle was based on the traditional use of the plant leaves as antiseptic.


Auscape/Frank Woerle

FIGURE 4.2.11 Aboriginal communities bioharvesting Kakadu plum.

Bioharvesting is a term used to define the activities involved in collecting living organisms from the natural environment to be used as food or for medicinal purposes. Aboriginal and Torres Strait Islander people have used bioharvesting to provide for their needs for hundreds of years.

Modern medicine is aware of the benefits of many Australian native plants used by Aboriginal communities. However, the bioharvesting from Country to Place to produce medicinal drugs has ethical implications for local Aboriginal and Torres Strait Islander communities. Many Country to Place areas are sacred or have a significant meaning for the local Aboriginal and Torres Strait Islander community, and the knowledge about the use of native plants as traditional medicines is considered to be Indigenous cultural and intellectual property. In addition, and as previously mentioned, due to the nature of the Australian climate and soil composition, many plants are slow to grow and tricky to pollinate, or they are found in small patches of remote areas. Unsustainable bioharvesting of native plants affects the biodiversity and ecological balance of natural native Australian environments. Therefore, before starting the collection from Country to Place, pharmaceutical companies need to consult with the local land council, local elders and Indigenous communities to understand the spiritual and biological value of the area, and reach a consensus as to how the stakeholders will benefit from the bioharvesting in an ethical way.

INQUIRING FURTHER

A partnership created between Mt Romance (an Australian sandalwood company), Aveda (a US-based multinational cosmetics corporation) and the Kutkabubba community (represented by the Songman Circle of Wisdom) has recognised the intellectual property of Aboriginal communities for the use of the sandalwood tree.

Research and write a short article about the use of the sandalwood tree by traditional and modern medicine, and the ethical and legal processes followed by all the stakeholders to reach a consensus about the use of the sandalwood tree and recognise the intellectual property of Aboriginal people.

4.2.16 Indigenous peoples and intellectual property rights

INVESTIGATION 4.2.3

Emu bush – medicinal uses and bioharvesting

4.2.17 A review of the use of *Eremophila*

4.2.18 *Eremophila*, the emu bush

4.2.19 Bush medicine

AIM

To investigate the medicinal use and bioharvesting of emu bush

MATERIALS

The weblinks are secondary sources suggested for this investigation.

PROCEDURE

1. Identify the geographical location of emu bush.
2. Identify the botanical classification of emu bush.
3. Outline all the different medicinal applications of emu bush by different communities across Australia.
4. Describe how emu bush was prepared by local Aboriginal communities to be used as medicinal plant (e.g. infusions, crushed leaves, ointments).
5. Explain how emu bush is bioharvested, include areas, seasons and procedures.
6. Research the active ingredient/s in emu bush that can be used as a potential drug in modern medicine.
7. Contact your local land council to investigate the ethics behind the bioharvesting of emu bush in your local Country to Place.

RESULTS

Create a visual media to be shown to the local communities during NAIDOC week.

DISCUSSION

In your display, present an analysis of:

1. the medicinal uses of emu bush in Aboriginal medicine and modern medicine
2. the ethical implications of bioharvesting emu bush from Country to Place.

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SECTION REVIEW 4.2

REMEMBERING

1 Describe how science and technology are related in a continuous cycle.

2 Detail the impact of science and technology using an example.

3 Describe, using examples, the uses of plants by Aboriginal and Torres Strait Islander people.

UNDERSTANDING

4 Explain how technologies are useful when collecting evidence to support a scientific principle. Give an example.

5 Explain how scientific principles drive the development of new technology. Give an example.

6 Explain the difficulties encountered by the pharmaceutical industry when collecting information from different Aboriginal communities in order to use native plants as medicines.

APPLYING

7 Bt Cotton is a genetic modified cotton plant developed in Australia that is resistant to pests. Assess the scientific principles and technologies that have been applied to develop the genetically modified Bt cotton.

8 Since 1990, the Hubble telescope has orbited Earth collecting information about the cosmos. Assess how this technology contributes to our scientific understanding of the universe.

9 You are the owner of a pharmaceutical company and the latest research tells you that there is a native Australian plant growing in a specific area of the Northern Territory that has the perfect active ingredient to develop an antiseptic cream to use on burns. Discuss a suggested procedure to follow to collect the native plant from Country to Place.

WS

4.2.1 Symbiosis between technologies and science

CHAPTER REVIEW QUESTIONS

REMEMBERING

1 Define 'technology'. Identify some examples.

2 Describe how technologies can limit or enhance scientific advances.

3 Describe the differences between analogue and digital technologies.

4 Identify the types of errors that can happen when using technologies and give examples.

5 Describe the continuous cycle between advances in science and technology.

UNDERSTANDING

6 Discuss the importance of technologies to advances in science.

7 Explain the advantages and disadvantages of using analogue and digital technologies when collecting data in an investigation.

8 Discuss the impact of a new technology on advances in science, using a specific example.

9 Using an example, discuss the impact of knowledge and understanding of scientific principles on the development of technologies.

10 Summarise how Aboriginal and Torres Strait Islanders used native plants as medicine.

11 Discuss the ethical issues of bioharvesting from Country to Place.

APPLYING

12 Temperature affects the rate of a reaction. Design an experiment to test this statement. Explain what technologies you are going to use to collect data and make a risk assessment about the use of those technologies.

13 Temperature and pressure affect the volume of gases. A sample of hydrogen has an initial temperature of 40°C. When the temperature is lowered to –3°C, the volume of hydrogen becomes 180 cm^3. Calculate the initial volume of hydrogen applying Charles' law.

14 The tank of a scuba diver has a capacity of 10 L of compressed oxygen. Research whether the pressure during deep-ocean diving will affect the volume of available oxygen for the diver.

15 A balloon contains 8 L of helium. The pressure is reduced to 2.00 atm and the balloon expands to occupy a volume of 20.3 L. Applying Boyle's law, calculate the initial pressure exerted on the balloon.

16 In a testing tunnel facility, a group of engineers are testing the speed of a hover train. Calculate the speed of the train that travelled 500 m through the tunnel in 12 minutes.

17 A spear fisherman is trying to calculate how the speed that he can throw the spear affects the distance it travels. He tested three different speeds measured over 30 seconds to improve his hunting. Decide what speeds to use to test his spear. Create a table with the results and explain how speed affects the distance that the spear travelled over 30 seconds.

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ANALYSING

18 Choosing the best technologies to use for an investigation is not an easy task. For each of the investigations below, research and justify which technology is best suited to collect the data.

- Effect of temperature on plant growth
- Effect of pressure on oil extraction
- Effect of wind speed on racing car design

19 Discuss what scientific principles helped develop Positron Emission Tomography (PET) scan technology, which detects cancerous tumours in patients with lymphoma, and how the technology helps in the scientific understanding of lymphoma.

20 Eucalyptus oil is one of the major pharmaceutical exports from Australia. Research how the oil is produced and how pharmaceutical companies have overcome ethical issues to collect the plants from Country to Place.

21 Aboriginal Australians have a good knowledge about how to use thermoplastic resins extracted from porcupine grass and grass tree. Research how Aboriginal Australians extract and use thermoplastic resins, and discuss their uses.

SYNTHESISING

22 You are the head of the Academy of Science and a company that provides services for people with disabilities has contacted you. They have asked you to create a simple device to help a person who cannot open their hand properly to hold a spoon to eat. Write a short scientific report to submit to the company.

In your report, write about:

a the technology that you are going to use to create the device

b the scientific principles that you have applied to create it

c the impact that the knowledge of science has on how you have created this device.

23 Write an interview for an Aboriginal or Torres Strait Islander elder to learn and discuss what local plants are available to collect for medicinal purposes from the local Country to Place. If you have the opportunity, record the interview for your NAIDOC week.

EVALUATING

24 Space exploration is a controversial issue. Some people are against it because they argue that the amount of money spent on exploring space would be better used for health and education here on Earth. In class, debate this issue by applying the knowledge learned from this chapter about the impact of technologies on scientific developments.

25 Look at the cartoon (Figure 4.3.1) and evaluate its statement in terms of the following:

- How technology has affected today's society.
- Why did the cartoon say that humans do not change?

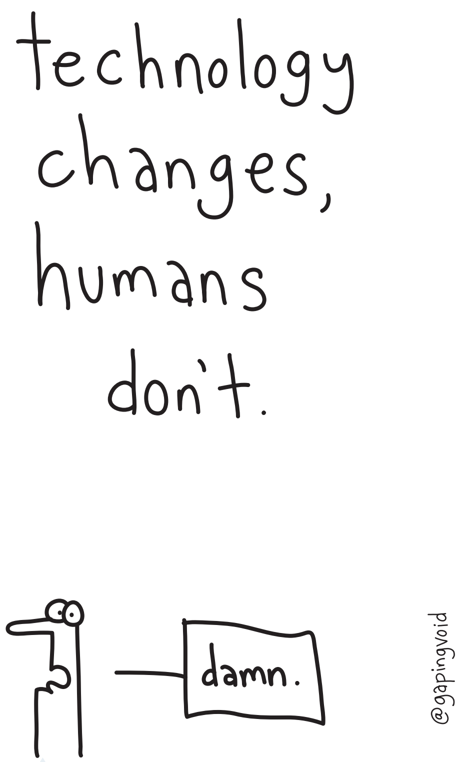

FIGURE 4.3.1 Illustration about the differences between the advances in technology and humans.

DEPTH STUDY
BIOLOGY

MEDICINAL USES OF NATIVE PLANTS

Suggested length: 10 hours including research and submission of visual media

Focus: Analysis of secondary sources, visual media (e.g. video/sway)

WS
4.4.1 Secondary investigation scaffold

SECONDARY-SOURCED INVESTIGATION SCAFFOLD

Syllabus outcome

Write a summary of the syllabus outcome you will be investigating.

Syllabus statement: Investigating the medicinal use of native Australian plants.

Note: You can choose only one plant, or you can investigate different native plants and compare their uses across different areas and communities.

Inquiry question

This is the question you will investigate, analyse and discuss in the investigation. Suggested examples:

- Are all the native Australian plants suitable to be used as medicinal plants?
- What properties or active ingredients in a native Australian plant would be suitable for medicinal use?
- Why are different native Australian plants used for the same medicinal purpose?

Introduction

This is the background information about the topic. In a primary investigation, identify the experiment you will conduct. In a secondary investigation, make sure that your sources are valid.

- Write around 800 words
- Define medicinal plant and describe the botanical characteristics of your chosen plant
- Explain what an active ingredient is, and how it can be identified and extracted
- Explain how pharmaceutical companies create medicines and compare with the methods of Aboriginal Australians

Hypothesis (if applicable)

This is an educated guess as to what will happen in when you relate the independent and dependent variables.

Aim

Write one sentence starting with 'To' followed by a verb; for example, 'investigate', 'measure', 'test' and so on.

To investigate the medicinal use of native Australian plants.

Secondary sources

4.4.1 Top 10 Aboriginal bush medicines

4.4.2 Bush medicine – Aboriginal remedies for common ills

4.4.3 Aboriginal plant use in south-eastern Australia

List all of the sources used and cite them using the correct protocols. See weblinks for suggested references:

- Sultanbawa, Y. & Sultanbawa F. (2016), *Australian Native Plants: Cultivation and uses in the health and food industries,* CRC Press Publisher.
- Australian Institute of Aboriginal and Torres Strait Islander Studies (2017), Publications.
- Australian National Botanic Gardens educational services (2000), *Aboriginal Bush Medicine.*

Investigation design

Outline how you will design the final presentation of your information.

»

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SECONDARY-SOURCED INVESTIGATION SCAFFOLD

Procedure

These are numbered steps. Each sentence must start with a verb. For example:

1 Choose one or more Australian medicinal native plants to compare. Some examples are emu bush (*Eremophila sp.*), Kakadu plum (*erminalia ferdinandiana*), snake vine (inospora smilacina), sandpaper fig (*Ficus opposita*), *goat's foot* (*Ipomoea pes-caprae*).
2 Research the botanical characteristics of the plant/s and geographical distribution across Australia.
3 Research all the different medicinal uses across different communities and regions.
4 Explain how the plant is prepared for medicinal use (e.g. infusing, crushing or leaching).
5 Compile all the medicinal uses and analyse common patterns and trends.
6 Investigate the active ingredient in the plant and discuss whether the ingredient can be produced to create a new medicine.
7 Analyse ethical issues in relation to bioharvesting the plant from Country to Place.

It would be beneficial if you can liaise with a local Aboriginal community, elders or the local Land Council to do this research.

Results

These could be recorded in tables, graphs, observations in sentences, interviews with local Aboriginal elders.

Validity and reliability

Validity means the sources are from reputable education, government or scientific websites, journals and textbooks.

Reliability means a similar explanation of the concepts is evident in and collected across many sources

Discussion and conclusion

Analyse your findings to answer your hypothesis, aim and inquiry question/s.

DEPTH STUDY
CHEMISTRY

ORGANIC POLYMERS

Suggested length: 10 hours including research and submission of report

Focus: Primary investigation, scientific report

WS 4.5.1 Primary investigation scaffold

PRIMARY INVESTIGATION SCAFFOLD

Syllabus outcome

Write a summary of the syllabus outcome you will be investigating.

Syllabus statement: Production of a polymer (organic or/and inorganic) to test the effect of temperature on reaction rate.

Inquiry question

This is the question that you have to investigate, analyse and discuss in the investigation, such as the following.

- How does temperature affect the formation of a polymer?
- How are the properties of a polymer affected by temperature?
- What polymers are more affected by temperature?

Introduction

This is the background information about the topic to investigate. In a primary investigation, identify the experiment you will conduct. In a secondary investigation, make sure that your sources are valid.

- Write around 800 words
- Define polymers and explain how they are created
- Describe your chosen polymer and how it is produced; include chemical formulas and diagrams

Hypothesis (if applicable)

This is an educated guess as to what will happen when you relate the independent and dependent variables.

Aim

Write one sentence starting with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on.

To investigate the formation of a polymer (organic or/and inorganic) under different temperatures.

Investigation design

Outline how you will design the final presentation of your information. Include the following in your design:

- independent, dependent and controlled variables
- control and treatments
- diagrams of experimental apparatus, if needed.

Procedure

Write the procedure in numbered steps. Start each sentence with a verb, as shown below.

1 Choose a polymer (organic/inorganic or both to compare).
2 Perform experiments to test the effect of different temperatures on the formation and properties of your chosen polymer.
3 Write a log book with your research and experimentation.
4 Measure the temperature with thermometers and data loggers to compare technologies.
5 Record your results in tables, observations and graphs.
6 Analyse your results and write a scientific report.

»

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PRIMARY INVESTIGATION SCAFFOLD

Results

The results may be recorded in tables or graphs, or written as observations in sentence form.

Validity and reliability

Validity is related to the procedure and equipment used to perform your experiment, while reliability is ensured by repeating the experiment to confirm similar results and reduce the chance of errors.

Discussion and conclusion

Analyse your findings to answer your hypothesis, aim and inquiry question/s.

Secondary sources

List all sources you have used and cite them using the correct protocols. See weblinks for suggested references:

- CHM130 Organic lab, (2017) 'Organic polymers, the synthesis of nylon'.
- Brewer, J. (2017) *A silly polymer*. University of Illinois, MAST.
- 'Experiment. Polymers' (2017), Materials of Engineering Laboratory, LSU.
- Polymer Chemistry group (2017) Projects (2017) The University of Queensland.

4.5.1 Organic polymers, the synthesis of nylon
4.5.2 A silly polymer
4.5.3 Experiment – polymers
4.5.4 Polymer chemistry group – projects

DEPTH STUDY
PHYSICS

BOOMERANGS AND SPEED

Suggested length: 10 hours including research and submission of video to be presented to the community during NAIDOC week

Focus: Primary investigation, video

WS 4.6.1 Primary investigation scaffold

PRIMARY INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating.
Syllabus statement: Changes of speed on distance travelled.

Inquiry question

This is the question you will investigate, analyse and discuss in the investigation. For example:

- How does the shape of the boomerang affect the speed and distance travelled?
- How does the force applied when throwing a boomerang affect the speed and distance travelled?
- Why does the shape of the boomerang affect the speed and distance travelled?

Introduction

This is the background information about the topic to investigate. In a primary investigation, identify the experiment you will conduct. In a secondary investigation, make sure that your sources are valid.

- Write around 800 words
- Define speed and explain how speed affects distance travelled by different objects, include formulas
- Describe what a boomerang is and how Aboriginal people use it
- Explain the physics behind throwing boomerangs, include diagrams and formulas

Hypothesis (if applicable)

This is an educated guess as to what is going to happen in your investigation relating the independent and dependent variables.

Aim

Write one sentence starting with 'To' followed by a verb; for example, 'investigate', 'measure', 'test' and so on.

To investigate the … (related to your inquiry question)

Investigation design

Outline how you will design the final presentation of your information. Include the following in your design:

- independent, dependent and controlled variables
- control and treatments
- diagrams of experimental apparatus if needed.

Procedure

Write the procedure in numbered steps. Each sentence must start with a verb; for example:

1 Select two or more different types of boomerangs to investigate.
2 Consult with an Aboriginal elder about how boomerangs are made and the throwing techniques.
3 Set up relevant equipment to measure speed and distance. (Write detailed steps of how you will do this).

»

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PRIMARY INVESTIGATION SCAFFOLD

Results

The results may be recorded in tables or graphs, or written as observations in sentence form.

Validity and reliability

Validity is related to the procedure and equipment used to perform your experiment, and reliability is associated with repeating the experiment to confirm similar results and reduce error.

Discussion and conclusion

Analyse your findings to answer your hypothesis, aim and inquiry question/s.

Secondary sources

Lis all sources used and cite them using the correct protocols. See weblinks for suggested references:

- Nave, R. (2017), *Boomerangs*, Hyperphysics
- 4Physics (2012), Why does a returning boomerang come back?
- Boomerang Association of Australia (2017), How to throw a boomerang.

4.6.1 Boomerangs as vector rotation

4.6.2 What makes a boomerang come back?

4.6.3 Boomerang physics 101

DEPTH STUDY
INVESTIGATING SCIENCE

AUSTRALIA'S GEOLOGICAL HISTORY

Suggested length: 10 hours including research and submission of data analysis report

Focus: Analysis of data from secondary sources

WS 4.7.1 Secondary-source investigation scaffold

SECONDARY INVESTIGATION SCAFFOLD

Syllabus outcome

Write a summary of the syllabus outcome you will be investigating.

Syllabus statement: Analysis of technologies to collect data that support evidence about Australia's geological history.

Inquiry question

A question that you have to investigate, analyse and discuss in the investigation, such as:

- How did scientists use different technologies to collect evidence about the geological history of Australia from the past to today?
- Using different technologies, what type of evidence did scientists collect about the geological history of Australia?
- What technologies have had a major impact in collecting evidence on the geological history of Australia?

Introduction

This is the background information about the topic being investigated. In a primary investigation, identify the experiment you will conduct. In a secondary investigation, make sure that your sources are valid.

Suggested points:

- write around 800 words
- describe the Australia continent geologically
- explain the movement of the Australian plate
- describe the technologies use to collect evidence about Australia's geological history

Hypothesis (if applicable)

This is an educated guess as to what is going to happen in your investigation when relating the independent and dependent variables.

Aim

Write one sentence starting with 'To' followed by a verb such as 'investigate', 'measure', or 'test'. For example:

To analyse the technologies used to collect data that support evidence about Australia's geological history.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested resources:

- Struckmeyer, H. & Totterdell, J. (1990), *Australia – Evolution of a Continent,* Geoscience Australia.
- Geoscience Australia (2017), Australian landforms and their history.
- CSIRO (2017), Big data for Earth sciences.
- Virtual Geophysics Laboratory (2017), Nectar Group. National Research Infrastructure for Australia.

Investigation design

Outline how you will design the final presentation of your information.

»

4.7.1 *BMR Journal of Australian Geology & Geophysics*

4.7.2 Australia's fossil past

4.7.3 Australian landforms and their history

4.7.4 Landforms

4.7.5 Big data for Earth sciences

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» SECONDARY INVESTIGATION SCAFFOLD

Procedure

Write the prodedure in numbered steps, with each sentence starting with verb. For example:

1 Choose two or more technologies used to collect geological data, one used in the past and one currently.
2 Research the type of data that each technology collects and how that data supports the evidence for Australia's geological history. Include maps and data tables comparing the technologies and types of evidence.
3 Discuss and analyse your collection of evidence to compare the technologies.

Results

The results may be recorded in tables or graphs, or written as observations in sentence form.

Validity and reliability

Validity is related to using sources from reputable education, government or scientific websites, journals and textbooks. Reliability means a similar explanation of the concepts is evident in and collected across many sources.

Discussion and conclusion

Analyse your findings to answer your hypothesis, aim and inquiry question/s.

5

MODULE 7 FACT OR FALLACY?

American scientist and sceptic, Michael Shermer, is credited with saying, 'Science is the best tool ever devised for understanding how the world works'.

Indeed, the application of science has helped society make tremendous advances, particularly in the last 300 years. However, as Shermer states, science is a tool that is ultimately used by humans and, as such, is only as good as the humans who wield it. For this reason, the scientific process has numerous conventions to compensate for the inevitable errors, misrepresentations and occasional frauds that result from human failings.

INQUIRY QUESTIONS

- How can a claim be tested?
- What factors can affect the way data can be interpreted, analysed and understood?
- What type of evidence is needed to draw valid conclusions?
- How does the reporting of science influence the public's understanding of the subject?
- Can the scientific community and the process of peer review find 'the truth'?

CONTENT

Students investigate:

- Testing claims
- Impacts on investigations
- Evidence-based analysis
- Reading between the lines
- Science as self-correcting – the issues

OUTCOMES

A student:

- selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media INS11/12-4
- analyses and evaluates primary and secondary data and information INS11/12-5
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes INS11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose INS11/12-7
- uses evidence-based analysis in a scientific investigation to support or refute a hypothesis INS12-14

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Getty Images/Moment/Busakorn Pongparnit

5.1 Testing claims

Claims of 'truth'

Every day we are confronted by claims, propositions and statements that the media, educational institutions, the healthcare system, the church, the law, our community and our family and friends understand to be **true**. However, when we examine and compare these claims by various individuals and institutions in detail, there invariably are different interpretations and even **contradictions** regarding what people believe to be true. This means making informed decision can be difficult because it becomes impossible to be certain that the information provided is a reflection of reality or a misguided belief.

true
a depiction of a phenomena that conforms to or reflects reality

contradiction
a statement or depiction that is inconsistent and does not adhere to logic when compared to one or more other statements or depictions

flickr/Brett Jordan

FIGURE 5.1.1 Just like the buttons above, working out which claim to 'truth' is real can be exceptionally difficult when two or more contradictory claims are made.

This is where science comes in, as a primary purpose of the scientific process is to understand, with as much validity as is possible, what the truth of the world really is. The scientific process is the best tool we have to test and evaluate claims on the truth. Consequently, science can be thought of as a discourse, or discussion, conducted by scientists over time and around the world, as they investigate phenomena and make claims and counter claims on what the truth really is. The eventual outcome of this is discourse is that it allows individuals, communities, institutions and governments to make decisions on the most accurate information available in order to promote progress and, hopefully, benefit society as a whole.

5.1.1 Science aims to explain and understand

5.1.2 Swallowing it: how Australians are spending billions on unproven vitamins and supplements

5.1.3 No rust bust: warning re car rust reduction devices

5.1.4 Heart of the matter

WS

5.1.1 Testing claims

INQUIRING FURTHER

It is common to find contradictory claims to truth in the wider society. Often these claims are controversial, as different parties try to assert the validity of their claim. As such, the public is exposed to mixed messages on the issues and this means making an informed decision can be difficult.

Examples of this include the effectiveness of vitamin supplements, the use of computerised electronic corrosion inhibitors (CECI devices) for motor vehicles, the effectiveness of cholesterol medication for treating heart disease and the role of sugar in weight gain. Research details on the conflicting claims around these products using the weblinks provided.

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INVESTIGATION 5.1.1

Testing a claim

Every day we are confronted by different claims; for example, that insects only live for 24 hours, or that one cleaning product is superior to another. If we do not investigate these claims, they can spread quickly. Accepting a claim at face value can be detrimental, especially when it affects people's lives. For this reason, scientists often test claims to determine their validity and reliability.

AIM

To conduct an investigation to test a common claim and determine its validity. Choose an investigation from *one* of the following points or create your own.

- House flies only live for 24 hours
- Water conducts electricity
- Diamond is the hardest mineral
- pH indicators change colour at a pH of 7

MATERIALS

Relevant equipment and secondary sources to conduct the investigation. Be sure to do a risk assessment on any materials that have an associated risk.

PROCEDURE

1. Make a prediction and propose a hypothesis based upon an inference about the selected claim.
2. Plan and conduct an investigation on the selected claim. You should consider validity, reliability and sources of error by:
    - a. controlling the variables
    - b. making use of control groups
    - c. selecting appropriate sample sizes
    - d. repeating the experiment to confirm results
    - e. confirming measurement and observational accuracy.

    (See Chapters 1 and 2 for further details.)
3. Conduct a secondary-source investigation on the claim to verify the accuracy of your investigation.

RESULTS

Analyse the data and compare the results with the prediction and the proposed hypothesis.

DISCUSSION

1. Outline and justify the methods used to ensure the investigation was valid.
2. Describe the ways the investigation could be improved to increase its validity.
3. Outline and justify the methods used to ensure the investigation was reliable.
4. Describe the ways the investigation could be improved to increase its reliability.
5. Describe the possible sources of error in this investigation, both random and systematic.
6. Discuss how errors can be accounted for in a report on a scientific investigation.

The influence of sample selection and sample size

There are a number of ways that a scientist can inadvertently distort or bias the results they obtain from their data through the way they select the sample used in the investigation. This has important implications if scientists are trying to collect data and draw conclusions that are based on a true representation of the world. The two most common ways in which sampling error can be introduced is inappropriate sample selection and poor sample size, both of which can lead to the increased chance of random effects caused by an inadequate sampling protocol.

Sample bias

sample bias
is the tendency to under or over represent a particular group within the sample population

Sample bias is an important consideration when determining the validity of an investigation. Sample bias can occur if the scientist or researcher fails to consider whether the sample they are examining is truly representative of the population they wish to investigate. Typically, such biases are inadvertent and not something that the scientist or researcher is consciously aware of, however, such biases do have implications for the validity and reliability of the investigations conclusion.

For example, Ashish wants to investigate the inquiry question 'How does the concentration of salt in the soil affect the growth of wheat plants?' Ashish gathers 20 large planting trays, fills them with identical soil and sets about planting out the trays with 20 wheat seeds in each before watering with various concentrations of salt water. However, Ashish has inadvertently selected a variety of wheat that has been bred to be salt resistant. Consequently, when Ashish presents his results, the levels of salt tolerance are greater than if Ashish had selected a mixed sample of wheat seeds. Unfortunately, Ashish's work could create problems if someone wants to use his results to determine if they can grow wheat in their salt-affected soil. Such a sample bias is likely to see the crop fail.

convenience sampling
a sample that is used in an investigation primarily because it is the most readily available sample that the investigator can access

voluntary response samples
a sample (most commonly of people) that is investigated because they are willing to take part in the investigation

The University of Adelaide

FIGURE 5.1.2 Agronomists go to significant lengths to eliminate sample bias by planting growth trails of various crops and varieties in different conditions. The above image is of a growth trial of a number of varieties of wheat and barley grown in salt-affected soils.

The above example with Ashish is most likely to have been caused by **convenience sampling**, which occurs because the sample selected is the most readily available to the researcher. In Ashish's case, it is likely the seed used was the first available wheat seed he found. Another example of sample bias is **voluntary response samples**, which are common to investigations that involve volunteers. These tend to be biased towards people from a particular demographic who are more willing to participate in surveys and experimental trials; for example, middle class people who speak English as their first language.

It is not always possible to eliminate sample bias in an investigation, what is more important, however, is that the scientist acknowledges these possible sources of sample bias when they report their results so that those reading the report can make informed decisions with this in mind.

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Sample size

Sample size is an important consideration when determining the reliability of an investigation. Problems with sample size typically arise when the sample size is too small to eliminate random chance from swaying the results.

An example of this is demonstrated by tossing a coin to determine the chances of it landing heads or tails. If the coin is only tossed 10 times, random chance may produce a result that sees the coin land eight times on heads and only two on tails. From this, we could easily conclude that when a coin is tossed there is an 80 per cent chance that it will land on heads. However, if we increase the sample size to 1000 tosses instead of 10, it becomes far more likely that we will see a more reliable result of a 50 per cent chance of getting a head or tail.

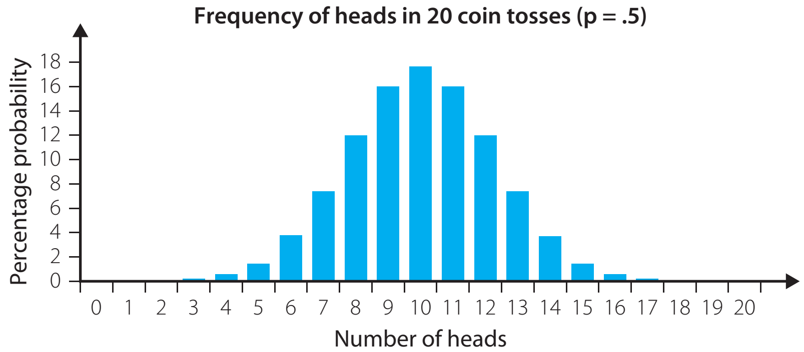

FIGURE 5.1.3 Statistically, if a coin is tossed 20 times, random chance will mean that 14 heads will be tossed 4 per cent of the time. This type of random variation has implications for determining the reliability of an investigation.

5.1.5 Sample size calculator

Consequently, the greater the sample size, the more reliable the results are likely to be. However, collecting results for large samples is extremely time consuming and often costly, so scientists need to predict which sample size will be large enough to produce reliable results, while eliminating unnecessary sampling that would only confirm the data already obtained.

Determining optimum sample size typically depends on the **confidence level** and **confidence interval** that the researcher determines they need to obtain a reliable result. Typically, the confidence level is set at 95 per cent, this indicates that if the investigation was conducted on another random sample, then the results would be comparable to the real population 95 per cent of the time. The confidence interval is expressed as a value, with an associated margin of error that reflects the results of the investigation. A sample size calculator is often used to determine how large a sample needs to be to meet these required reliability thresholds.

confidence level expressed as a percentage likelihood that a repeated investigation on a random sample will produce a comparable result

confidence interval a value, with an associated margin of error, that indicates the range in which a random sample from the population is likely to fall into for a given measure or treatment

Truth in advertising

It is not uncommon for science and advertising claims to contradict each other. The primary reason is that these fields have different purposes. The purpose of science, it can be argued, is to develop an understanding of the truth of the world and empower people to make informed decisions, while the purpose of advertising is to persuade a potential customer to purchase a good or service. For this reason, advertisers employ a variety of different techniques, some of which take advantage of innate human biases and vulnerabilities, to persuade customers to purchase their products. However, by testing advertiser's claims using the scientific process, it is possible to become aware of such biases and vulnerabilities and determine the real merits of a product sold in the market.

INVESTIGATION 5.1.2

Claims in advertising

One of the most common places to find a claim on the merits of a product is in advertising, which aims to persuade consumers to purchase a product or service. Some claims are not necessarily based on evidence but instead on techniques that influence consumer's emotions. Recognising these elements in advertising can help consumers make more informed decisions when selecting products that will meet their needs.

efficacy the ability of a product or process to produce a desired result

AIM

To compare evidence-based research on a product/s against the claims made in advertising. Choose an investigation from the following options.

- A food product that makes a health claim on its packaging
- A consumer product that makes a claim to **efficacy** when compared to similar products (detergents, face creams and toothpastes are often suitable)

MATERIALS

- Relevant equipment and secondary sources to conduct the investigation.
- Be sure to do a risk assessment on any materials that have an associated risk.

PROCEDURE

1. Examine the language used in the advertiser's claims to encourage consumers to purchase the food or product.
2. Plan and conduct a scientific investigation to verify the advertising claim using either first-hand or secondary sources about the food or product.

RESULTS

Analyse the data and compare the accuracy of the advertising claim made when compared to the scientific evidence.

DISCUSSION

1. Describe the nature and detail of the information provided in the advertising of the food or product.
2. Describe what information is missing or misrepresented when comparing the advertising claims with the information obtained via the scientific investigation.
3. Analyse the possible reasons why advertising claims may not be as informative as they could be.
4. Suggest ways in which advertising can be regulated to provide consumers with the information they need to make informed choices.

Alamy Stock Photo / studiomode

FIGURE 5.1.4 Food products such as breads and cereals are promoted by saying they are high in fibre, to attract health-conscious consumers. However, claims of 'high fibre' are sometimes only valid when compared with another product and may not be high enough to meet dietary requirements.

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SECTION REVIEW

5.1

REMEMBERING

1 Describe two ways in which a scientist may inadvertently bias the sample used in their investigation.

UNDERSTANDING

2 Using an example, explain how increasing sample size in a study can increase the reliability of an investigation's results.

3 Figure 5.1.5 is a representation of confidence interval for an investigation. Explain why the confidence interval is important for obtaining reliable results.

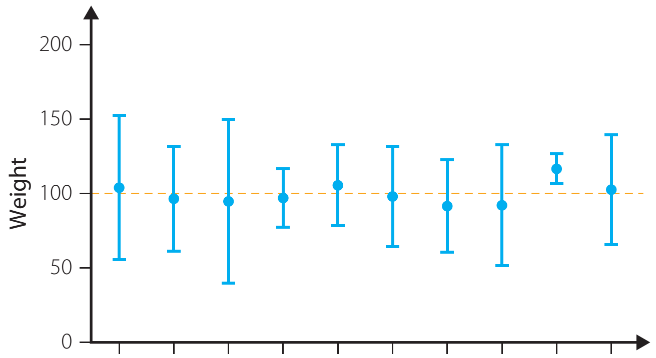


FIGURE 5.1.5 The confidence interval of representative samples around a mean weight of 100.

APPLYING

4 The image in Figure 5.1.6 is similar to one commonly used on food packaging to advertise their product as healthier and safer for consumers than a competitive brand. From your findings from Investigation 5.1.2, explain how such branding may be making a claim that is not necessarily supported by empirical scientific evidence.

5 If you were going to investigate the question 'how does resting heart rate differ with age among male humans?', justify the number and type of participants you would select as a sample to obtain reliable and valid results for the investigation?

FIGURE 5.1.6 An example of GMO-free labelling that can be found on many food products claiming to be healthier and safer for consumers.

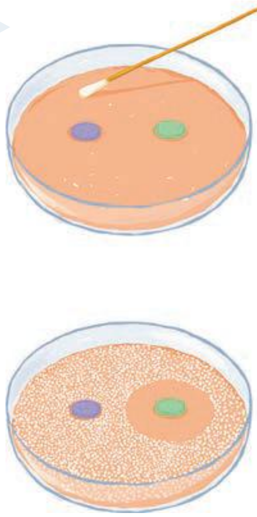
5.2 Impacts on investigations

Controlling for bias

When reading a scientific report, it can often be confusing as to why a scientist would go to such lengths to carefully manage and control not only the methods they use but their research subjects as well. A closer analysis of the techniques they use, however, will typically illustrate that the scientist is trying to eliminate possible sources of error that could inadvertently bias the results. For this reason, scientists use a number of techniques to reduce the chance of bias.

Control groups

control group
the group in an investigation that is used as a benchmark in comparison to a second group that receives a prescribed treatment



Alamy Stock Photo/BSIP SA

FIGURE 5.2.1 The green dot represents a small piece of filter paper soaked in an antibiotic treatment. The purple is the control and would normally just be soaked in distilled water. After incubating the bacteria the efficacy of the antibiotic treatment can be compared to the control.

Control groups enable a scientist to determine whether a particular treatment or process applied to a sample group actually has an effect or whether a change in a variable is the result of random circumstances. In an investigation that makes use of control groups, two identical (or statistically identical) groups are set up under the same conditions. One group is then exposed to the treatment variable while the other group is not. The researcher then studies the difference between these two groups to determine the effect of the treatment when compared to the normal conditions. Without a control group to compare with, a scientist may think there is a greater or lesser effect than there actually is.

Control groups are primarily used in an investigation that seeks to determine the efficacy of a treatment. An example of this would be a scientist who wishes to determine the effect of a potential antibiotic in treating a bacterial disease. The researcher would set up two groups of petri dishes with colonies of the bacterial disease growing on them and then would apply the antibiotics on one colony, while leaving the control group petri dish untreated. After incubating both groups of petri dishes under the same conditions, the scientist could compare them to determine the efficacy of the antibiotic.

INQUIRING FURTHER

Another example of a control group investigation is examining the effect that a catalyst, such as potassium iodide, has on the decomposition of hydrogen peroxide. Design a controlled investigation that compares the effect of potassium iodide on hydrogen peroxide.

pharmacological
the characteristics and properties of a drug that make it medically effective

placebo
a medicine or procedure that has no therapeutic effect

Alamy Stock Photo/Peter Hermes Furian

FIGURE 5.2.2 Placebo, also known as sugar pills, are given to participants in the control group of a medical drug trial.

Placebos

In the 18th century, a number of doctors noted that prescribing an inert or **pharmacologically** mild 'medicine' often had a positive impact on a patient's health and wellbeing. The physicians concluded that simply prescribing a medication could increase a patient's expectations of feeling better, and this had subsequent physiological effects that helped the patient's overall health improve even though the medicine was inert. These false treatments were named **placebos** which is Latin for 'I shall please.'

Today placebos are commonly used in trials for medical treatments and variations of placebos are often used in experimental trials that have human subjects. This is because it is impossible to make a person unaware that they are participating in an experimental trial, particularly if they have to take a tablet or modify their behaviour in some way. Because participants are aware they are part of an investigation, they have a tendency to expect some sort of effect. Consequently, the mere expectation of this effect can result in the supposed

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effect being overreported and, in extreme cases, can result in physiological changes even when no active treatment is given. This is known as the placebo effect.

For this reason, scientists conducting human trials need to account for this effect, which can bias the results. They do so by giving one group in the trial the true treatment and a second group, the control group, a placebo. They can then compare the two groups to see if any reported effects from the true treatment group actually measured above the 'noise' or false positives of the placebo control group. If they do, then a scientist can be reasonably confident that the drug or experimental treatment is producing the effects observed.

5.2.1 A history of the placebo

5.2.2 The placebo phenomenon

INQUIRING FURTHER

The placebo effect is well documented and scientists go to considerable lengths to control for its effect in their investigations. However, the cause of the placebo effect is only now starting to be uncovered. Professor Ted Kaptchuk has been investigating the causes behind the placebo effect for 20 years and is getting close to the answer. Research his findings and write a report on his work.

Double-blind trials

When conducting research on humans, particularly in medical research, the research scientist often has to talk to research participants. This can create a problem, particularly if the researcher has an expectation about what the investigation outcome should be. This is because the researcher's own expectations could bias their interpretation of the results and, in extreme cases, their reactions and body language could give away their expectation of the results to the participant.

For this reason, scientists and researchers conduct **double-blind trials**, where even the administrator is unaware of the treatment a particular participant will receive. Such investigations are considered the gold standard in experimental research and are commonly used in medical research as they have the best chance of eliminating the administrator's own biases.

double-blind trials an experimental technique in which neither the participants nor the researcher in contact with them are aware of who is receiving the treatment and who gets the control

Another version of a double-blind trial is now starting to even be used in law enforcement where eye witnesses are asked to identify a potential perpetrator. In such incidences, the participant is typically shown a line-up to see if they can identify the perpetrator but in these incidences the police officer or legal representative who is with the witness during the identification process is equally unaware of whom the perpetrator in the line-up may be. This way their body language cannot be used as a means of 'tipping off' the witness to the prime suspect.

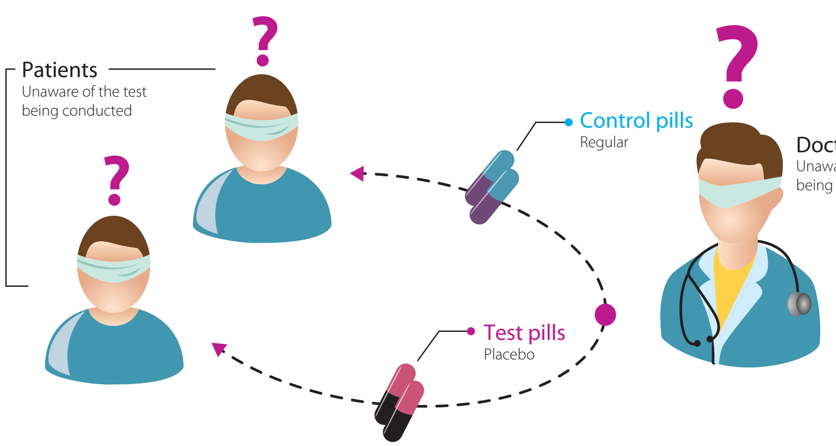

FIGURE 5.2.3 In double-blind trials neither the participants nor the researcher in contact with them are aware of who is receiving the treatment and who is receiving the control.

INQUIRING FURTHER

Double-blind trials are not just used in medicine and law enforcement; they are also often used to conduct taste tests in the food industry. This is done by removing the labels from the food or beverage product and having a research collaborator, who is unaware of which product is which, provide the research participants with the food. This process helps determine which food product customers prefer based on taste alone. Conduct your own double-blind trials to test for the most favoured recipe produced by a range of different companies/brands.

Introducing bias

The scientists conducting investigations are not robots; they are real people with real lives. They have their own beliefs about the world, they have been raised in a particular culture and they need to earn a living. This means that scientists are not only swayed by the findings of their investigations, but also by the social and economic factors that influence their lives. This can and does tend to introduce bias in the analysis and interpretation of the results, as well as the subsequent conclusions and generalisation that they make.

These influences have been seen to have an effect on the findings of scientists in a number of areas.

Seeing variation in the climate

In 1938, Guy Stewart Callendar presented a research paper to the Royal Meteorological Society on his analysis of the carbon dioxide measurements he had been taking (combined with work of other scientists). This revealed a global rise in temperatures of 0.3°C, which he attributed to the burning of fossil fuels over the previous 50 years. At the time of Callendar's submission, climate scientists were more interested in what caused ice ages than the apparent impact of a climate shift that caused temperatures to rise. If Callendar's work was not dismissed as inconclusive, it was welcomed as a means of limiting the threat of a potential ice age.

Photo from the Archives of the Rosenstiel School of Marine and Atmospheric Science, University of Miami

FIGURE 5.2.4 Though well renowned for his work on past climates, time and increasing temperatures have shown that Cesare Emiliani misinterpreted the mid-20th-century cooling period.

5.2.3 The discovery of global warming

5.2.4 The history of change science

Research continued and J. Murray Mitchell reported a cooling period between the 1940s and the 1960s despite increasing build-up of CO_2 as measured by Charles David Keeling. Though Mitchell urged caution in interpreting these temperatures, in 1966, renowned climatologist Cesare Emiliani predicted that a new glaciation would begin. Emiliani likely made the prediction because he was influenced by the years he had spent researching paleoclimates with a particular focus on ice ages. His interpretation of the data was likely biased by his own personal and sociological experience.

Today, climate change, with an increase in average global temperatures, is attributed to the release of CO_2 from the burning of fossils fuels and has a 95 per cent or greater level of consensus among climate scientists. The mid-20th-century 'cooling' phase is recognised by climate scientists as a pause in an overall trend of increasing temperatures.

INQUIRING FURTHER

The path to reaching a scientific consensus on climate change was not a smooth one. The research data was often incomplete, subject to interpretation and wider social influences for a considerable period. Plot a timeline of the major events in the history of climate change science.

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Bias in medicine

Humans have a natural tendency to classify things; for example, a look out a window may reveal numerous individual living things with trunks and leaves all with slightly different shapes and forms, but we have no problem collectively identifying them as trees. Doing this is like taking a mental shortcut, a way of quickly identifying objects in our environment without the need to identify them individually.

Unfortunately, this process tends to carry over when it comes to people. Research indicates that this process of classifying objects tends to extend to the unconscious classification of people in the form of **stereotyping**. This presents a problem, particularly in the medical profession where doctors, healthcare professionals and medical scientists have to make recommendations for health conditions affecting a wide range of people. The results of such stereotype biases are clear, with studies indicating that racial minorities and women are more likely to have delayed diagnoses and treatment, and higher mortality rates despite the relatively equal prevalence of a disease in the population.

The primary reason for this is cited as the **observer-expectancy effect**. This is the idea that the biases of the researcher or the individual making a judgement on the quality of a performance, behaviour or effect can lead to an inaccurate assessment of the data. A famous experiment by Robert Rosenthal asked students to rate the performance of rats negotiating a maze. There was no difference in the rats; however, before running the maze, the students were told that one group of rats were 'very bright' and the others just normal. The results were significant, as the students consistently rated the 'very bright' rats better than the other rats – when in reality there was no noticeable difference between the two groups. These same phenomena are often given as the reason why stereotypes can have such a negative effect in medicine.

Alamy Stock Photo/Rai Toone

FIGURE 5.2.5 Overcoming cultural stereotypes in medicine is one part of the solution for closing the gap in Aboriginal health outcomes. Medical students and current medical practitioners are being made more aware of how cultural bias can influence their treatment of Indigenous patients.

stereotyping the process of classifying someone (or something) on the basis of superficial characteristics and attributing generalisations to all individuals that fit within the bounds of that classification

observer-expectancy effect an effect in which an individual making a judgement on the presented data is inadvertently biased by their own preconceptions of the subject to be judged

5.2.5 Implicit bias in health care

5.2.6 Where bias begins: the truth about stereotypes

INQUIRING FURTHER

Design your own investigation to examine the observer-expectancy effect. You may wish to use snails in a maze, much like Rosenthal did. Another idea would be to find a range of images of people wearing different clothing, ranging from shabby to professional, and ask your participants to match their images with a randomly generated set of IQ results.

Another form of bias in medicine is the result of **survivor selection**. This bias occurs in observational medical research studies, where patients who live longer are more likely to receive a wider range of treatments when compared to patients that die earlier. The result is that in a random group of patients only those that survive longer are likely to receive a trial treatment and have their treatment assessed. This can inadvertently bias the outcomes and may lead to a treatment being recommended for future patients, even though it has minimal effectiveness.

survivor selection a research phenomenon where not all participants who begin a longitudinal study complete it. For this reason, incomplete data on participants is removed to maintain the integrity of the study

calibrated
to have correlated the readings of an instrument against that of a known standard to ensure the accuracy of the instrument

ideology
a set of beliefs and ideas, both conscious and unconscious, that an individual or group of individuals, have in relation to the way the world works. Also referred to as a worldview

Bias in statistics

There are a number of ways in which statistics can consciously or unconsciously be biased. These are in the collection, analysis and presentation phases of statistical research.

Collection

The most common form of bias in the collection phase of statistics is the results of sample bias. Issues such as convenience sampling, voluntary selection sampling and survivor selection may means that a representative sample of the population has not been obtained. The result is that the sample is biased in favour of the group most prevalent in the sample and not the true population.

Another problem in data collection stems from a bias in the collection technique used. Equipment that is incorrectly calibrated will consistently show a bias in a particular direction. This is often easily corrected when using physical instruments such as a pH meter. However, more serious issues can happen when using questionnaires or observational techniques, which can be biased in a particular direction according to the beliefs and ideologies of the person who wrote the questions or did the observation. One example of this is the use of IQ tests to measure intelligence. Such tests have often been found to favour particular groups within a population simply through the design of the questions. For example, IQ tests written in English will automatically disadvantage people from non-English-speaking backgrounds.

TABLE 5.2.1 The recorded number of eggs laid by 11 breeding pairs of swift parrot.

BREEDING PAIR	NO. EGGS LAID
1	2
2	6
3	3
4	3
5	3
6	2
7	7
8	2
9	3
10	2
11	2

Analysis

Statistical data can be analysed in a myriad of ways and often the techniques used are dependent on the type of information the researcher wants to find. Take, for example, a hypothetical data set of the number of eggs laid in breeding pairs of swift parrots in a given area.

The arithmetic mean (or average) of the number of eggs laid would be 3.1, yet 5 of the 11 breeding pairs only laid two eggs, while 2 of the 11 laid much more than five eggs. The result is that breeding pair 2 and 7 have skewed the mean higher, so it does not necessarily represent the number of eggs that the majority of swift parrots lay.

Another option would be to use the median. This is the middle value of all the data. In case of the number of eggs laid the median would be three.

The final option would be to use the mode. This is the most common value recorded. In the above case, this would be two.

Such differences in the analysis may seem inconsequential at first glance, but their implications must be placed into context. Swift parrots breed in nesting hollows, with the best hollows having the most dominant pairs, who often lay more eggs. If only the mean number of eggs were taken into account, then it may appear reasonable to support logging in the breeding area as the birds are laying enough eggs to both replace and grow the population. However, if the two nest hollows of pairs 2 and 7 were eliminated, this would significantly affect the breeding potential of the population as it would force the dominant pairs into poorer quality nesting hollows. This means they will likely lay fewer eggs and will prevent the lower dominance pairs from laying at all due to being evicted by more dominant pairs.

mean
a central tendency within the range of a data set, calculated by adding all the values in a data set and dividing by the number of values

median
the central value within the range of a data set; a value that is generally determined by having an equal number of values from the data set on each side (larger data samples and group frequencies make this calculation more complex)

mode
the most common value recorded within the range of a data set

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When we look at the issue in this light, using the mode number of eggs laid would be best when making decisions regarding the protection of this endangered species and would necessitate a recommendation against logging. The statistical technique we use to analyse a problem can have significant effects on the decisions we make.

Presentation

How statistical data is presented can also have a significant impact on how that data is interpreted. For example, data presented in a table, particularly if there are a large number of variables, is often complex and difficult to read as humans tend to be visually orientated. Consequently, important information can be overlooked or even dismissed if the statistical data is only presented in this manner.

For this reason, researchers often present statistics graphically, but even here the presentations can be misleading. For an example, look at the following two graphs.

FIGURE 5.2.6 The swift parrot is listed as critically endangered.

5.2.7 Same stats, different graphs: generating datasets with varied appearance and identical statistics through simulated annealing

INQUIRING FURTHER

Investigate how the same statistical values, such as mean and standard deviation, can be generated but will have divergent graphical representations.

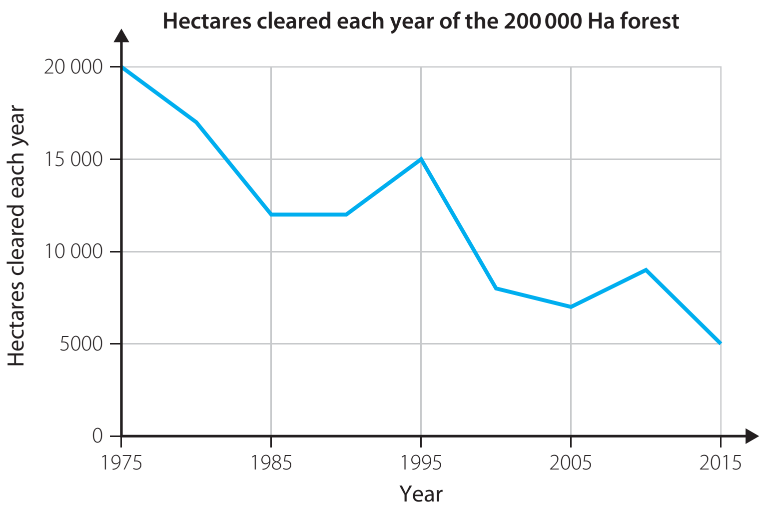
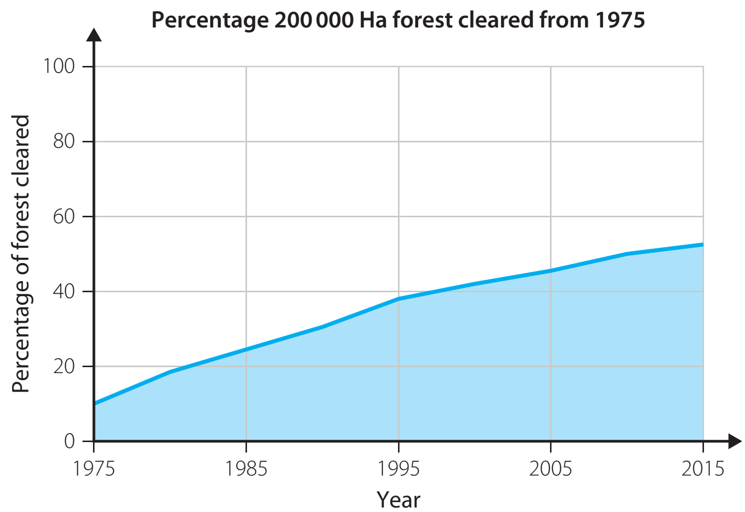


FIGURE 5.2.7 This graph is best described as showing the declining rate of forest clearing in the area.

Both graphs were created using exactly the same data set; however, how the data was manipulated and presented creates two different 'stories' about how the 200 000 Ha forest is fairing. Figure 5.2.7 indicates that the rate of clearing is decreasing and is inclined to make the reader feel positive about the state of the forest. Figure 5.2.8 indicates how much of the forest has cumulatively been lost over time and is inclined to make the reader feel despondent about the state of the forest. Which graph a researcher will present is often influenced by their own personal opinions and feelings on the issue as well as the audience they wish to influence.

5.2.1 Impacts on investigations

FIGURE 5.2.8 This graph is best described as showing the amount of forest that has been cleared between 1975 and 2015.



SECTION REVIEW 5.2

REMEMBERING

1 Define 'placebo' and describe its use in medical investigations.

UNDERSTANDING

2 Figure 5.2.9 represents a way in which statistical data can be misrepresented. Describe how the two images can give different impressions of the same results, even though the same raw data was used to generate them.

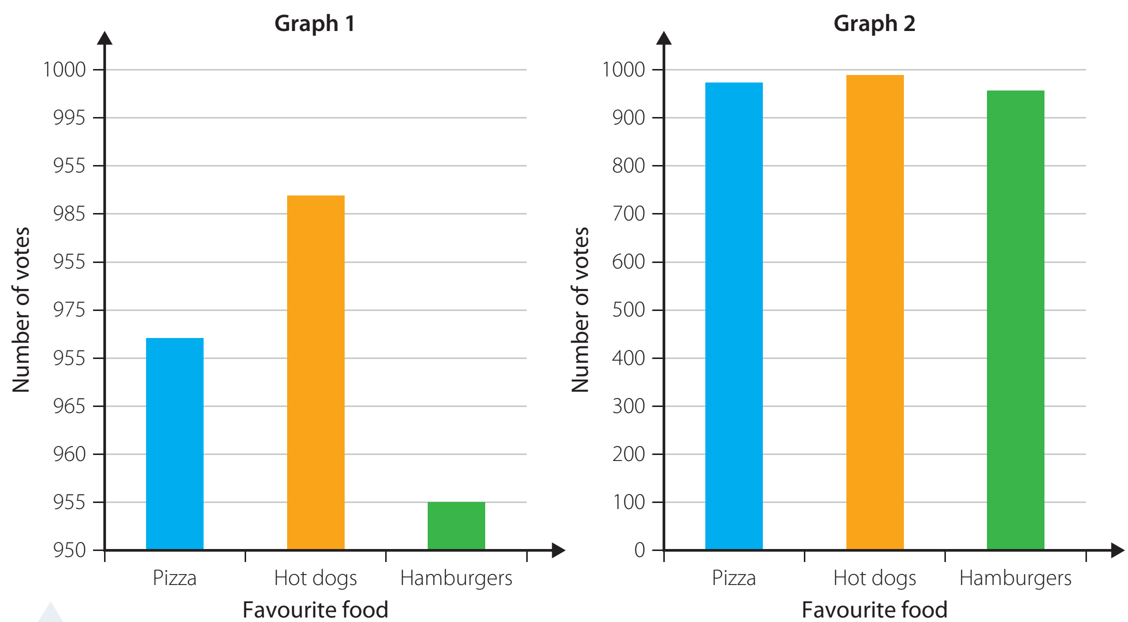


FIGURE 5.2.9 The above graphs represent two ways of showing the same data on the favourite food of a sampled group of people.

3 Explain why a double-blind trial for testing a new cholesterol drug that incorporated the use of placebos would be preferable over a drug trial in which the doctor administering the treatment knew who was given the placebo and who was not.

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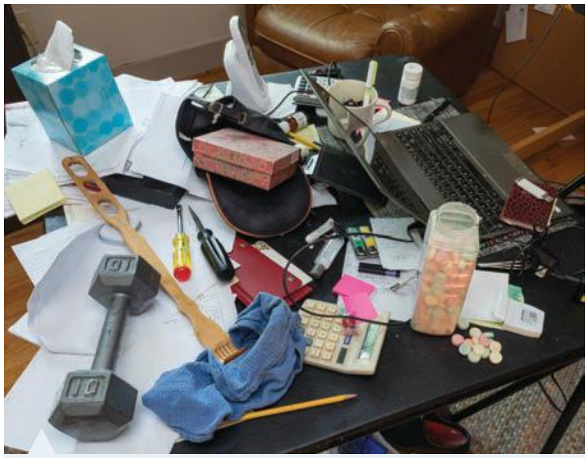
APPLYING

4 Kawan wanted to investigate how many different objects a person could recall from an image, such as the one shown in Figure 5.2.10. Describe how the image that was chosen could result in a cultural bias in the collection of the results, particularly if some people were not actively studying at school or university, or working a desk job.

5 Alex wanted to see what effect soap would have on the number of bacteria that will grow after washing your hands. Design a method for an investigation that would get the answer desired through the use of control groups and appropriate sample size.



Getty Images/iStock/AG-ChapelHill

FIGURE 5.2.10 Though the objects in this picture of a cluttered desk may be very familiar to some people, they are not necessarily as familiar to others and this has the potential to introduce bias.

5.3 Evidence-based analysis

Correlation does not mean causation

One of the most important things that scientists are warned of when they embark on an investigation is that just because two or more variables may correlate with each other does not mean that one necessarily causes the other to happen. This can be illustrated when we compare shark attacks with ice-cream sales, as shown in Figure 5.3.1. When we compare ice-cream sales and shark attacks we can observe a **correlation**, with each following the same general trend, and with the incidence of shark attacks and ice-cream sales increasing as summer approaches and decreasing during the winter. But saying that eating ice-cream makes you more likely to be attacked by a shark implies **causation** when there is none. If we examine other related variables more closely, we can determine that people are more likely to eat ice-cream and swim in the ocean (and therefore be at risk of a shark attack) when the weather is warm.

correlation connection between two or more things, or a measure of how things are related

causation where a change in one variable affects the other variable; also referred to as cause and effect

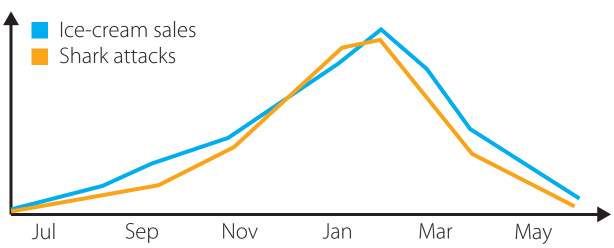


FIGURE 5.3.1 This exaggerated graph illustrates the correlation between ice-cream sales and shark attacks.

Such examples show we should be cautious when ascribing causation and for this reason, scientists tend to be hesitant when asked to explain why any given event or phenomena occurs.

The Hawthorne effect

In 1924, researchers from the National Research Council and Massachusetts Institute of Technology in the US, were conducting experiments at Western Electric's factory in Cicero in the Hawthorne complex. The researchers were investigating the effect light levels had on the productivity of the workers in the factory and noted that productivity increased. However, the researchers also noted that the workers in the control group increased their productivity even though the light levels had not changed. Initially researchers assumed this was because the workers were conscious of being observed and changed their behaviour in response to this observation. However, it has since been found that the increased productivity was most likely because the researchers supervising the workers were much more approachable and more inclined to listen to the workers' suggestions and opinions than the managers that normally oversaw their work. This resulted in workers feeling more positive about their work and being much more productive.

The Hawthorne effect highlights that investigations involving humans, and to some extent animals, can inadvertently influence the behaviour of their subjects in ways that are not anticipated and researchers must take care to control the conditions of the experiment as much as possible.

Hormone replacement therapy and heart disease

The effects of heart disease can be devastating for individuals and their families. For this reason, researchers try to identify the factors that can increase or decrease the likelihood that a person will suffer from coronary heart disease. One such factor was thought to be found in a series of observational investigations conducted between 1976 and 1996, which showed that women who were taking hormone replacement therapy (HRT) after they reached menopause appeared to have a lower incidence of heart disease. This led to doctors prescribing HRT to many women when they reached menopause. However, further clinical studies showed no significant reduction of heart disease for those taking HRT and further statistical analysis indicated that the women who took HRT in the observational studies were more likely to come from a higher socioeconomic background and have better education and, as such, maintained healthier lifestyles and diets. This example highlights how we should be cautious when drawing causation from a correlation in the data.


Shutterstock.com/wavebreakmedia

FIGURE 5.3.2 Despite research studies published to the contrary, the Mozart effect is still a commonly held belief.

The Mozart effect

Understandably, new parents want to give their children the best start in life that they can. As such, when Frances Rauscher published a study in 1993 that found that 36 college students who listened to Mozart performed better in spatial reasoning tasks linked to IQ than a control group, it caused a significant stir and parents soon learned about it. Named 'the Mozart effect', the link between listening to classical music and increased IQ became a part of parenting folklore because of its supposed ability to beneficially wire, or rewire, the brain. Many parents have since paid significant amounts of money to purchase listening programs to enhance this supposed effect. However, further studies and analysis of the data indicate that, at best, the effect is temporary and even then, it is restricted to specific spatial tasks. Such research demonstrates that preliminary findings from studies with small sample sizes should be treated with caution and analysed carefully for possible error and bias.

WS 5.3.1 Evidence-based analysis

INVESTIGATION 5.3.1

Causes that are not there

There have been a number of occasions when scientists have assumed a causation between variables when there was merely a correlation due to unseen bias or the inability to account for an external variable that has influenced the interpretation of the results. For this reason, we advise you to learn from the mistakes of others rather than repeat them.

AIM

To evaluate the reasons why scientists could have misinterpreted a correlation and incorrectly implied causation to a phenomenon, investigate the following studies.

- The Hawthorne effect
- The 1991 study linking HRT to reduced risk of coronary heart disease
- The Mozart effect on child development

MATERIALS

Relevant secondary sources to conduct the investigation, such as the weblinks listed on the right of the page.

PROCEDURE

Examine secondary sources and write a report on the controversy surrounding the studies. Be sure to include the following points.

1. The author of the original studies that suggested the correlations
2. Counter studies that refute the original author's claims
3. The likely reasons given that the correlation was mistaken as causation in the original studies
4. The state of ongoing research in the area

RESULTS

Analyse the data and write a report on the three studies.

DISCUSSION

1. Describe the most likely reasons why the initial studies were erroneous.
2. These studies have all reached the public attention in some way. Give a possible explanation on why they have tended to persist in the public perception.
3. Outline the advice you would give to a person conducting an investigation as they draw conclusions regarding their findings.

5.3.1 The Hawthorne effect: an old scientist's tale lingering 'in the gunsmoke of academic snipers'

5.3.2 The Hawthorne effect: what do we really learn from watching teachers (and others)?

5.3.3 Was there really a Hawthorne effect at the Hawthorne plant? An analysis of the original illumination experiments

5.3.4 Hormone replacement therapy and cardiovascular disease. What went wrong and where do we go from here?

5.3.5 Fact or fiction? Babies exposed to classical music end up smarter

5.3.6 The Mozart effect: a closer look

SECTION REVIEW 5.3

REMEMBERING

1. Describe the difference between correlation and causation.

UNDERSTANDING

2. The Hawthorne effect states that research participants will modify their behaviour when in the presence of the investigator. Describe how the Hawthorne studies led investigators to establish this as an effect that may bias an investigation on people.

APPLYING

3 Besna did an investigation where she found that the angle of slope of a nearby hill correlated closely with the amount of soil erosion she recorded. However, on closer investigation it is noticed that the hill Besna studied was a hill that had recently been cleared of most of its vegetation, yet a neighbouring hill was still covered in vegetation. Justify further steps that Besna may have taken in the investigation to confirm or negate the impact that the angle of slope has on the amount of erosion recorded.

5.4 Reading between the lines

Debating science in the public sphere

Science and scientists do not exist in isolation in universities and research institutions. The conclusions drawn from scientific research can, and does, affect the rest of society. For this reason, the public needs to be informed of, and literate in, the processes of science, as scientific research findings are often used to inform public policy. However, this has its own implications, as much of the public only have a cursory familiarity with the nature and practice of science and the language used by scientists is often specific to their field of study.

Scientific research papers about issues that may impact wider society often need to be 'translated' for public consumption. This translation often falls to media outlets and journalists, and as in any translation there can often be a number of details that are missed, misinterpreted or that are not deemed to be appropriate for the intended audience. These issues can be compounded when the reader also brings their own **innate bias** and ideology to the reading of the text, particularly if the subject under discussion triggers an emotional response that could cloud a person's judgement.

innate bias
the tendency for an individual to draw a flawed inference because of the assumptions and experiences that have influenced them and the mental 'short cuts' the brain makes when making an observation

The result of innate bias and the application of ideology is that there are numerous scientific issues in the public sphere that are subject to considerable debate, even if there is scientific consensus and the debate is not reflected in the scientific community. Examples of such issues include climate change, vaccinations, fossil fuels and alternative energy sources, evolution, the possibility of extra-terrestrial life, appropriate cancer treatments, genetically modified organisms, organic food, diet and exercise, radiation from devices, appropriate screen time, the value of space exploration and the validity of standardised tests in education.

INVESTIGATION 5.4.1

Reporting on the science

Journalists and media outlets have a responsibility to make recent research findings interesting, digestible and contextually accurate so as to inform the public on developments that may affect their lives. However, on occasion journalists may make mistakes and sometimes organisations deliberately misinform in an effort to push their own ideology or agenda.

AIM

To choose a scientific issue that is publicly debated and examine how it is portrayed in the media and review media publications for their accuracy, validity and reliability

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MATERIALS

Relevant secondary sources to conduct the investigation.

PROCEDURE

1 Examine secondary sources and write a report on the portrayal of a scientific issue in the public sphere. Be sure to include:
   a how accurate the information given is
   b any potential biases that may be introduced
   c the validity of the data, that is, are the studies using only preliminary data? Or is there a large body of evidence to support the findings reported?
   d the reliability of the information, that is, are the original findings sourced from reputable published scientific journals?

RESULTS

Analyse the data and write a report on how well the issue is portrayed in the public sphere.

DISCUSSION

1 Describe the differing positions people may have on the issue concerned.
2 Describe the position of the scientific community on the issue.
3 Outline the factors that fuel the debate in the public sphere.
4 State your own position on the issue and justify your stance.

Getty Images/iStock/Andrey Popov

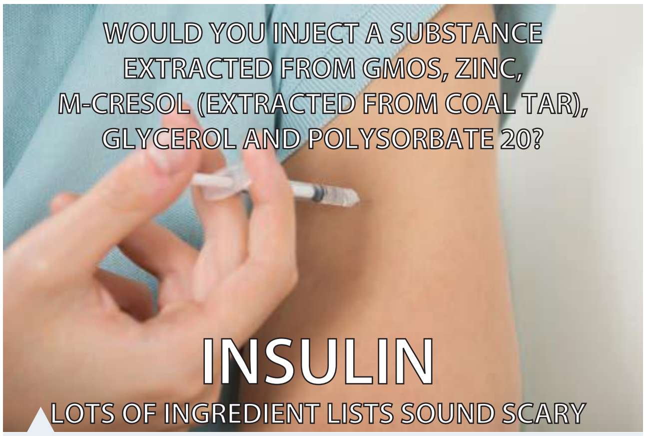

FIGURE 5.4.1 Memes are commonly employed in the public sphere to sway the opinion of potential readers. Many memes are about scientific issues.

INQUIRING FURTHER

Memes are produced by their creators in the hope of arguing a point and swaying public opinion. The effectiveness of a meme is debatable. One argument against memes states that 'liking' a meme indicates an already predetermined viewpoint – in other words, the person was already inclined to agree with the sentiment of the meme, while disregarding other memes because of their own cognitive bias.

Investigate the effectiveness of memes to persuade the public on a scientific issue, such as genetically modified foods, vaccinations, evolution via natural selection or climate change. Collect at least five memes on the issue and analyse the language used and the position of the creator of the meme. Then using the memes, conduct a survey to analyse the position of survey participants before and after being exposed to the meme. Record if the participants have changed their viewpoints or not after exposure to the meme.

The meaning of the words we use is very important. Words that are used specifically within a given field or discipline are referred to as **terminology**. Such words or terms typically have very precise, narrow meanings that are applicable to a given field but not the wider community. This allows people within the field to communicate ideas and concepts easily without the need to premise it with detailed definitions.

terminology
the specialised terms and words used within a particular field or profession that have a technical definition within this context

Science is just one example of a field of study that has its own specific terminology. Science tends to encounter problems when specific science terms are 'translated' into common (everyday) language. For example, scientific definitions of specific terminology are often not the same as the common language definitions of the same word. The primary reason for this is that common language is fluid, it tends to evolve and change from one generation to the next or be can be co-opted and adapted to be used in a specific context and consequently, the definition of words also changes. For example, the word control is commonly understood to mean the ability to influence the behaviour of a person or the outcome of events. However, in science the word control means to limit the variables in an experimental setting so that they can be examined individually. The reason for this difference is that terminology and language within a particular field such as science tends to remain much more static and the meanings of the terms used are often reinforced over time to maintain consistency. This ensures there is a universal understanding within that field.

The result is that a particular word can have two or more meanings depending on how a person is using it. Confusion arises when one person ascribes the word with one particular definition while another person uses a different definition. For this reason, part of being science literate is understanding what a scientist means when they use a particular term from within their field. The following table illustrates some common terms that are often misinterpreted.

TABLE 5.4.1 The different meanings of some terms used both in sciences and in common language.

TERM	SCIENTIFIC DEFINITION	COMMON LANGUAGE DEFINITION
Theory	Explanation of why phenomena happen and is supported by empirical evidence	A proposed explanation whose status is subject to debate and verification.
Hypothesis	An initial explanation or conception of an observed phenomenon that is tested scientifically and is either supported or rejected by the empirical evidence.	A proposition or explanation put forward as the basis of an argument.
Belief	A mechanism through which humans understand the world. A scientific belief system is one which requires empirical evidence to support a claim.	A faith-based belief system to which one ascribes with no requirement for empirical evidence.
Law	Description, usually expressed as a mathematical relationship, of what happens in a phenomenon under given conditions	The regulations that must be complied with, set down by an authoritative body.

INQUIRING FURTHER

Collect a range of media articles that cover a scientific issue and identify how terms such as theory, hypothesis, belief and law are used. Describe which definitions the articles use, the scientific definitions of the terms or the common language use of the terms.

INQUIRING FURTHER

Media articles, commonly known as 'click bait', will typically use emotive language and imagery that is not necessarily indicative of the content of the article. Analyse a range of 'click bait' media articles that cover scientific issues and analyse how the titles and content of the articles can mislead the reader through the inappropriate use of scientific language.

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INVESTIGATION 5.4.2

Comparing media and research articles

The intended audience a person is writing for has a significant impact on the way a science article is presented. Research articles or papers are intended to be read by fellow researchers that are working in a specific scientific field. The language is often technical and full of specific terminology and the paper is usually extensively referenced. In contrast, articles published for public consumption use language that is much more accessible to the general reader and the referencing requirement is significantly reduced.

AIM

To compare the difference between the reporting in a peer-reviewed journal article and an article published for the public on the same or related scientific issue

MATERIALS

Relevant secondary sources to conduct the investigation. Students may choose any two related articles on a scientific issue of their choice provided one is a published peer-reviewed journal article and one is a general media article.

PROCEDURE

Compare the two articles and write a report on the differences and similarities between them. Be sure to include the following details.

1. Whether the names and qualifications of the author/s are given.
2. The type of title used, that is, does it use emotive language or technical language?
3. The structure of the article, that is, does it make use of subheadings? Does it fit a formulaic structure; for example, with introduction, method, results, discussion and conclusion or some similar variation?
4. A description of the type of language used: is it technical, does it make use of specific terminology or is it easily accessible for the average reader?
5. The presentation style of diagrams, tables and graphs, if they are used.
6. The use of qualifiers, that is, do the authors urge caution in interpreting results for any particular reason?

RESULTS

Write a report on how the different intended audiences have influenced the structure, presentation and language of the authors.

DISCUSSION

1. Describe the expectations an audience for a peer-reviewed journal article would have.
2. Describe the expectations an audience for a general media science article would have.
3. Explain how each format forces the author to conform to a particular writing style.
4. Discuss how 'translating' information from a peer-reviewed journal article can compromise the integrity of the information when it is converted into a general media article.

Geophysical Journal International, Volume 199, (2), 2014, Pages 1110–1124. Screenshot. Leonardo Sagnotti et al. Extremely rapid directional change during Matuyama-Brunhes geomagnetic polarity reversal.

FIGURE 5.4.2 The online presentation of a peer-reviewed journal article. Note the technical language used in the title and the lack of pictures.

Shutterstock.com/Snowbelle

FIGURE 5.4.3 The online presentation of a popular media article based on the peer-reviewed article in Figure 5.4.2. Note the emotive language in the title and the imagery used.

Conflict of interest

The practice of science is not separate from broader society, and science can be appropriated to further the interests of different social, political and economic groups. This can occur because there is a **conflict of interest** between the findings of science, the needs of the broader community and the interests of particular individuals or groups within society. This is particularly prevalent in industries where an already established and profitable practice is threatened by scientific findings that advise the practice be halted or modified. An example of could be when the fishing industry is advised that they are overfishing in a particular area and that if they continue fishing then there will not be enough fish to restock the area and the industry will collapse in the near future. Unfortunately, there have been occasions where such warnings have resulted in increased fishing as the industry tries to make as much short-term profit as is possible from the area before the fish stocks collapse. The **incentive** structures that encourage corporations and industries to make profits and continue in a given practice despite the warnings from scientists has serious implications. Changing industry practices can mean a company has to go to great expense or could suffer serious financial losses while changing their business model. They may even go out of business altogether if they are not able to adapt fast enough to the new circumstances. This can mean that industries ignore, or dismiss as unfeasible, the scientific recommendations that benefit the wider community.

conflict of interest a situation in which two parties or groups have incompatible objectives. If such parties have an unequal balance of power, then one party may use their power for personal benefit

incentive a structure or thing that encourages and motivates someone to behave in a given manner

This conflict is further compounded by the fact that the typical corporate model demands that the company maximises their profits for shareholders. Diverting funds to retooling and changing the business model would not only reduce shareholder dividends but may also mean the company's share price goes down.

Consequently, in many instances corporations are incentivised to suppress scientific research that conflicts with their business practice. Where the scientific information cannot be suppressed, corporations may engage in campaigns of misinterpreting or misrepresenting the scientific findings to create confusion in the public sphere in order to delay the effective implementation of the scientific recommendations.

Conflicts of interest can also result in the skewing and bias of the findings of scientists that are working in research and development within a particular industry. This is because their employment depends on producing research that is favourable to the industry or that can be used to develop a profitable product. As such, there is a growing call for scientists to declare their employment status when submitting articles for publication.

Such conflicts of interest are not isolated or minor events, and numerous incidences have been recorded as a matter of public record, some of which are discussed below.

INQUIRING FURTHER

Research the history of the Ford Motor company and the oil industry to determine how the discovery of oil in America incentivised Ford to abandon their development of electric cars and instead develop vehicles using the combustion engine. Identify the incentives and conflicts of interest that make it difficult for the motor vehicle industry to change their business model and build vehicles that emit less greenhouse gas, despite the warning of climate scientists that we need to rapidly decrease greenhouse gas emissions to prevent the worst of climate change.

The tobacco industry and lung cancer

As early as the 1950s, independent scientific research had established a statistical link between cigarette smoking and lung cancer. Even more damning was that fact that the cigarette industries own scientific research had confirmed the presence of **carcinogens** in cigarette smoke and established a causal link between smoking and lung cancer.

carcinogen a chemical known to cause cancer

Rather than adapt or change their business models, cigarette companies embarked on a campaign of denial and misinformation. The tobacco industry's only meaningful response to public concern was to add filters to their cigarettes. The effectiveness of these filters was minimal and only served as a means of delaying real action.

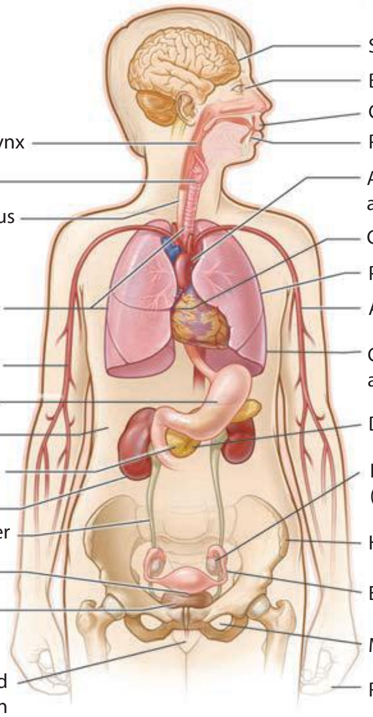
In the 1960s, based on recommendations from industry lawyers, the tobacco industry began putting health warnings on their products in order to negate possible litigation from people who developed lung cancer after smoking cigarettes. However, the industry still maintained that the evidence linking smoking to lung cancer was inconclusive.

Even in 2012 in an Australian High Court case, two plaintiffs, Phillip Morris and Imperial Tobacco, tried to block evidence of the connection between smoking and lung cancer in court and denied the contents of the documents in a case disputing the plain packaging of cigarettes in Australia.

Today Australia has introduced legislation requiring plain packaging and visual health warnings in an effort to improve public health through the reduction of cigarette smoking. The tobacco industry has actively fought such measures, claiming that it breaches international property rights, infringes on international trade agreements and that there is no evidence plain packaging works.

5.4.1 Tobacco explained. The truth about the tobacco industry ... in its own words

5.4.2 Health issues irrelevant, tobacco firms tell court



U.S. Department of Health and Human Services. The Health Consequences of Smoking: 50 Years of Progress. A Report of the Surgeon General. Atlanta, GA, 2014.

FIGURE 5.4.4 The negative impact of smoking has been found by medical science to extended far beyond just lung cancer. However, the tobacco industry still claims the evidence of harm is inconclusive.

The fossil fuel industry and climate change

By the early 1970s, climate scientists were beginning to reach a consensus that the burning of fossil fuels by humans and the subsequent release of CO_2 and other greenhouse gases was causing global temperatures to rise and the climate to shift. However, western nations were extremely dependent on fossils fuels to drive their economies, as demonstrated by the impact of the 1973 oil embargo that limited oil supplies to many western nations.

The fossil fuel industries were not simple bystanders in the search for answers regarding climate change. Exxon (now ExxonMobil) suppressed a series of internal documents that showed their own climate scientists had warned Exxon's management committee as early as 1977 'there is general scientific agreement that the most likely manner in which mankind is influencing the global climate is through carbon dioxide release from the burning of fossil fuels'. Further warnings indicated that Exxon was aware that action needed to be taken within five to ten years to change their energy strategy and prevent global warming.

Such warnings were ignored or dismissed by Exxon's upper management. In 1988, when the National Aeronautics and Space Administration (NASA) told a US congressional hearing that Earth was already warming, Exxon maintained a public stance that the science was not yet conclusive.

It has since been found that Exxon and other fossil fuel corporations have spent millions of dollars on campaigns and lobbying government officials. Their aim was to deny and mislead the public and governments on the climate science in order to delay any meaningful action on legislating to reduce carbon emissions.

Today public pressure is mounting in favour of the climate science. In 2016, 75 per cent of the Australian public indicated that climate change is a major concern, with 57 per cent wanting immediate action irrespective of global action.

5.4.3 Exxon knew about climate change almost 40 years ago

5.4.4 A brief history of fossil-fueled climate denial

Pesticide use and risk

In 1939, the Swiss scientist Paul Hermann Müller developed the pesticide DDT (dichloro-diphenyl-trichloroethane). This organic pesticide was hailed as a safe and effective means of combating agricultural pests and insect-borne diseases such as malaria and typhus. The widespread application of DDT during World War II was credited with saving thousands of lives by controlling typhus-carrying lice and insects such as the potato beetle that were ravaging crops. Paul Hermann Müller was awarded the Nobel prize for Medicine or Psychology.

insecticide resistance
a micro-evolutionary process whereby insect populations become increasingly resistant to the effects of an insecticide

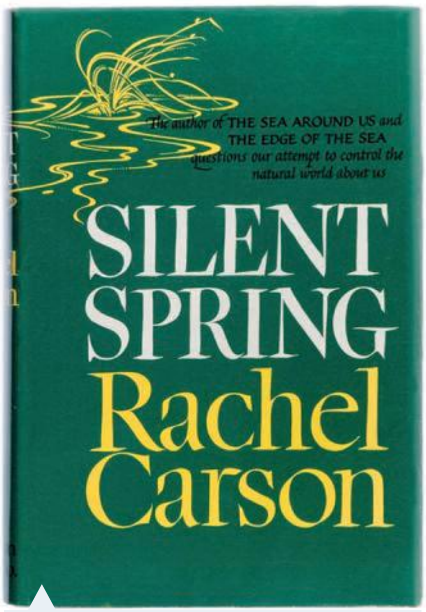
However, its widespread use quickly resulted in **insecticide resistance** and the need for larger applications for the pesticide to be effective. Meanwhile evidence was also mounting that DDT was having serious health effects both in humans and in the wider environment. In 1962 Rachel Carson published *Silent Spring*, a carefully documented account of the effects DDT was having on the environment and its implications to human health. The pesticide industry was outraged and attacked Carson's credibility as a scientist. However, by 1972 the Environmental Protection Agency in the US had cancelled orders for DDT. In Australia DDT use was banned in 1987.

5.4.5 DDT environmental effects

Today the effects of DDT are known to included eggshell thinning in predatory birds such as eagles. This happens as DDT bio-accumulates through the food chain with those animals at the top of the chain having the highest DDT levels. In humans, DDT is classified as probably carcinogenic and has been connected with an increased risk of breast cancer in women exposed to high levels of DDT prior to puberty.

However, despite the known risks of DDT and its long-term persistence in the environment, the World Health Organization still allows DDT to be used as a means to control mosquito-borne malaria. This is despite the proven effectiveness of techniques that use a variety of approaches and community involvement to control malaria without the need for pesticides.

Such controversies surrounding pesticide use are still prevalent today. In 2015, the International Agency for Research on Cancer classified glyphosate, the active ingredient in common herbicides used both commercially and domestically, as *probably carcinogenic to humans*. Countering this, representatives that manufacture such herbicides stated that the evidence is not conclusive and that they will be contesting the classification.



Alamy Stock Photo/Universal Art Archive

FIGURE 5.4.5 Rachel Carson's book *Silent Spring* created considerable controversy when it was first published. Numerous pesticide industry representatives refuted her claims of environmental risk.

INQUIRING FURTHER

The controversy surrounding the use and availability of glyphosate is ongoing. In 2016, France banned its sale for non-professional gardeners and use in public green spaces. Identify the countries that have bans or limitations in place on glyphosate. Research the different sides of the debate, examine the language used and give a justified stance on whether or not glyphosate is safe to use and, if so, under what circumstances.

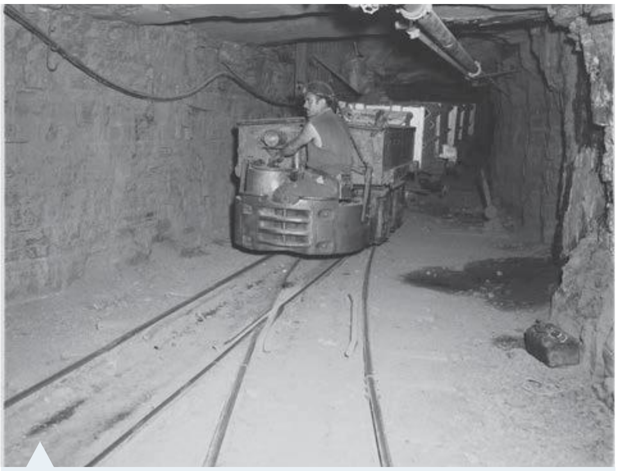
Asbestos mining and lung cancer

Asbestos is a naturally occurring fibrous crystal mineral that is strong and extremely resistant to heat. For this reason, it was highly sought after as insulation, and used in heat and fireproof material, cement and plaster. Asbestos is mined from serpentinite rocks and industrial-scale asbestos mining began around 1880.

Concerns were raised about the safety of asbestos miners as early as 1899, when people began to note the negative health effects of being exposed to asbestos dust. However, the extreme versatility of asbestos for the building industry meant that mining continued despite health insurance companies in the US increasing premiums and refusing to cover people exposed to asbestos. This was due to the finding that half the men working in the mines developed lung disease within three years. At the time, the only measures to counter this was some dust control in the mines.

Then in 1943, the Samac Laboratory in New York confirmed the link between asbestos dust and lung cancer. The report was suppressed even as the known death toll continued to climb across the world. Over the next 40 years, the evidence about the negative health effects of asbestos continued to mount – along with the death toll. Finally, in 1984, Australia banned asbestos mining as well as the manufacture, importation and installation of crocidolite and amosite asbestos. Meanwhile, with the support of unions, workers started class actions to sue mining corporations for refusing to acknowledge the damage to workers' health and seek compensation for asbestos-related diseases.

In 2003, an Australia-wide ban on the manufacture and use of all asbestos products took effect, even as work health and safety legislation was introduced for the safe removal and disposal of materials containing asbestos. In 2012, the High Court of Australia found the directors of the company James Hardie guilty of permitting the release of misleading statements to the stock exchange in relation to victim compensation for asbestos-related disease.



State Library of WA (b1851556_2)

FIGURE 5.4.6 A miner working in the WA Wittenoom asbestos mine. The mine was closed in 1966. Before 1966, the risks to miners from breathing asbestos dust was well documented yet the mine was poorly ventilated and personal protective breathing equipment was often not provided to miners.

5.4.6 The shameful legacy of James Hardie

5.4.7 History of asbestos

Buying a feeling

When trying to determine the validity of a scientific claim, make a decision on the best medical treatment or even select the most cost-effective product, it is quite common to seek advice from others. If the person is well presented, has an honest reputation and is someone who is trusted and well regarded in the community, then it is very likely that other people will follow their recommendations without much analysis as to the validity of their claim. This tendency to 'listen' to others that are perceived positively is known as the **halo effect** and it tends to bias a person's decisions in favour of the person speaking.

halo effect
a psychological phenomenon where a person is perceived more favourably because of an initial positive perception of that person

The halo effect can become problematic when people who are commonly in the public eye, for example some politician and public figures, use their positive public perception as a means to support a product, service or opinion, even if they have no expertise or training in the efficacy of the product, service or the field of knowledge. For example, a public figure may use their public profile as a platform to voice their opinion and suggest their expertise on the most suitable diet for weight-loss despite having no training in nutrition. Because this person is perceived positively by the public, their advice is perceived more positively. The halo effect means that people are predisposed to feel familiar with and trust public figures they see often in a positive light, even if it is only through a televisions screen.

A similar, related effect extends to brands. Companies go to great lengths to ensure their brands are associated with positive emotions. This is why advertising campaigns use a lot of positive emotional imagery and language, they want consumers to feel good when they see their brand and to therefore buy their products. However, this approach to branding does not usually provide factual information or scientific data as a means of persuading consumers.

The halo effect and branding is often used by companies and people with **vested interests** when it comes to scientific issues. Typically, they use these techniques to sway public opinion in their direction. This tactic can be exceptionally misleading when issues centre on what is in the best interest of the individual and the greater community.

Alamy Stock Photo/StockFood GmbH

FIGURE 5.4.7 Children and families are often used in advertising. This is because children and families are associated with purity, innocence and safety. This association however, may have nothing to do with the product itself.

vested interest a situation where a person or group would benefit from influencing circumstances to favour their position

INQUIRING FURTHER

Advertisers are well aware of the halo effect and will commonly employ public figures to endorse their products in the hopes of getting consumers to buy more of their product. Investigate two examples in which public figures are used to promote or support a product, service or opinion. Conduct a survey to find out how susceptible people are to the halo effect by comparing how receptive the survey participants are to being persuaded with and without the associated image and or voice of the public figure.

INVESTIGATION 5.4.3

Seeing through the halo effect

The use of the halo effect and branding is common when it comes to swaying people's perceptions of scientific issues. Such techniques manipulate the human psychological tendency to trust people and things we perceive positively and may in no way be related to the actual message or product.

AIM

To explain how the halo effect and branding is being used to manipulate the public to reject valid scientific positions in favour of other vested interests

MATERIALS

Relevant secondary sources to conduct the investigation. Students may choose any form of media advertising or publicity campaign that uses the halo effect and branding to sway the public to make decisions that run counter to scientific opinion and may not be in the public's best interest.

»

PROCEDURE

1. Research the position of the scientific community on the selected issue/s.
2. Describe how the halo effect is used in the selected advertisement or campaign. Be sure to include:
   - a) the persona and emotions being used to influence the perception of the message or product
   - b) the objective and aims of the advertisement or publicity campaign – how does it want you to feel, what decisions does it want you to make or what opinions does it want you to have?
   - c) the areas of agreement with the scientific community
   - d) the areas of disagreement with the scientific community
   - e) the people or organisations that benefit from using the halo effect in this instance.
3. Describe how branding is used in the selected advertisement or campaign. Be sure to include:
   - a) the emotions being used to influence the perception of the message or product
   - b) the objective and aims of the advertisement or publicity campaign – how does it want you to feel, what decisions does it want you to make or what opinions does it want you to have?
   - c) the areas of agreement with the scientific community
   - d) the areas of disagreement with the scientific community
   - e) the people or organisations that benefit from using branding in this instance.
4. Research any polls that outline how effective or ineffective the advertisements or media campaign may be.

RESULTS

Summarise the results in a table to outline the similarities and differences between the use of the halo effect and branding.

DISCUSSION

1. Describe why it would be important for people to be aware of advertising and media campaigns that use the halo effect and branding when it comes to scientific issues that impact the public.
2. Outline how you would explain to someone that they have been manipulated by the halo effect and/or branding to make a particular decision or form a given opinion.
3. Suggest a procedure you could use to verify the claims made by people or organisations that use the halo effect and branding to manipulate you.

Is it real science?

Asking questions, posing hypotheses and suggesting links between variables is a major component of science and is done in an attempt to further an understanding of how the world works. This is a critical component of science and the scientific process, and is supported by the requirement for empirical evidence to support a claim or assertion. This means that if you wish to state that one thing causes another, there must be measurable and observable connections that link those things (or more correctly those variables). If the ability to gather such evidence is still beyond the capacity of science, then such claims remain within the realm of scientific hypothesis.

However, there are numerous popular practices that claim a definitive connection between variables when in reality no such connections have ever been conclusively determined by measurement or observation in science. Such practices are commonly called **pseudoscience**, because they often claim to be grounded in scientific principles but their basic claim of cause and effect has no supporting empirical evidence as no valid link between the supposed independent and dependent variable/s can be found.

pseudoscience a practice that portrays itself as a science, often through complex terminology and processes but does not meet the criteria for contributing to the greater knowledge and/or burden of evidence for science

Examples of pseudoscience include astrology, numerology and iridology. The investigations performed in these fields do not meet the requirements and standards of repeatable and publishable science, and do not actively contribute to the greater search for knowledge that is a primary purpose

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of science. Instead they either knowingly or unknowingly prey on the ignorance of people that have low scientific literacy and are easily swayed by explanations that often have a number of logical flaws. They also commonly use complex language, terminology and processes to confuse and confound their adherents, and establish the practitioner as an expert.

For this reason, we recommend that if you encounter a claim you believe may be suspect, that you research the underlining premise of the explanation of cause and effect in the scientific literature and examine who benefits most by making such a claim.

5.4.8 What is pseudoscience?

5.4.1 Reading between the lines

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FIGURE 5.4.8 Above is a typical astrological chart. It has complex terminology, processes and charts that only those well trained in astrology can decipher. Astrology is a very old pseudoscience that has been practiced for thousands of years by various cultures around the world.

INVESTIGATION 5.4.4

The tricks of pseudoscience

Practitioners of pseudoscience often use complex terminology and common scientific processes in order to mislead the public. However, their claims of cause and effect are typically not based on empirical evidence and their work does not meet rigorous scientific standards for publication. Being able to identify pseudoscience is an essential component of scientific literacy.

AIM

To identify the methods pseudoscience practitioners use to manipulate public opinion, and the gaps in their claims of cause and effect

»

MATERIALS

Relevant secondary sources to conduct the investigation. Students are to select secondary sources on the following pseudoscientific fields or another field of their own choosing.

- Astrology
- Numerology
- Iridology
- Another pseudoscience

PROCEDURE

1 Describe the history and development of the pseudoscience.
2 Describe how the pseudoscience manipulates public perception. Be sure to include:
   a any claim to contributing to the greater search for knowledge and truth
   b any claim of cause and effect employed by the pseudoscience along with any reference to evidence that is used to support such a claim
   c the nature of specific terminology used
   d the types of processes used to obtain and interpret 'results'
   e the target audience for the pseudoscience.
3 Identify how the broader scientific community perceives these pseudoscientific fields. Be sure to include:
   a the justification given for the acceptance or rejection of these 'sciences'
   b any instances of the pseudoscience being published in a reputable journal.

5.4.9 Ten pseudo-science theories we'd like to see retired forever

RESULTS

Write a report the scientific legitimacy of the various pseudosciences.

DISCUSSION

1 Describe why identifying pseudoscience is important to maintain the integrity of science and its related fields in the public perception.
2 Scientists often propose links between variables that have not, or cannot, be verified. Describe the circumstances that make this acceptable in as a legitimate form of science when compared to pseudoscience.

INQUIRING FURTHER

Many different pseudosciences are currently prevalent in society. In Australia, one such pseudoscience that has drawn a considerable amount of attention is homeopathy. This practice has come under the review of the National Health and Medical Research Council and its findings have been published by the Australian Government. Review the council's findings and write a media release to make the public aware of the ability of homeopathy to deliver the results they claim to be able to.

SECTION REVIEW 5.4

REMEMBERING

1 Identify the differences in how the words 'theory' and 'law' are used in science and in common language.
2 Describe and give an example of the halo effect.

UNDERSTANDING

3 Describe the responsibility of the media in accurately portraying scientific findings for the public.
4 Researchers have argued that the colourful and attractive cigarette packaging helps to glamorise cigarette smoking and actively works against public health measures to reduce smoking and smoking-related diseases. Explain why vested interests may play a part in tobacco companies' resistance to the plain packaging that health officials hope will make cigarette smoking less appealing and confer less social status on the smoker through the use of brands.

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5 Explain how specific and complex terminology is often used by those practising pseudoscience to give the impression that what they are offering is legitimate science.

APPLYING

6 If you were unsure about the authenticity of a media article that made assertions about scientific issues, describe how you could verify and cross-check the claims made in the article using your findings from Investigation 5.4.2.

7 In recent years, there has been a growing demand within the scientific community that journal publications disclose the employment status of authors submitting research investigations for publication. Identify what issues this demand is hoping to address and justify why such measures are seen as an important step in retaining and increasing public confidence in scientific findings.

5.5 Science as self-correcting – the issues

publish or perish a phenomenon in academic disciplines where academics need to regularly publish or risk losing research funding or their job

Publish or perish

It is exceptionally rare for a scientist to be completely independent and self-funded. In the majority of instances, a scientist must earn a living by working for a corporation, public institution or university if they wish to do research science. This means that to justify their position they need to demonstrate that they are making contributions to science that will be of benefit to their employer and the wider public (particularly if they work in at a public institution). One of the most effective means of gauging a scientist's contribution is by the number of research articles and papers they publish in reputable scientific journals.

The result is scientists are put under a considerable amount of pressure to 'publish or perish'. This phrase means that a scientist needs to have a number of journal articles regularly accepted for publication in appropriate journals in order to keep their jobs and/or maintain their grant funding. If they fail to do so, they could lose their position within the institution, or lose their research funding, particularly as there is considerable competition for secure research positions.

The unfortunate consequence of this is that scientists are incentivised to continually submit articles for publication even if the investigation has inadequate sample sizes or subjects, are not fully complete, need to have their results confirmed or the analysis is of the results is subject to interpretation. This can, and has led to the publication of articles that are only preliminary in nature, are misleading or, in rare instances, are fraudulent.

The scientific community is seeking ways to ameliorate the effects of the 'publish or perish' paradigm. But as yet a fully workable solution has yet to emerge.

5.5.1 Publish or perish culture encourages scientists to cut corners

5.5.2 Publish-or-perish: peer review and the corruption of science

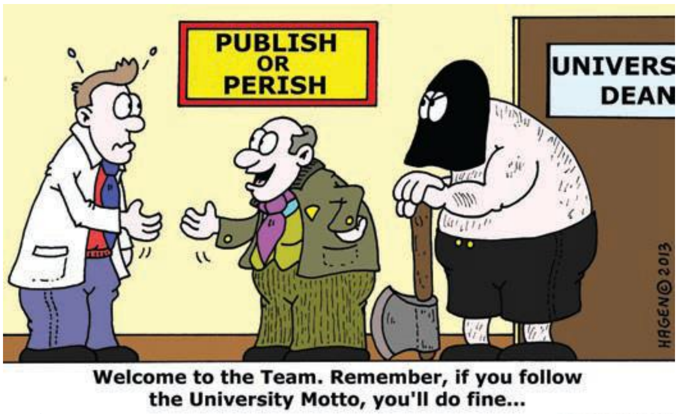

FIGURE 5.5.1 As amusing as this cartoon is, it illustrates a current reality in science. 'Publish or perish' has serious implications for the quality of research papers that are submitted to journals.

Falsified science

The incentive to 'publish or perish' has its consequences. One of them is the greater likelihood that a scientist who submits their paper for publication may falsify part or all of their research. Although such papers comprise only a small fraction of those submitted for publication, an important part of the publication process is that methods are put in place to try to weed out falsified papers and the scientists who go to such lengths to falsify their work.

This is because science as a discipline needs to maintain its value as a means of seeking knowledge and finding truth that people can trust. If that trust is damaged, then it becomes increasingly difficult for people to be sure they are making decisions based on real evidence. For this reason, an academic paper must meet certain requirements and go through the following processes.

Research proposal and ethics approval

A scientist needs to submit a research proposal and seek ethics approval from the appropriate controlling institutions before beginning their research. Though fraud cannot be detected at this stage, the institution can review the proposed investigation to ensure it is viable and that no undue harm will come to the scientist or the research subjects. Research proposals and ethics requirements also make the scientist accountable for following the research procedure they outline and if they need to make any changes, this can ensure they are only done so with approval. When the paper is finally ready for submission, it can be checked against both the proposal and ethics approval, which ensures that the institution has taken all reasonable steps to ensure the validity and appropriateness of the investigation.

Replicable

Every research paper submitted for publication must provide sufficient details about how the investigation was performed so that if another scientist wanted to verify the results then they would be able to replicate the original paper's research methods. Papers that have insufficient detail in this area are typically rejected with a request that the researcher provide more specific detail in order to make the paper **replicable**.

replicable
able to be repeated

Peer review

A large range of scientific papers are submitted to journals for publication, and the editors of these journals do not have sufficient expertise in the various science fields to know if every paper is valid and reliable enough to pass scrutiny. For this reason, reputable journals require that papers be **peer reviewed**. This means that before being published, the submitted papers are sent out to scientists working in the field who are familiar with that area of research. The peer reviewer then provides feedback to the journal editor about any concerns, problems or inconsistencies regarding the paper. The more scientists that peer review the research paper prior to publication, the greater the level of trust in the paper can be assumed.

peer review
a process where acknowledged experts in a field review and critique the work of others working in the same field, usually undertaken before a paper is published

Replication

Research papers that have passed the peer-review process and have been published can now come under scrutiny through replication. Often other scientists may wish to build on the conclusions and theoretical underpinnings of the published paper. To be confident that such findings are sound, they may wish to repeat the published investigation to see if they can replicate the results. At this point, any inconsistencies in the reported results in the original paper can be found and the scientist replicating the paper can refute or confirm the finding via a paper of their own.

Retraction

If, through replication or closer scrutiny by the wider scientific community, a published paper is found to be fraudulent, then a paper may be **retracted** by the journal that originally published it, as shown in Figure 5.5.2. The institution may also elect to take disciplinary action. In most instances, if a paper is found to have been knowingly published as fraudulent by the author, the scientist's reputation is typically destroyed and the chances of them ever publishing again are minimal.

retracted
the removal of a published paper/book by the journal editors as a result of misconduct, such as fraud

Understandably, it can take some time for a misleading or falsified paper to be detected and retracted. The delay between when the paper was published and when it is retracted is a significant concern and many in the scientific community are taking steps to try to improve the cross-checking process.

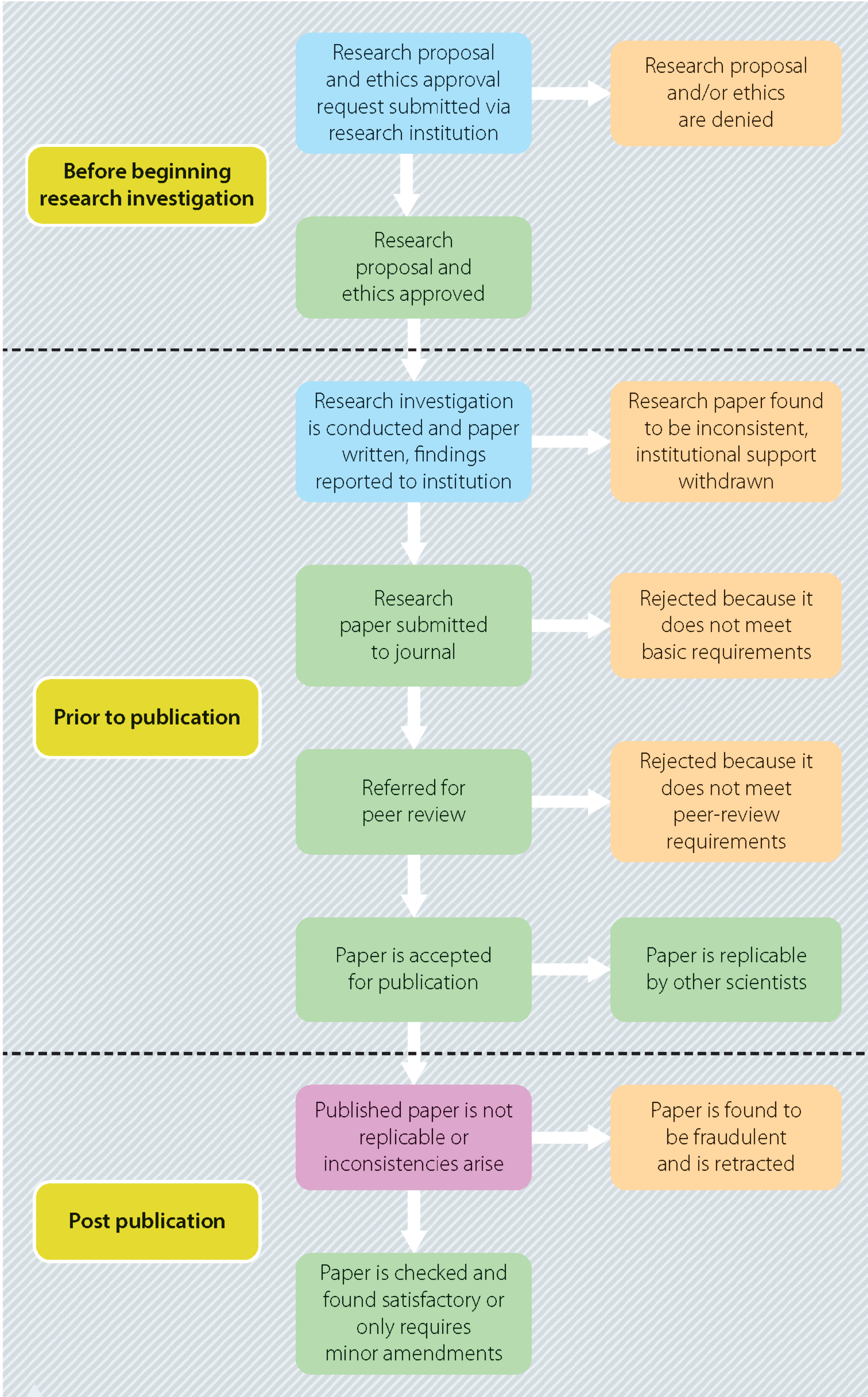

FIGURE 5.5.2 The basic processes for detecting and eliminating potentially fraudulent research papers. Each branching stage represents a point at which research is evaluated for authenticity.

RETRACTED

Early report

Ileal-lymphoid-nodular hyperplasia, non-specific colitis, and pervasive developmental disorder in children

A J Wakefield, S H Murch, A Anthony, J Linnell, D M Casson, M Malik, M Berelowitz, A P Dhillon, M A Thomson, P Harvey, A Valentine, S E Davies, J A Walker-Smith

Summary

Background We investigated a consecutive series of children with chronic enterocolitis and regressive developmental disorder.

Methods 12 children (mean age 6 years [range 3–10], 11 boys) were referred to a paediatric gastroenterology unit with a history of normal development followed by loss of acquired skills, including language, together with diarrhoea and abdominal pain. Children underwent gastroenterological, neurological, and developmental assessment and review of developmental records. Ileocolonoscopy and biopsy sampling, magnetic-resonance imaging (MRI), electroencephalography (EEG), and lumbar puncture were done under sedation. Barium follow-through radiography was done where possible. Biochemical, haematological, and immunological profiles were examined.

Findings Onset of behavioural symptoms was associated, by the parents, with measles, mumps, and rubella vaccination in eight of the 12 children, with measles infection in one child, and otitis media in another. All 12 children had intestinal abnormalities, ranging from lymphoid nodular hyperplasia to aphthoid ulceration. Histology showed patchy chronic inflammation in the colon in 11 children and reactive ileal lymphoid hyperplasia in seven, but no granulomas. Behavioural disorders included autism (nine), disintegrative psychosis (one), and possible postviral or vaccinal encephalitis (two). There were no focal neurological abnormalities and MRI and EEG tests were normal. Abnormal laboratory results were significantly raised urinary methylmalonic acid compared with age-matched controls (p=0·003), low haemoglobin in four children, and a low serum IgA in four children.

Interpretation We identified associated gastrointestinal disease and developmental regression in a group of previously normal children, which was generally associated in time with possible environmental triggers.

Lancet 1998; **351:** 637–41

See Commentary page

Inflammatory Bowel Disease Study Group, University Departments of Medicine and Histopathology (A J Wakefield FRCS, A Anthony MB, J Linnell PhD, A P Dhillon MRCPath, S E Davies MRCPath) **and the University Departments of Paediatric Gastroenterology** (S H Murch MB, D M Casson MRCP, M Malik MRCP, M A Thomson FRCP, J A Walker-Smith FRCP,), **Child and Adolescent Psychiatry** (M Berelowitz FRCPsych), **Neurology** (P Harvey FRCP), **and Radiology** (A Valentine FRCR), **Royal Free Hospital and School of Medicine, London NW3 2QG, UK**

Correspondence to: Dr A J Wakefield

Introduction

We saw several children who, after a period of apparent normality, lost acquired skills, including communication. They all had gastrointestinal symptoms, including abdominal pain, diarrhoea, and bloating and, in some cases, food intolerance. We describe the clinical findings, and gastrointestinal features of these children.

Patients and methods

12 children, consecutively referred to the department of paediatric gastroenterology with a history of a pervasive developmental disorder with loss of acquired skills and intestinal symptoms (diarrhoea, abdominal pain, bloating and food intolerance), were investigated. All children were admitted to the ward for 1 week, accompanied by their parents.

Clinical investigations

We took histories, including details of immunisations and exposure to infectious diseases, and assessed the children. In 11 cases the history was obtained by the senior clinician (JW-S). Neurological and psychiatric assessments were done by consultant staff (PH, MB) with HMS-4 criteria.[1] Developmental histories included a review of prospective developmental records from parents, health visitors, and general practitioners. Four children did not undergo psychiatric assessment in hospital; all had been assessed professionally elsewhere, so these assessments were used as the basis for their behavioural diagnosis.

After bowel preparation, ileocolonoscopy was performed by SHM or MAT under sedation with midazolam and pethidine. Paired frozen and formalin-fixed mucosal biopsy samples were taken from the terminal ileum; ascending, transverse, descending, and sigmoid colons, and from the rectum. The procedure was recorded by video or still images, and were compared with images of the previous seven consecutive paediatric colonoscopies (four normal colonoscopies and three on children with ulcerative colitis), in which the physician reported normal appearances in the terminal ileum. Barium follow-through radiography was possible in some cases.

Also under sedation, cerebral magnetic-resonance imaging (MRI), electroencephalography (EEG) including visual, brain stem auditory, and sensory evoked potentials (where compliance made these possible), and lumbar puncture were done.

Laboratory investigations

Thyroid function, serum long-chain fatty acids, and cerebrospinal-fluid lactate were measured to exclude known causes of childhood neurodegenerative disease. Urinary methylmalonic acid was measured in random urine samples from eight of the 12 children and 14 age-matched and sex-matched normal controls, by a modification of a technique described previously.[2] Chromatograms were scanned digitally on computer, to analyse the methylmalonic-acid zones from cases and controls. Urinary methylmalonic-acid concentrations in patients and controls were compared by a two-sample *t* test. Urinary creatinine was estimated by routine spectrophotometric assay.

Children were screened for antiendomyseal antibodies and boys were screened for fragile-X if this had not been done

FIGURE 5.5.3 Above is the retracted version of the paper published by Andrew Wakefield that links the MMR vaccine with autism in children. After initial publication it was found that he did not obtain appropriate ethics approval, patients were mistreated and his results were falsified. Today Andrew Wakefield has been banned from working in medicine and the cited reason for the retraction is fraud.

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INVESTIGATION 5.5.1

Detecting fraud

When a falsified research paper is accepted for publication, it can often take some time before the fraud is detected and the paper finally retracted. This is because a complex process of checking and cross-checking must be used in order to be certain that the paper is fraudulent.

AIM

To identify the processes used to uncover a scientist that knowingly published a fraudulent research paper

MATERIALS

Relevant secondary sources to conduct the investigation. Students are to select at least one case of fraud perpetrated and published by a scientist. The weblink lists a number of cases of research fraud that could be investigated.

PROCEDURE

1 Identify a scientific research paper that has been found to be fraudulent and note the following information:
   a the scientist and the date of publication of the original paper
   b the findings of the original paper
   c the scientist and/or discrepancies that alerted other scientist to the potential fraud
   d the method used to check and verify the fraud
   e the final consequences for the fraudulent scientist and their paper/s.

RESULTS

Write a report or timeline detailing how the fraud was uncovered and the eventual consequences for the scientist.

DISCUSSION

1 Describe the reasons why the identification of fraudulent research papers often takes so long.
2 Suggest ways in which the detection of fraudulent papers can be improved prior to publication. What implications would this have for the practice of the wider community of scientists?

5.5.3 The ten greatest cases of fraud in university research

Ever-increasing volumes

Science is an ever-expanding field, with more people being trained in and actively researching in science every year. Though this is a good thing, it does come with some inherent problems, the biggest of which is the sheer number of research investigations that are submitted and published every year. In 2014, there were an estimated 2.5 million science papers published in an estimated 28 100 active peer-reviewed journals.

The scientific and wider community expect that each year, all 2.5 million of these research papers are peer reviewed before they are published. However, a scientist needs to be of **reputable** standing and already have been published and cited widely to be requested to do peer reviews for a reputable journal. The result is that there are not enough scientists peer reviewing, particularly when we consider that one paper is expected to be reviewed by at least three scientific peers. The result is that reviewers find it exceptionally difficult to keep up with the reading required to be able to effectively manage and review the number of papers required. The result is that an increasing number of papers that cannot be reproduced, are misleading and even fraudulent are reaching the publication stage.

The volume of journal articles is compounded by the increasing number of '**open access**' or 'pay-to-publish' journals, some of which have a reputation as predatory publications that claim to be peer-reviewed journals but whose standards are not transparent or accountable.

reputable to be seen as well respected and trusted

open access a journal that allows scientific researchers to pay to have their paper published

predatory journals a class of open-access journals that solicit money, often from inexperienced research scientists that want to get their paper published, but do not enforce the recognised cross-checking processes such as peer review to ensure scientific rigour

reproducibility crisis a phenomenon where the number of research papers being published cannot be reasonably cross-checked by reproducing the investigation and/or that insufficient replication is being done before publication

5.5.4 An overview of scientific and scholarly journal publishing

5.5.5 1500 scientists lift the lid on reproducibility

5.5.6 Maggie Simpson and Edna Krabappel are publishing scientific papers now

5.5.7 Spears: how my fake science paper earned me a shot at an editor's job

5.5.8 Cold fusion: a case study for scientific behaviour

5.5.9 Explainer: what is peer review?

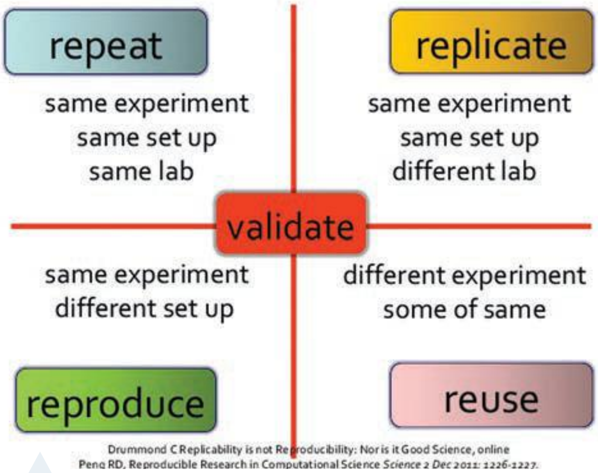


FIGURE 5.5.4 The conditions a research paper must be able to meet if it is to be considered valid research.

To illustrate the lack of rigour in the peer-review process in suspected **predatory journals** a number of people have deliberately published a number of openly fraudulent research papers. These include the paper submitted by scientist Alex Smolyanitsky under the names Maggie Simpson and Edna Krabapple (characters from 'the Simpsons' cartoon series) to the pay-to-publish *Journal of Computational Intelligence and Electronic Systems* and the *Aperito Journal of Nanosceince* in 2014. As well, a nonsense paper submitted to a pay-to-publish journal by Tom Spears, which not only accepted his paper but asked him to be a guest editor (peer reviewer).

Even after the whittling down process of peer review, there are still massive volumes of research papers being published. This means that scientist in their various fields are finding it exceptionally difficult to manage the reading required to keep up with the number of papers being published in their field. Even when they do manage to keep up with the amount of reading required, if they find an article they have an issue or concern about, or even admire, there is an expectation that they write a review on the work to highlight the issues for other scientists. This creates increasing pressure for scientists to verify the work of their peers by conducting replication investigations, even as they try to do their own research. The result has been termed a **reproducibility crisis**, with a survey of 1500 scientists showing that 52 per cent agree that there is a significant crisis.

The benefits of peer review

As problematic as the sheer volume of published articles and the emergence of predatory journals is, the peer-review process is still the most trusted means of cross-checking and verifying the authenticity of a research paper prior to publication.

The established protocols around peer review demand that a scientist's ideas and work are judged by other scientists who work in the same field. The alternative is that the work be judged by others who are potentially more open to being manipulated for political or economic gain. The process is also further improved through the use of 'blind' peer review in which the reviewer does not know the name, and hence the reputation, of the author of the paper. In this way, the paper can be judged only on its merits without bias from the reviewer.

It must also be noted that scientists who do peer reviews are not paid. On principle, the scientific community does not support paying scientists to review research papers. This is because payment can lead to the potential for bribes or misconduct, particularly if a reviewer is paid for each journal article they review. Such incentives could tempt a researcher to only give a cursory review of the paper in return for payment rather than the rigorous review that is required.

The journal publisher can also provide an indication of the quality of the peer review. Over time, scientific journals have developed a hierarchical structure due to the quality and validity of the research papers they publish. Highly reputable journals are widely read and typically have rigorous standards in the reproducibility and accuracy of their papers, in part because their reviewers are carefully vetted. Less reputable journals, though they may be publishing genuine scientific work, do not meet standards that are as rigorous and their reviewers are often less experienced.

Though there are known and identified flaws and problems with the peer-review process, very few viable alternatives have come forth. However, a more recent conception of peer review has arisen as an outgrowth of digital publishing and social media. Today almost all journals publish their research papers online, which allows other scientists to comment on and review the paper after publication. If online comments and reviews are available for all readers to see and they are used extensively as a form of peer review, it will help to limit and eliminate misleading and fraudulent research papers. As yet the debate is still continuing on the legitimacy of **post-publication peer review**, a debate that is not likely to be settled until, or unless, reliable online platforms are built for the process, though there are numerous publishers working on the issues.

post-publication peer review a process of peer review that is done after the publication of the research paper that utilises the flexibility of online media

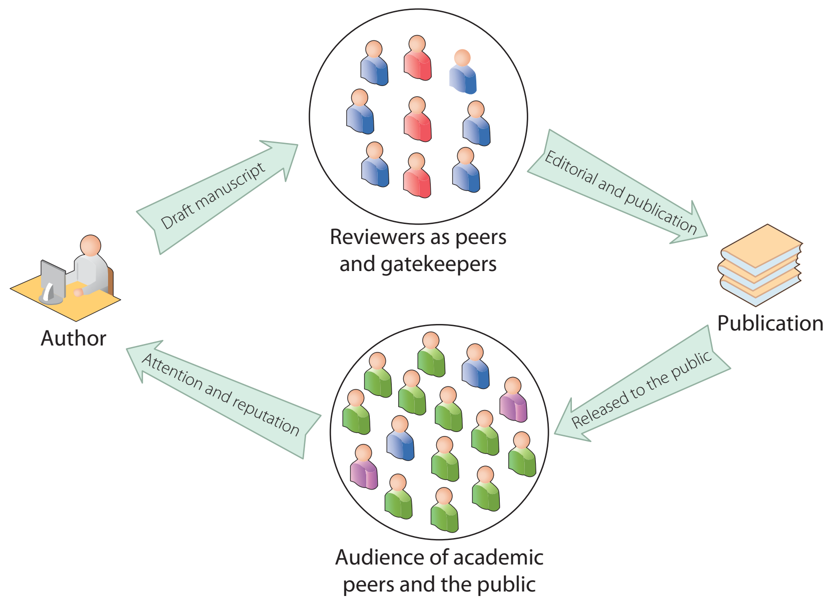


FIGURE 5.5.5 This image represents a traditional interpretation of the peer-review process where a paper must pass the peer review 'gatekeepers' prior to publication. Once the paper is published, the academic audience and public's reference to and citations of the paper helps build the reputation of the author.

Predatory and fake journals

Over the last 10 to 15 years, an ever-increasing number of open access and pay-to-publish journals have appeared online. The digital environment means that there are far fewer barriers to starting a journal.

Every year, reputable publishers reject a significant number of journal articles, while the requirement and fierce competition for scientists to publish is unabated. This creates a demand that open access journals quickly and easily step into. A good majority of these journals try to do the best by the scientists that submit research papers, but unfortunately the temptation to exploit inexperienced and desperate scientists seeking to publish has been too tempting for some, particularly those that require scientists to pay before they will publish the paper. As such, a significant number of predatory and fake journals have emerged, most with very official sounding names.

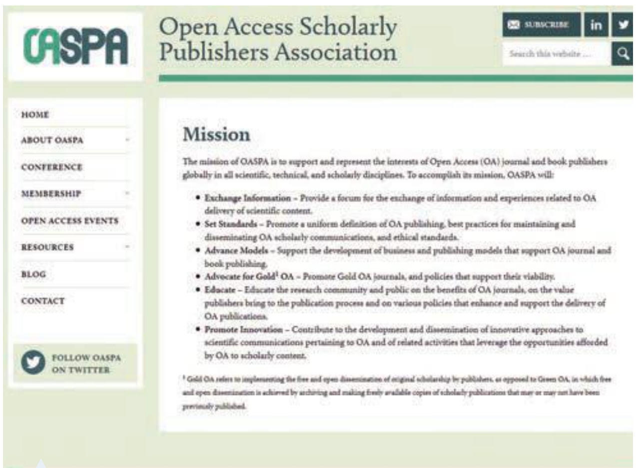


FIGURE 5.5.6 The mission statement of the Open Access Scholarly Publishers Association. Associations and organisations like these advance policies and procedures to help eliminate predatory journals.

5.5.10 Predatory journals recruit fake editor

5.5.1 Science as self-correcting – the issues

This problem is compounded by the fact that predatory publishers often have substandard editing and may not have any peer-review process. The consequence is that a significant number of articles that are fraudulent or plagiarised are published under the auspices of genuine science. This damages the public's trust of published journal papers and threatens to harm the reputation of science and of the government policies that are based on scientific evidence.

Scientists and research institutions around the world are attempting to put measures in place to counter the prevalence and effect of predatory journals by introducing more transparent peer review (including post-publication review) and by establishing the non-profit Committee on Publication Ethics and the Open Access Scholarly Publishers Association, journal review websites and awareness campaigns.

SECTION REVIEW 5.5

REMEMBERING

1 Describe 'publish or perish' as it applies to a scientist hoping to achieve or retain a research position for employment.

UNDERSTANDING

2 Describe the benefits and limitations of the peer-review process.

3 Over 50 per cent of scientists in various fields believe there is a significant reproducibility crisis. Outline the 'reproducibility crisis' and explain why scientists are concerned about it.

APPLYING

4 Kolya is looking to publish a research investigation on pollution levels in the local river. Describe the verification and peer-review processes the investigation and paper would have to undergo from the start of the investigation right up to after it was published in a journal.

5 Explain how the incentive structure of most modern scientific research institutions can lead to a proportion of scientific journals being found to be fraudulent. Propose at least two measures that could be taken to reduce the likelihood of fraudulent research investigations being published.

CHAPTER REVIEW QUESTIONS

KNOWLEDGE

1 Identify what it means when a person or organisation makes a 'claim to truth'.

2 Define 'bias' and describe one way in which an investigation can be biased.

3 Outline one example where people have mistaken correlation for causation.

4 Identify two examples of a pseudoscience and the claim of cause and effect associated with them.

5 Describe the features that can be used to classify a journal as 'fake' or 'predatory'.

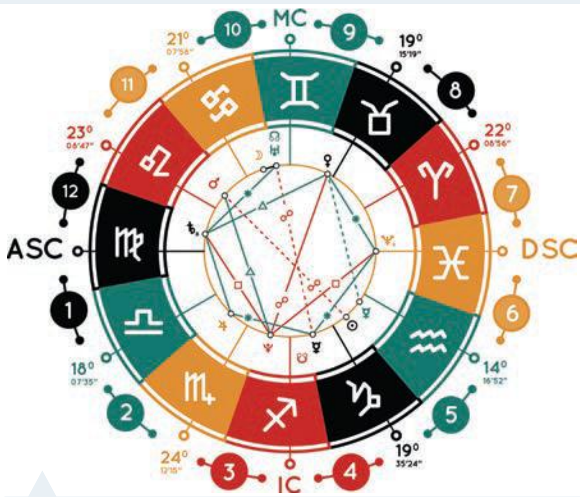
COMPREHENSION

6 A term in science often has different meaning from the same word in common language. Explain why such language differences can occur.

7 Describe the ways in which a scientist can minimise the chances of statistical bias when conducting an investigation.

8 Describe the incentives that can lead a company or industry to ignore the findings and advice of science and maintain their current business practices.

9 Figure 5.6.1 is used in the pseudoscience of numerology. Describe the features of this chart that make use of specific terminology and symbolism to give a sense of authenticity.



Alamy Stock Photo/Maxim Pavlov

FIGURE 5.6.1 A numerology chart

10 Describe two reasons why members of the public may not accept the evidence presented to them on a scientific issue.

APPLICATION

11 Ronald wanted to test what effect adding nitrate- and phosphate-based fertilisers had on the growth of his tomatoes in order to get the best crop. Design a controlled investigation, with consideration to sample selection and size, that Ronald could use to find out which fertiliser, or combination of fertilisers, would best promote the growth and production of his tomatoes.

12 Some food producers promote their foods as being healthy through the use of branding and the halo effect. Imagine you were an advertiser hired to promote a health food, then make a recommendation on the types of brand symbols you would use and/or people you would employ to sell the product to consumers.

13 Peter hypothesised that listening to loud rock music while driving had a negative effect on a person's reactions times and subsequent ability to brake in times of danger. To test this, Peter conducted the investigation by playing loud rock music with three friends and asking them to catch a ruler he dropped between his index finger and thumb as seen in Figure 5.6.2.

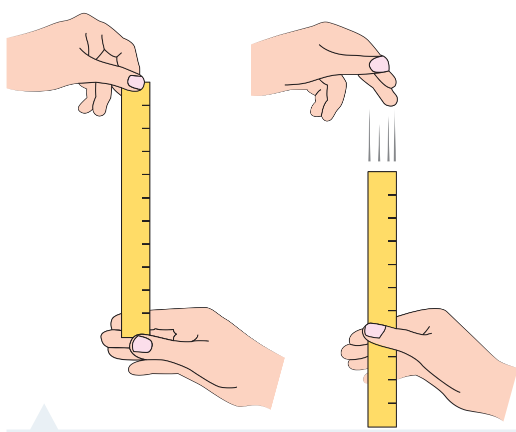


FIGURE 5.6.2 A reaction-time test using a ruler

However, when he went to do the control trial, a number of other students had come to watch how Peter's friends would go at doing the rule drop. Peter then analysed the results and found there was no significant difference between listening to loud music and not listening to loud music. When Peter consulted with his teacher, his teacher suggested that his results may have been influenced by the presence of the other students. Explain why the results could have been influenced and what Peter would need to do to ensure they were not influenced when he repeated the investigation.

ANALYSIS

14 Evaluate the conflicts of interest in the tobacco industry and the asbestos mining industry that led to these industries failing to act on scientific evidence that cigarette smoke and asbestos fibres were harmful to human health.

15 Double-blind trials are often considered the 'gold' standard of scientific research. Describe the reasons why double-blind trials are often considered better than other types of investigations.

16 The meme in Figure 5.6.3 illustrates an issue that can influence the public's perception of a scientific issue. Identify the type of influence and the perceived impact it is having on the perception of people around the climate change issue.

Alamy Stock Photo/Photo 12

FIGURE 5.6.3 A climate change meme

SYNTHESIS

17 The following quote was taken from the article *Predicting who will publish and who will perish as career academics* on The Conversation website.

> Publishing scientific papers is a complex and challenging skill, and once a young scientist begins mastering this process, their path gets less rocky. It becomes easier to get other papers accepted, to win grants and fellowships, and to gain more research opportunities.
>
> Small differences early in a career can snowball into much greater differences over time. For the biologists and environmental scientists we studied, the number of papers they published over their careers varied hugely, by over a hundred-fold.

From your understanding of the publish or perish phenomenon and with reference to the above quote, explain why it is recommended that young scientists begin publishing scientific papers as soon as possible in their careers.

18 Two patients came to an emergency department after each fell and fractured their ankle. One patient was a woman in her mid-thirties who fell while going down the stairs at her job as an office assistant; the other was a teenage boy who fell while riding his skateboard. The woman was treated by X-raying the ankle and putting it in plaster it to stabilise the fracture. The boy's treatment was a recommendation to ice and rest the ankle, take some pain medication, and to return if the pain didn't settle. He did return, at which point the ankle was then X-rayed and found to be fractured and a plaster applied to stabilise the fracture.

Explain the most likely reason why the two patients that came to the hospital with the same condition received different treatments. Suggest how such discrepancies in treatment can be avoided in future.

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EVALUATION

19 Figure 5.6.4 demonstrates the importance of the use of confidence intervals when evaluating and analysing data. The data compares global average temperatures from a number of different sources between 1951 to 1997 and 1998 to 2014. Evaluate the likely impact the data would have on the public perception of climate change if the bars indicating the confidence interval had not been included in the graph.

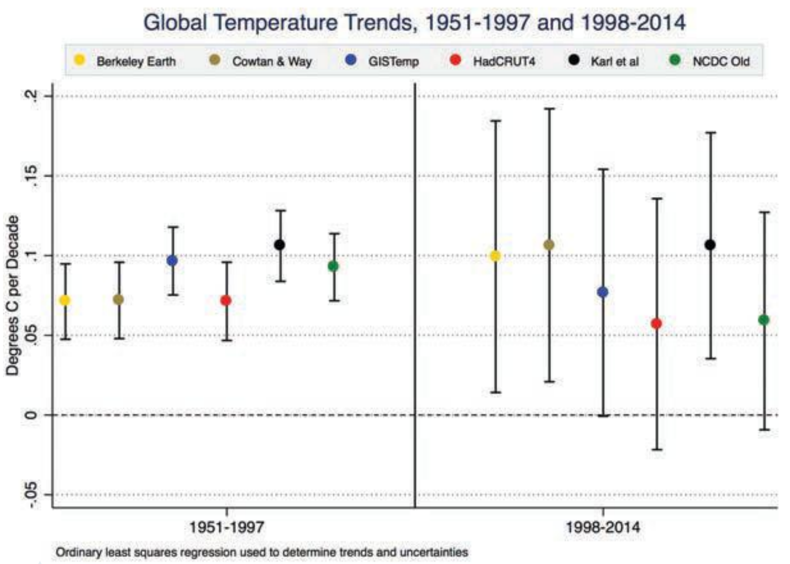

FIGURE 5.6.4 Global temperatures and the associated confidence intervals from various climate research centres and scientists over the 1951 to 1997 and 1998 to 2014 periods.

20 In April 2017, the Journal *Tumour Biology* announced that it would be retracting 107 research papers due to 'fake peer review'. The problem has occurred because 'authors are often asked to suggest potential reviewers for their own papers. This is done because research subjects are often blindingly niche; a researcher working in a sub-sub field may be more aware than the journal editor of who is best-placed to assess the work.'

Evaluate the reasons why a research scientist would go to such lengths to submit a fraudulent paper and then organise a fake peer review to ensure that the paper was published. Describe how the publication and peer-review process may benefit from post-publication peer review, journal review websites, awareness campaigns and not-for-profit associations organised around this issue to minimise the publication of fraudulent research.

DEPTH STUDY
BIOLOGY

STEREOTYPES IN MEDICINE

Suggested length: 8 hours including research, first-hand investigation and presentation

Focus: Primary investigation

5.6.1 Primary investigation scaffold

PRIMARY INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Syllabus statement: Selects and processes appropriate qualitative and quantitative data and information using a range of appropriate media to evaluate the impact of societal and economic influences on the collection and interpretation of data in medical treatment.

Introduction

This is the background information about the topic. In a primary investigation, identify the experiment you will be conducting. In a secondary investigation, make sure your sources are valid.

Hypothesis (if applicable)

A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on.

To investigate the different experiences people of different social/gender/ethnic backgrounds have when being treated for a medical condition.

5.6.1 Unconscious bias
5.6.2 Questionnaire design

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references:

- Blair, I. V., Stiener, J. F. & Havranek, E. P. (2011), Unconscious (implicit) bias and health disparities: Where do we go from here? *The Permanente Journal.*
- Deakin University. (NA) Questionnaire Design.

Investigation design

Outline how you will design the investigation and the final presentation. (Refer to Chapter 2 for further information.)

Procedure

The procedure is written as numbered steps. Each sentence must start with a verb.

Students design a questionnaire to gather data on the various experiences that different people of different social, gender and ethnic background have when they come into contact with the medical community for treatment

Results

The results may be recorded in tables or graphs, or a written recording of individual responses.

Validity and reliability

Remember that validity is related to the procedure and equipment used to perform your experiments, and reliability is associated with the repetition of the experiment obtaining similar results with minimal error.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your hypothesis and aim.

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USING DOUBLE-BLIND TRIALS AND CONTROL GROUPS

DEPTH STUDY
CHEMISTRY

Suggested length: 8 hours including research and slide presentation

Focus: Primary investigation

5.7.1 Primary investigation scaffold

PRIMARY INVESTIGATION SCAFFOLD
Syllabus outcome Identify the syllabus outcome you will be investigating and write a summary of the outcome. *Syllabus statement: Uses double-blind trials and control groups to design and evaluate an investigation in order to obtain primary data and information and draw valid conclusions.*
Hypothesis (if applicable) A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.
Aim Write the aim as a sentence. Start the sentence with 'To' followed by a verb, such as 'investigate', 'measure', 'test' and so on. *To design an investigation that uses double-blind trials and/or control groups in determining the effectiveness of a washing powder for stain removal.*
Secondary sources List all the sources you have used in your investigation and cite them using the correct protocols. See weblinks for suggested references: ▪ Shuttleworth, M. (2008), Double Blind Experiment. ▪ Canstar Blue (2017), Laundry powder reviews.
Investigation design Outline how you will design the final presentation. (Refer to Chapter 2 for further information.)
Procedure The procedure is written as numbered steps. Each sentence must start with a verb. Suggested steps: 1 Identify a number of different laundry powder brands that you could use for the trial. 2 Design the investigation and select research participant/s willing to apply the designated treatments and make an evaluation on the effectiveness of the various treatments. 3 Collect and analysis the results. 4 Present findings and make a recommendation on the most effective laundry detergent.
Results The results may be recorded in tables or graphs, or written as observations in sentence form.
Validity and reliability Remember that validity is related to the procedure and equipment used to perform your experiments, and reliability is associated with the repetition of the experiment obtaining similar results with minimal error.
Discussion and conclusion In the discussion and conclusion, analyse your findings to answer your hypothesis, aim and inquiry question/s.

5.7.1 Double-blind experiments

5.7.2 Laundry powder reviews

DEPTH STUDY
PHYSICS

FRAUDULENT RESEARCH IN THE PHYSICAL SCIENCE: IS IT A PROBLEM?

Suggested length: 8 hours including research and submission of report

Focus: Secondary-source investigation

WS
5.8.1 Secondary investigation scaffold

SECONDARY-SOURCED INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Syllabus statement: Analyses and evaluates primary and secondary data and information to uncover a scientist/s who has falsified their scientific experimental results in the field of physics, and discuss the process used to uncover the fraudulent research.

Hypothesis (if applicable)

A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb such as 'investigate', 'measure', 'test' and so on.

To investigate the recorded incidences of fraudulent research such as Pons and Fleischmann's cold fusion announcement in 1989 and describe the incentive structures and conditions that lead to this research becoming 'famous'.

5.8.1 Cold fusion: a study in scientific controversy

5.8.2 Genies in a jar – the 'discovery' of cold fusion

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references

- Chung, D. (2015), Cold Fusion: A study in scientific controversy. *Stanford University*.
- Dewdney, A. K. (1997), 'Genie in a jar – the discovery of cold fusion'. Nu Energy Research Archive.

Investigation design

Outline how you will design the final presentation. (Refer to Chapter 2 for further information.)

Procedure

The procedure is written as numbered steps. Each sentence must start with a verb. Suggested steps:

1 describe the initial reporting of the cold fusion 'success'
2 identify the flaws in the research finding that lead to Pons and Fleischmann's work being discredited
3 investigate the incentive structures that lead to fraudulent research being published.

Results

The results may be recorded in tables, graphs or diagrams, and a written report.

Validity and reliability

Remember that validity is related to ensuring that the sources come from educational, government or scientific websites, journals and textbooks. Reliability is associated with finding similar explanations of the concepts across many sources.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your hypothesis and aim.

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ENVIRONMENTAL IMPACTS OF SCIENCE DENIAL

DEPTH STUDY
INVESTIGATING SCIENCE

Suggested length: 8 hours including research and submission of video production (mock film documentary festival)

Focus: Secondary-source investigation

SECONDARY-SOURCED INVESTIGATION SCAFFOLD
Syllabus outcome Identify the syllabus outcome you will be investigating and write a summary of the outcome. *Syllabus statement: Evaluates a scientific problem using secondary data, critical thinking skills and scientific processes to examine a contemporary scientific debate and how it is portrayed in the mainstream media.*
Hypothesis (if applicable) A hypothesis is an educated (informed) guess that is tested through investigation to explain and reach answers to scientific questions.
Aim Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on. *To investigate how conflicting interest groups and subsequent reporting in the media have impacted the ability for people to effectively combat ecological problems.*
Secondary sources List all the sources you have used in your investigation and cite them using the correct protocols. See weblinks for suggested references: ▪ Susskind, Y. (2007), 11 solutions to halting the environmental crisis, Alternet. ▪ Manne, R. (2015), 'Diabolical: Why we have failed to address climate change', *The Monthly*.
Investigation design Outline how you are designing the final presentation. (Refer to Chapter 2 for further information.)
Procedure The procedure is written as numbered steps. Each sentence must start with a verb. Suggested steps: **1** Research about the history of an ecological problem that has conflicting interest and had media coverage. **2** Find out who are the stakeholders in the problem and identify their roles. **3** Review how the media has covered the issue in the past and up to the present day. **4** Assess the reasons why progress on the issue is slow and not moving as fast as is required to solve the ecological problem. **5** Make recommendations to overcome objections and make progress to solve the issue.
Results The results may be recorded in tables, graphs, video and images, as well as written as observations in sentence form.
Validity and reliability Remember that validity is related to ensuring that the sources come from educational, government or scientific websites, journals and textbooks. Reliability is associated with finding similar explanations of the concepts across many sources.
Discussion and conclusion In the discussion and conclusion, analyse your findings to answer your hypothesis and aim.

WS
5.9.1 Secondary investigation scaffold

5.9.1 Eleven solutions to halting the environmental crisis

5.9.2 Diabolical: Why we have failed to address climate change

6

MODULE 8 SCIENCE AND SOCIETY

The cultural norms of society fluctuate over time and, in response, so too does the direction of scientific inquiry. Government budgets and the scarcity of funding mean that investments in scientific research are directly influenced by the most dominant social issues of the time and are therefore subject to certain political pressures. The undeniable link between politics, investment agencies and scientific research may introduce an element of bias into the areas of science eligible for research grants. The potential for such bias must be recognised and accounted for when analysing and reviewing scientific literature.

INQUIRY QUESTIONS

- How do science-related events affect society's view of science?
- Why does scientific research need to be regulated?
- How is the direction of scientific research influenced by the economy, society and politics?

CONTENT

Students investigate:

- incidents, events and science
- regulation of scientific research
- influence of economic, social and political forces on scientific research.

OUTCOMES

A student:

- analyses and evaluates primary and secondary data and information INS11/12-5
- solves scientific problems using primary and secondary data, critical thinking skills and scientific processes INS11/12-6
- communicates scientific understanding using suitable language and terminology for a specific audience or purpose INS11/12-7
- evaluates the implications of ethical, social, economic and political influences on science INS12-15

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Getty Images/Stone/Zomi

6.1 Incidents, events and science

History has confirmed that when public health and safety are at risk, authorities turn to science for an answer. Vaccination programs, the development of elaborate flying machines and environmental initiatives such as river damming have all benefited the way societies function. However, when science is the cause of a national disaster, it is possible for society to lose confidence in the advantages of scientific technology. Over the last century, there have been many times when science has seemed to fail society. Regaining trust and attempting to rebuild a positive public image has proven to be difficult in cases such as nuclear meltdowns and disease outbreaks.

nuclear fission
a nuclear reaction where energy is released from splitting atoms

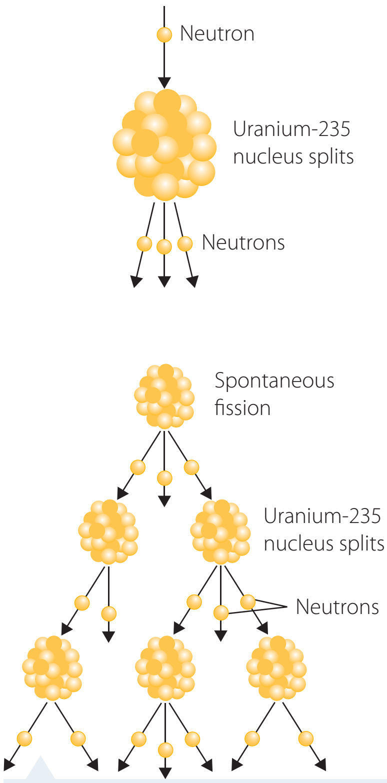

FIGURE 6.1.1 Nuclear fission is an alternative process used to generate electricity through the splitting of uranium atoms.

Nuclear reactors

Nuclear reactors generate energy through a process called **nuclear fission.** Shown in Figure 6.1.1, nuclear fission generates heat from the splitting of uranium atoms; the heat produces steam, which is used by a turbine generator to generate electricity. Nuclear reactors are made up of many pressure tubes and a control rod is inserted into each to control the rate of fission. The selling point of using nuclear fission to generate electricity is the absence of greenhouse gas emissions. However, as beneficial as nuclear energy may have appeared when it was first produced, scientists of the time did not foresee the implications that would occur if anything went wrong.

Chernobyl incident

The Chernobyl nuclear meltdown of 1986 could possibly be the most famous example of science gone wrong. The incident occurred as a combined result of flawed reactor design, insufficient staff training and communication, and a failure to adequately follow safety regulations.

How it happened

Pictured in Figure 6.1.2, the RBMK 1000 reactor was going through a series of tests to determine how long it could run following a cut of mains power before a routine shut down. During the tests, operators with inadequate training disabled the automatic shutdown mechanisms and, when the reactor was found to be in an unstable condition, there was not enough time to disable it manually. Increased pressure in one of the tubes resulted in the destruction of the nuclear reactor core and, eventually, two large explosions. The explosions killed two workers directly and released radioactive products of nuclear fission into the atmosphere. The reactor then continued to release toxic products into the atmosphere for about 10 days. The incident in Chernobyl was the largest uncontrolled release of radioactive products ever recorded.

The implications to society

Summarised in Table 6.1.1, the nuclear meltdown at Chernobyl caused both short- and long-term implications to society. Immediately following the release of radioactive products, an exclusion zone was established and over 116 000 people had to be relocated from the most heavily contaminated areas in various towns across Ukraine, Belarus and Russia. During the clean-up, over 80 exposed workers and other personnel contracted acute radiation syndrome (ARS) which lead to their death.

6.1.1 Chernobyl accident 1986

6.1.2 Scientific study finds Chernobyl may not have happened as we thought as Russia suffers another nuclear spike

6.1.3 Animals rule Chernobyl three decades after disaster

6.1.4 A long look at the Chernobyl disaster

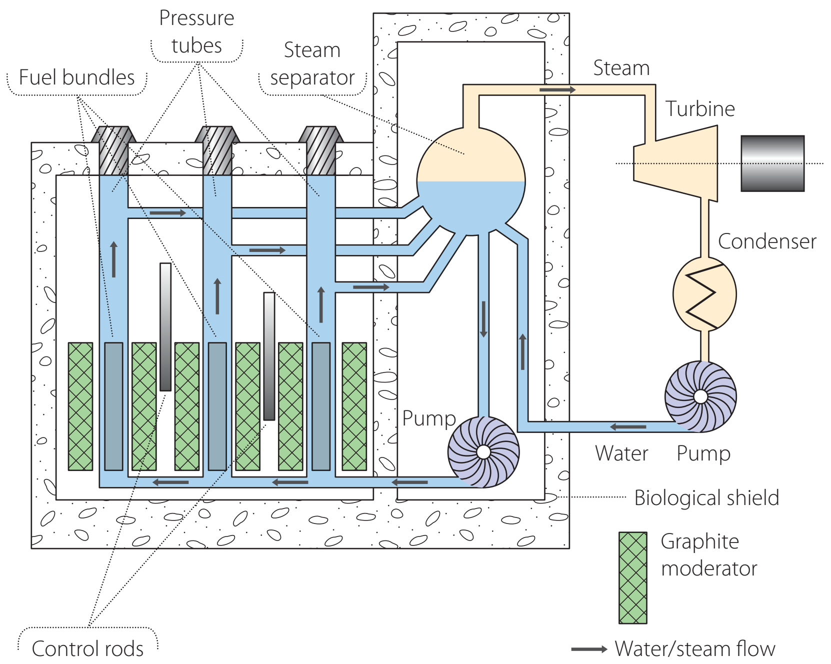

FIGURE 6.1.2 RBMK 1000 was the nuclear reactor that caused the meltdown at Chernobyl. An interaction between hot uranium fuel and cooling water caused in increase in pressure and steam production, which created two large explosions and the release of radioactive products into the atmosphere.

TABLE 6.1.1 The nuclear meltdown at Chernobyl had a number of implications on society, both short- and long-term.

SHORT-TERM IMPLICATIONS TO SOCIETY	LONG-TERM IMPLICATIONS TO SOCIETY
▪ Immediate relocation of those living within 30 km of the nuclear plant site ▪ Pressure on healthcare system from the hospitalisation of people who suffered acute radiation syndrome ▪ Loss of income for power plant workers and others who earned a living through agriculture in the surrounding areas	▪ International spread of radioactive products over almost 30 countries ▪ Accumulation of radioactive compounds such as plutonium, iodine and strontium in food chains and water sources ▪ Continued pressure on healthcare by those who require ongoing treatment for cancers attributed to radiation exposure ▪ Ongoing threats to agricultural industry

Within 15 years of the Chernobyl incident, there were some 4000 recorded cases of thyroid cancer in children of the surrounding areas. The cancers occurred as a result of over-exposure to radioactive iodine that, as depicted in Figure 6.1.3, could have been introduced to the body by a number of factors. In the overwhelming number of cases of thyroid cancer in children, it is believed that the cause may have been through their consumption of milk. The radioactive iodine was deposited over the pastures of surrounding farms and cows grazing on the pastures accumulated the radioactive product in their milk, which was subsequently bottled and distributed to nearby communities. Early detection allowed most children to be successfully treated for thyroid cancer, however, this placed significant pressure on the healthcare system at the time.

Another result of radiation is mutation, as shown in Figure 6.1.4. The ingestion of radioactive products may cause errors during DNA replication and can result in mutations producing cells that undergo rapid division.

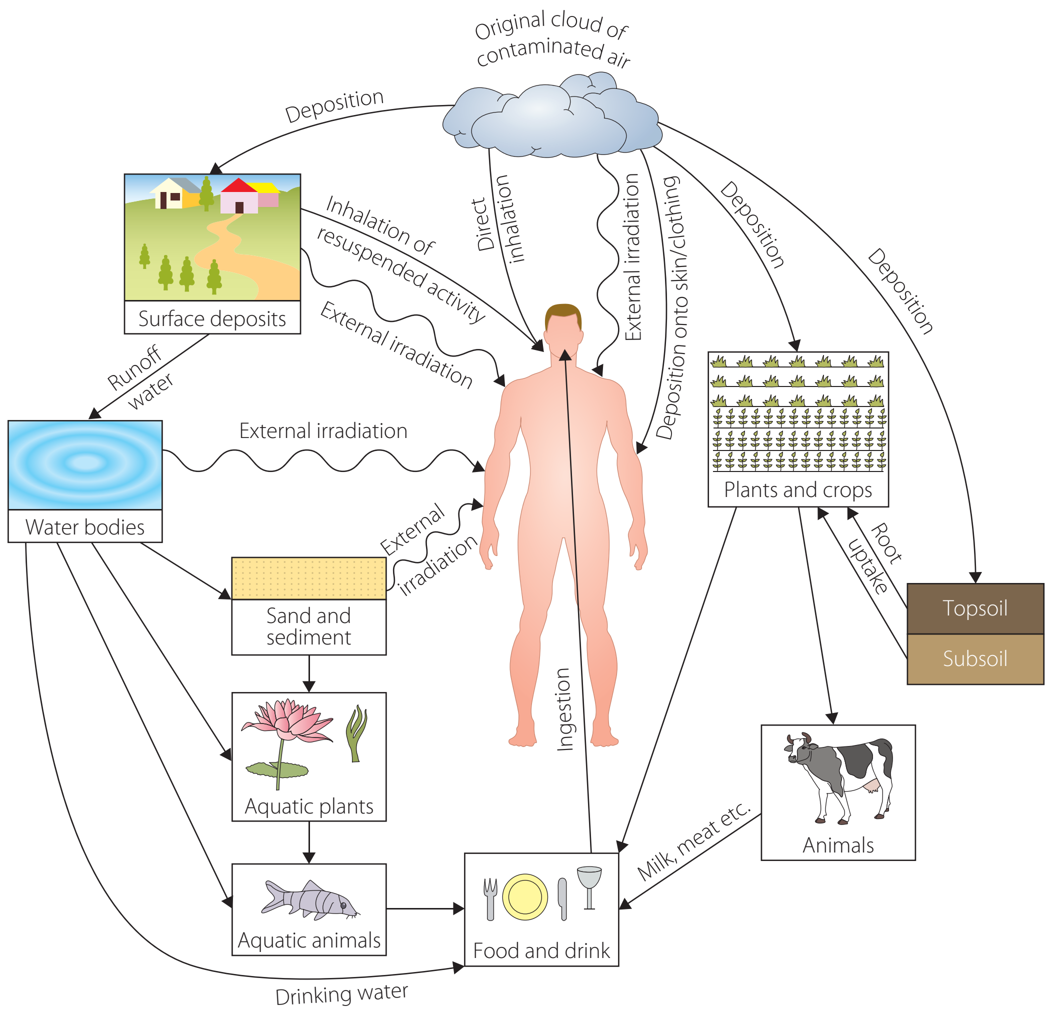

FIGURE 6.1.3 Once released into the environment, humans can be exposed to radioactive products in a number of ways. Once deposited, radioactive compounds accumulate in foodstuffs, which is subsequently ingested. Inhalation and irradiation of suspended particles are also a pathway for human exposure.

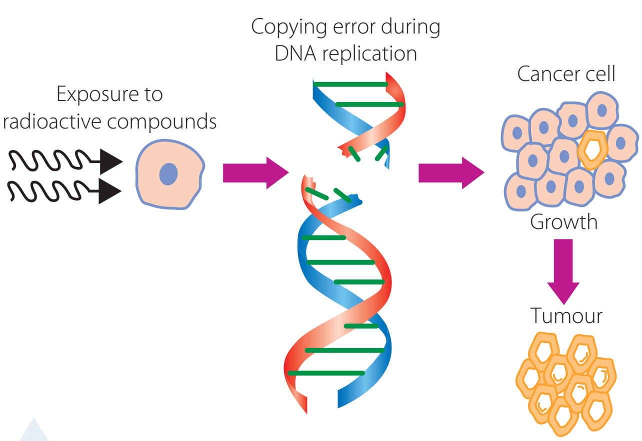

FIGURE 6.1.4 Cell mutation caused by radiation.

Mutations in exposed fauna

For many populations of fauna, the absence of human civilisation made the abandoned area an idyllic territory to populate. While some species appear to be thriving, others have succumbed to the radiation and experienced detrimental genetic changes. For example, within four years of the disaster, over 350 animals on farms surrounding the affected area were found to have serious congenital deformities such as missing or extra limbs, deformed skulls and missing eyes. The pig shown in Figure 6.1.5 is an example of the 'Chernobyl effect'.

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Getty Images/Hulton Archive/Martin Godwin

FIGURE 6.1.5 Many animals exposed to the radiation in-utero were born with life-ending or compromising mutations. This preserved pig is now displayed at the Chernobyl National Museum in Kiev, Ukraine as a reminder of the implications of the nuclear disaster.

INQUIRING FURTHER

The Chernobyl incident was not the only nuclear disaster that had serious social implications. Research the Fukushima Daiichi nuclear disaster that occurred on 11 March 2011. Compare and contrast the disaster at Chernobyl with the disaster at Fukushima. Present the research in an audio-visual format of your choice.

Vaccination

Vaccination is the process used to establish immunity to specific diseases through inoculation with a **vaccine**. Now embedded into the values and healthcare protocols of most developed societies, vaccination is responsible for saving millions of lives every year. The techniques used to vaccinate today are a product of collaboration between scientists and many years of trial and error. Almost two centuries passed between the first attempt to vaccinate and the development of modern vaccination.

As vaccination techniques developed the process became the subject of social debate and, despite the scientific evidence, continues to polarise opinions to this day. Shown in Figure 6.1.7, the controversial technique often involves introducing weakened strains of an infection through a serum injected intramuscularly. The body carries out an immune response to the weakened infection and through this, produces antibodies that can be released if the individual is exposed to the disease in the future.

Getty Images/E+/Imgorthand

FIGURE 6.1.6 From its initial introduction in 1796 until now, vaccination has been at the centre of public opinion.

vaccine
a weakened form of an antigen (or a synthetic substitute) that initiates an immune response to stimulate the production of antibodies and provide immunity to the targeted disease

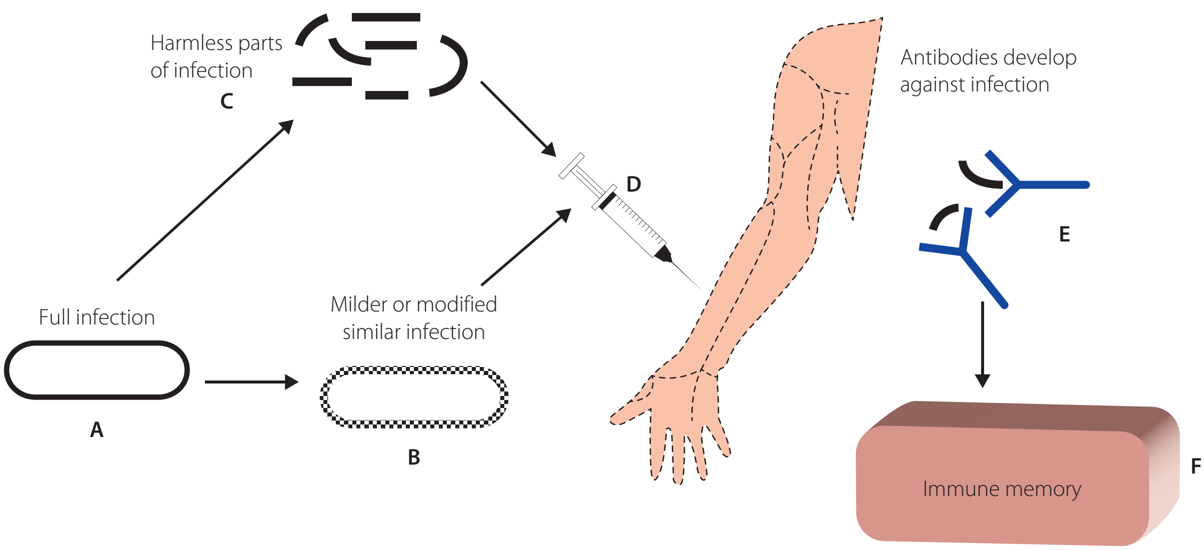

FIGURE 6.1.7 Vaccines can be produced by separating and injecting the harmless components of an infection or by injecting a modified form of the infection. In both cases, the vaccine initiates an immune response that helps form memory cells able to recognise and combat a harmful infection more effectively.


Alamy Stock Photo/David Cole

FIGURE 6.1.8 Smallpox was a debilitating viral disease, responsible for hundreds of millions of deaths.

incubation period the period of time between initial exposure to an infection and the appearance of symptoms


Alamy Stock Photo/Everett Collection Historical

FIGURE 6.1.9 Eight-year-old James Phipps was Jenner's first vaccination patient.

The first vaccine – smallpox

After causing hundreds of millions of deaths in the 20th century alone, smallpox was one of the first infectious diseases to be eradicated globally via vaccination.

Smallpox is a highly contagious disease caused by a virus that hijacks a cell and uses the cytoplasm to multiply. Once infected, the **incubation period** lasts between one and two weeks, then individuals experience increased body temperature, vomiting, nausea, abdominal cramps, severe back pain, chills and headaches. As the initial symptoms start to subside, a rash appears on the face and then spreads to the hands, arms and torso. Shown in Figure 6.1.8, the rash eventually develops into blisters filled with fluid and pus which break open and leak the highly contagious virus. Although the precise cause of death from the smallpox virus is still unknown, it involves the destruction of organs including the liver and spleen. Before vaccines were developed, there was no effective treatment for the disease.

As smallpox developed into an epidemic, it placed pressure on healthcare facilities and generated fear in members of society. The lack of treatment sparked scientific investigation into possible ways to combat the disease. Prior to vaccination, treatment attempts were made through herbal remedies and 'cold treatment' where rooms were left with windows open throughout the night and patients were advised against wearing any clothes above the waist.

As with many scientific breakthroughs, the answer to the smallpox epidemic came from a simple observation. In the late 18th century, Edward Jenner observed that milkmaids exposed to a similar condition in cows, aptly named cowpox, did not appear to have any symptoms of smallpox. Following this observation, Jenner formulated his first experiment. He extracted pus from a cowpox pustule and inserted it into an incision on eight-year-old James Phipps' arm. Controversially, Jenner later exposed Phipps to smallpox, which was particularly contagious among young children, and observed no symptoms of the disease.

Jenner regarded his own experiment as a success, but the Royal Society in the UK rejected his findings, claiming there was a lack of evidence. Jenner continued experimenting on many children including his own 11-month-old son, with consistent success. His findings were published three years after his initial inoculation of Phipps, where he coined the term 'vaccine' from the Latin 'vacca', meaning cow. However, despite Jenner's claims being evidence-based, it would be almost 200 years and hundreds of millions of deaths before the smallpox vaccine was accepted and the disease eventually eradicated.

INQUIRING FURTHER

Propose reasons why Jenner's use of an infant to support his hypothesis would be deemed unethical today.

Why did eradication of smallpox take so long?

At first, Jenner was widely criticised for his 'repulsive' technique that involved inserting material from a diseased animal into a seemingly healthy individual. As an example of his notoriety, Figure 6.1.10 depicts a caricature showing those who were vaccinated sprouting cow-like appendages. However, it wasn't long before doctors across Europe and the Americas adopted his innovative technique. Further refinement and experimentation with vaccination saw a dramatic decline in those suffering from the devastating disease and gave hope to the future of world health.

Subsequent to the initial reduction in smallpox cases, a more virulent strain of the disease emerged and caused two major outbreaks in the early 1900s. In 1958, the World Health Organization (WHO) launched a $2.4 million immunisation campaign as an attempt to globally eradicate the disease. Due to limited resources and insufficient supplies of the vaccine in some developing countries, the mission proved difficult to achieve. Although it took longer than expected, in 1980 all strains of the disease were eventually declared eradicated by WHO.

imagefolk/Mary Evans Picture Library

FIGURE 6.1.10 This satirical caricature of Jenner inoculating members of the public with material taken from pustules on milkmaids indicates social thought at the time of his discovery.

Current research on preserved smallpox strains

Despite being 'eradicated', scientists and members of health organisations determined that they wanted to continue research on the smallpox virus. While initially being held in four locations across the world, the virus is now held at only two; the US Centers for Disease Control and Prevention in Atlanta and the State Research Centre of Virology and Biotechnology in Russia. Researchers have justified holding stock of the live virus as it has allowed scientists to find out more about the development of and trace its evolutionary genetics, which helped them to determine that the virus is more than 8000 years old. However, not all public health officials believe that having a live virus is ethical. When the issue was debated by WHO in 2011, representatives from some countries voiced their concern over the possibility of accidental release or use of the stocks as biological weapons.

INQUIRING FURTHER

Whooping cough (pertussis) has recently received a lot of attention, particularly through social media platforms. Investigate how whooping cough vaccination programs were introduced in Australia and how social media has helped raise awareness of the disease. Present your findings in a portfolio.

WS

6.1.1 Vaccination

6.1.5 Smallpox

6.1.6 Goodbye smallpox hello monkey-pox

6.1.7 Should we save smallpox?

Social implications of smallpox eradication

The success of the global immunisation of smallpox led the way for further eradication of diseases such as polio and significantly reduced cases of whooping cough, measles, mumps, rubella, hepatitis B, diphtheria, tetanus and pneumococcal infections. Vaccination allows members of society to stay healthy, places less strain on hospitals and other healthcare facilities, and reduces taxpayer expenses for treating disease.

Development of flight

Over the centuries, the human fascination with flight has come a long way. While flying machines were initially developed as a product of human desire to fly at leisure, inventors soon realised that aeroplanes were able to fly long distances in a fraction of the time compared to cars and boats.

There is no mistaking that domestic and international travel are essential for coordinating and managing developed societies. Air travel enables face-to-face meetings between people who may be geographically distant, which can improve the quality of communications, help maintain vital political alliances, facilitate meetings for executives in international corporations and encourage employees to attend professional development conferences.

Alamy Stock Photo/The Print Collector

FIGURE 6.1.11 Lilienthal's glider was one of the very first attempts to design an apparatus that would allow humans to fly like birds. Unfortunately, after many successful flights, Lilienthal was killed after a strong wind caused him to lose control and crash to the ground.

INQUIRING FURTHER

Investigate another of da Vinci's inventions and discuss how scientific knowledge at the time influenced whether or not the invention was completed.

Alamy Stock Photo/Ian Dagnall Computing

FIGURE 6.1.12 The Wright brothers' aircraft, Flyer III

6.1.8 History of flight

6.1.9 History of the airplane

6.1.10 Aircraft that changed the world

The history of flight

Leonardo da Vinci's 15th-century 'Ornithopter' or 'flying machine' design was the first documented study of flight. Da Vinci illustrated his theory of flight through a series of drawings but these were never made into an actual invention. However, the flying mechanism referred to in his studies formed the basis of modern helicopter design.

In 1783, the Montgolfier brothers built the first hot air balloon prototype. It used smoke to blow hot air into a silk bag attached to a basket. Their initial design was tested using a rooster, a sheep and a duck and, following success, was later refined to carry two people.

In the late 19th century, German engineer Otto Lilienthal designed a glider that could carry a person over long distances. The flying device was based on his studies of bird anatomy, which were featured in his book on aerodynamics and later referenced by the Wright brothers as the basis of their aeroplane design.

Orville and Wilbur Wright, also known as the Wright brothers, built a glider kite in 1900 to test their ideas and determine the influence of wind on surfaces while in flight. They then spent the next three years experimenting with wing and tail design as well as building an engine used to propel the flyer. Their first design, the Kitty Hawk Flyer, successfully lifted off the ground and flew just under 260 metres in one minute but was both unstable and difficult to control. The brothers dedicated the next two years to perfecting their design and in 1905 Wilbur piloted the Flyer III, which flew in continuous circles for 39 minutes until it ran out of fuel.

As depicted in Figure 6.1.13, the next century produced many new developments in flying machines that would eventually result in the design and engineering of the aeroplanes that we now use across the globe. Aeroplanes transport people, animals, luggage and cargo within and between countries in a relatively short amount of time, and they are vital to the operations of the military all over the world.

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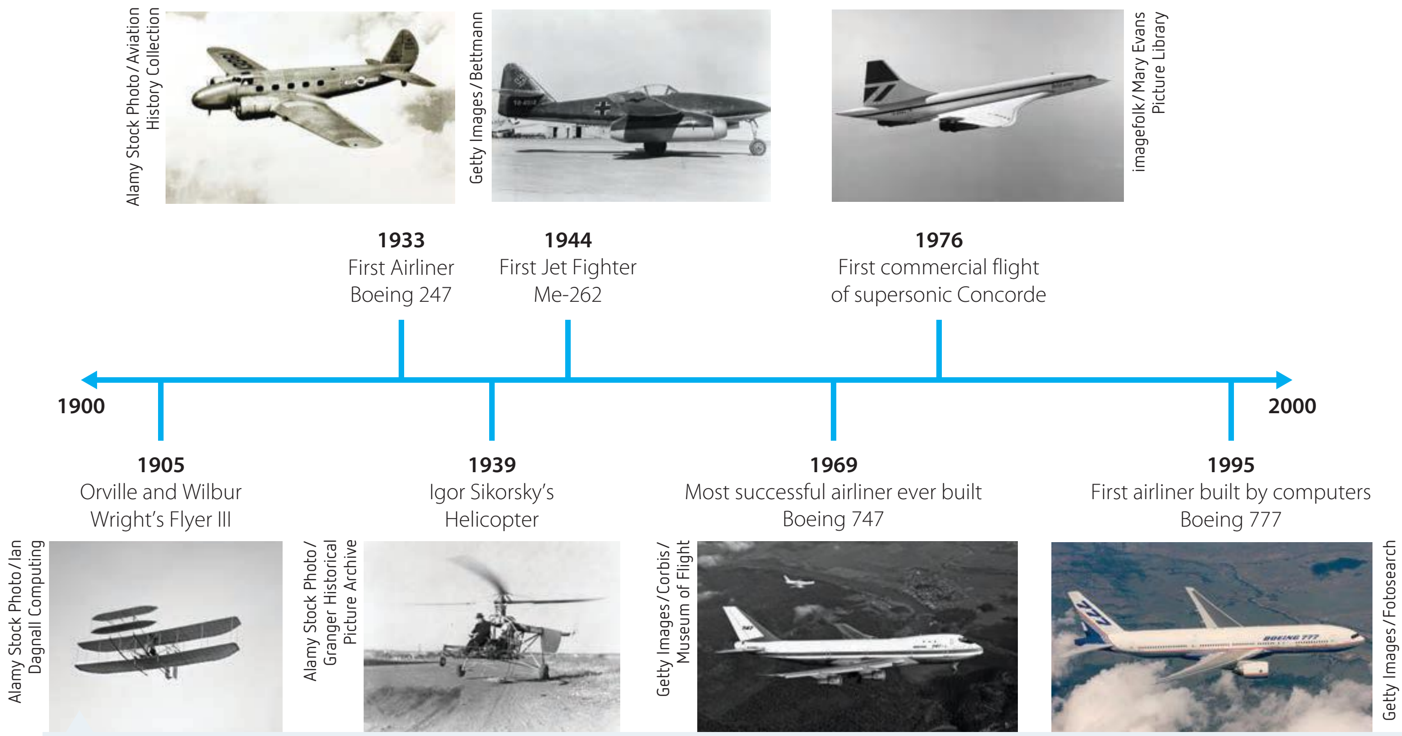


FIGURE 6.1.13 Timeline of the history of flight.

River damming

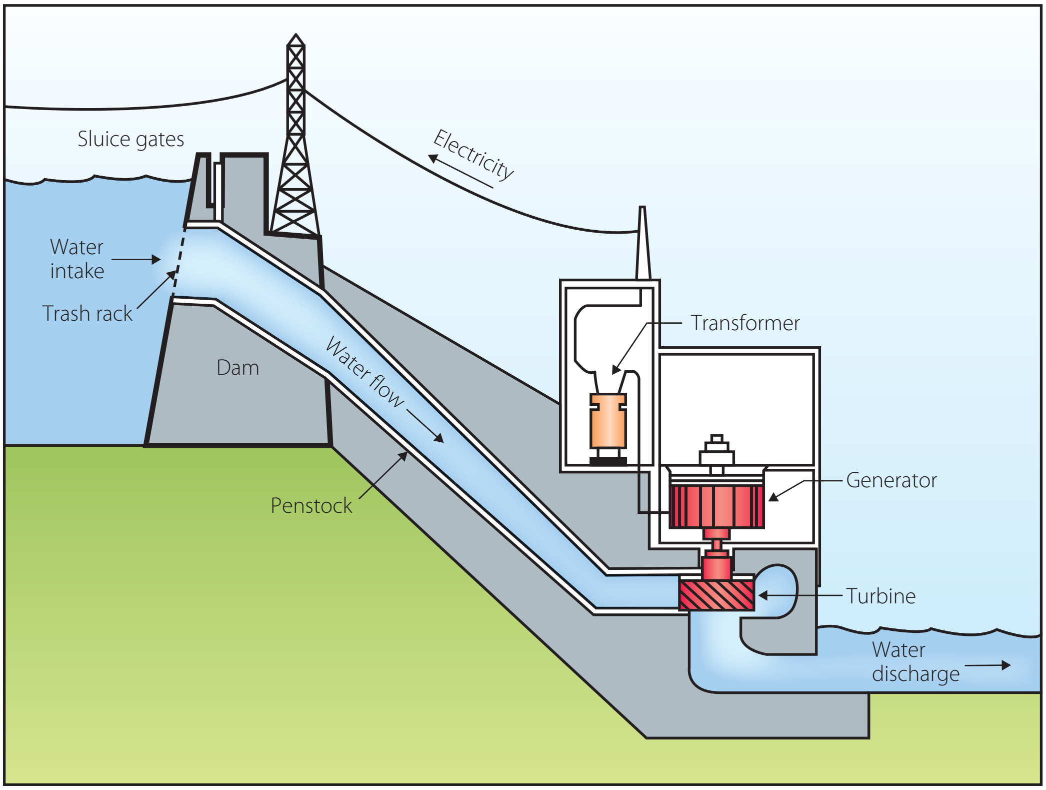
Damming refers to the process of blocking a river or stream using a dam (large wall) made from materials such as rock or concrete. Since the first Australian dam was built in the Yan Yean Reservoir in Victoria in 1850, thousands of dams have been constructed all over the country.

FIGURE 6.1.14 The Nepean dam is one of four dams making up the Upper Nepean Water Supply Scheme, which is responsible for almost 40 per cent of Sydney's water supply.

River damming in New South Wales

Throughout New South Wales, hundreds of dams create water reservoirs to supply the water required for agriculture, irrigation, domestic supply and public recreation. Less common but equally important, some dams are also used as an alternate power source by generating hydro-electricity as shown in Figure 6.1.15. The controlled release of water is achieved by opening and closing the sluice gates. When electricity demand is high, the gates are opened and gravity forces the water to flow at high energy to a lower reservoir after entering a turbine connected to a generator and transformer. When enough electricity has been produced, the sluice gates are closed and water is pumped back up to the higher reservoir. In 2016, hydro-electricity made up 71 per cent of the world's renewable energy sources and 16.4 per cent of the total electricity produced globally. In the same year, it made up around 42 per cent of Australia's renewable energy.

FIGURE 6.1.15 Damming can be used to generate hydroelectricity. When electricity demand is high, water flows from a high to a low water reservoir where the high-energy water passes through a turbine.



Tables 6.1.2 and 6.1.3 summarise the benefits and limitations of damming for society and the environment.

TABLE 6.1.2 Benefits of damming waterways

TYPE OF DAM	EFFECT
Water reservoir	▪ Supplies household water ▪ Supplies water used for agricultural irrigation ▪ Can be used as a form as recreation for nearby camping sites including boating, water skiing and swimming
Hydro-electric	▪ Generates clean, renewable energy that does not produce greenhouse gases ▪ Electricity is generated in a controlled manner

TABLE 6.1.3 Limitations of damming waterways

CHANGE CAUSED BY DAMMING	EFFECT
Alters free-flow of waterways	▪ Changes the physical properties of the river ▪ Organisms that have adapted to the amount of dissolved oxygen, chemical composition, temperature, timing and quantity of water flow may not cope with the changes to the ecosystem ▪ Loss of biodiversity
Disconnects river from other waterways	▪ Prevents fish migration in species that spawn in different habitats from which they live ▪ Loss of biodiversity ▪ Overpopulation of organisms lower in food chain
Blocks waterways	▪ Stops naturally occurring sediment from accumulating downstream ▪ Prevents natural maintenance of deltas, wetlands and floodplains

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SECTION REVIEW 6.1

REMEMBERING

1 Identify three impacts on society that occurred after the nuclear meltdown at Chernobyl.

2 Name four diseases that have been significantly reduced in Australia since the introduction of vaccines.

3 Define damming and list three reasons for damming waterways.

UNDERSTANDING

4 Describe how the nuclear meltdown at Chernobyl occurred.

5 Outline how Edward Jenner developed the smallpox vaccine in the form of a flow chart.

6 Using Tables 6.1.2 and 6.1.3 as a starting point, create more detailed tables that outline the benefits and limitations of river damming.

APPLYING

7 Evaluate the importance of Edward Jenner to modern healthcare.

8 Using Figure 6.1.13 as a starting point, construct a more detailed timeline that includes all major developments in flight between da Vinci's flying machine and the construction of the Boeing 777.

9 Design an alternative way of storing water other the river dams. Present your design as an illustration (either hand-drawn or digital).

ANALYSING

10 Using at least two examples, analyse how major science-related events have shaped society's view of science.

6.2 Regulating science

Like all major organisations, science must abide by certain regulatory statutes. Regulation ensures that all scientific research and activities are carried out ethically and are governed by laws related to safety and human rights.

Regulating science involves the consideration of **ethics**. Ethics can otherwise be referred to as the rules derived from moral principles that govern our behaviour and allow us to distinguish right from wrong. To differentiate the two terms from one another, **morals** are our internal principles or personal beliefs of 'right' and 'wrong' whereas ethics are the external rules related to 'right' and 'wrong' that are developed by social systems and governed by legal guidelines. For example, you may have a moral belief that receiving a gift from a client is acceptable, however, you may be governed by an ethical code of conduct in your workplace that prevents you from accepting gifts.

Shutterstock.com/a-image

FIGURE 6.2.1 Scientific regulation is necessary when developing new scientific tools and ensuring that existing products are meeting safety and quality standards.

Scientific ethics have arisen from the interaction between culture and science, particularly biology. Ethics differ between cultures, which becomes problematic when trying to develop international codes of conduct. For this reason, international guidelines are developed by an overarching association and individual countries adapt these guidelines to form their own laws and sanctions.

6.2.1 Codes and guidelines
6.2.2 Australian code for the responsible conduct of research
6.2.3 Research ethics and integrity

ethics
rules established by social systems that govern 'right' and 'wrong'

morals
a judgement about whether what is being done is good or bad

Genetic modification

Genetic modification is a process that involves manually adding new DNA to an organism. The technique for removing and transferring the genes from one organism to another is complex and is not always successful. The basic principles of genetic modification are outlined in Figure 6.2.2.

FIGURE 6.2.2 The basic principles of genetic modification.

Identification	• An organism that has the desired trait is identified.
Extraction	• DNA is extracted from the organism.
Cloning	• The desired gene is located and copied using a process called **gene cloning**.
Modification	• The cloned DNA may be slightly modified to make it more efficient.
Transformation	• The gene, now called a **transgene**, is delivered into the cells of the recipient organism via a process called **transformation**. • A common form of transformation involves injecting the transgene into bacteria that naturally invades and genetically alters the DNA of organisms.
Breeding	• If successful, the new transgenic organism is bred.

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FIGURE 6.2.3 Embryonic modification is used in in vitro fertilisation (IVF) to help those who have problems conceiving.

Genetic modification of sex cells and embryos

Genetic testing is vital to the success of fertility treatment such as in vitro fertilisation (IVF). In IVF, the embryo is tested before implantation to reduce the chances of the foetus being born with single gene disorders such as cystic fibrosis or BRCA1/BRCA2 (heredity breast/ovarian cancer).

Current scientific research is taking genetic testing one step further with the proposed genetic modification of sex cells and embryos. At the beginning of 2017, scientists from Sun Yat-sen University in China reported they had genetically modified a human embryo to remove a mutant strand of DNA that causes β-thalassemia, an inherited, life-threatening blood disorder that destroys red blood cells. The study was conducted on an

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embryo that could not develop into a foetus and was completed by using 'molecular scissors' to remove the mutant DNA and replace it with functional DNA. However, this technique is still very much experimental, as the scientists reported many copying errors that could lead to unpredicted complications in viable embryos.

While the prospect of eliminating hereditary diseases such as cystic fibrosis and Huntington's disease are what scientists are working towards, authorities are concerned that the technology will be abused and could become a way for parents to 'design' their offspring, including choice of sex and other characteristics, such as eye and hair colour.

To ensure this research does not become the gateway to making 'designer babies', the use of the technique is strictly regulated. Fortunately, the Embryo Research Licensing Committee formed by Australia's National Health and Medical Research Council (NHMRC) prohibits human genetic cloning and associated technologies. The NHMRC enforce strong penalties for non-compliance including issuing rogue scientists with large fines and prohibiting them from carrying out further medical research for a number of years.

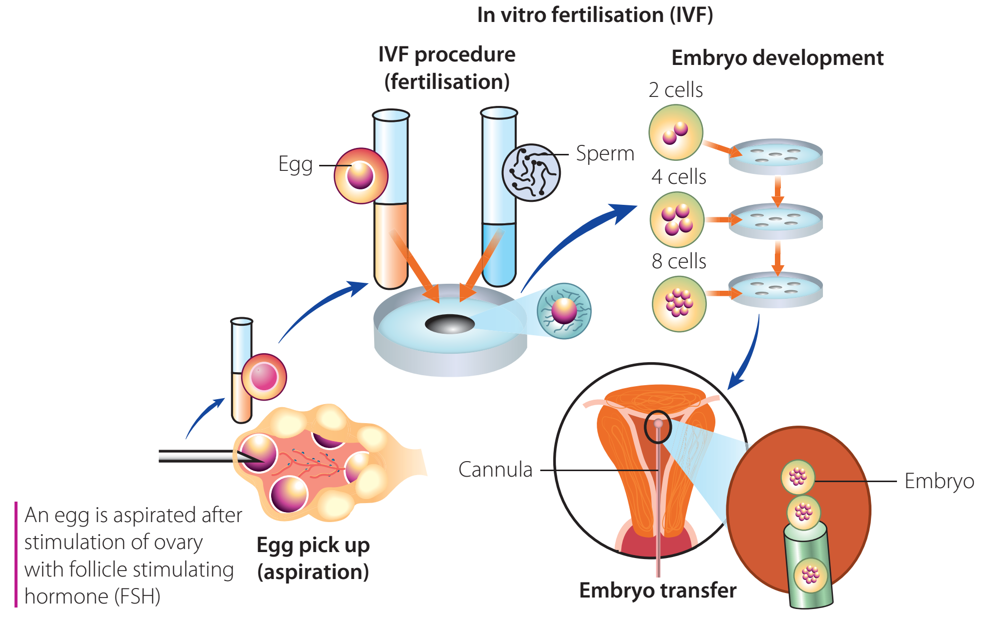

FIGURE 6.2.4 IVF involves the aspiration of eggs, external fertilisation and then embryonic transfer.

Genetic therapy

Genetic manipulation is a revolutionary branch of science that has potential to aid the prognosis and treatment of many diseases. Otherwise referred to as gene therapy, genetic manipulation in biotechnology uses genes to target areas of the body affected by a disease.

Gene therapy for cancer treatment

Cancer is the rapid and uncontrolled proliferation of cells. Metastatic cancers also have the ability to invade and continue replicating in other tissues. Cells are identified as cancerous when the genetic material responsible for regulating cell division is mutated. Research is currently taking place to determine whether these mutated genes

Getty Images/iStock/vchal

FIGURE 6.2.5 Authorities are concerned that genetic modification of embryos will influence a new generation of 'designer babies'.

can be removed and replaced with transgenes that give rise to toxic molecules responsible for producing cancer-killing proteins.

Gene therapy for severe combined immunodeficiency (SCID)

lymphocytes
a white blood cell with a single, round nucleus

vector
an organism that transmits a disease from one organism to another

germline gene therapy
the process where DNA is transferred to the cells that produce reproductive cells

bioprospecting
conducting tests to determine whether an organism could be used to manufacture a product

SCID is a disorder that disrupts the functioning of vital **lymphocytes** in the immune system. People with SCID, particularly children, become extremely susceptible to infectious diseases and must live in a sterile environment. Scientists have successfully used gene therapy to treat this disorder by inserting a functional variant of the gene into a viral **vector**, which transforms extracted bone marrow cells from the patients. When the transformed cells were returned to the patients, their immune system was able to produce functional lymphocytes capable of fighting diseases.

Ethics of genetic manipulation

The ethics behind genetic manipulation are debated as the technique deliberately changes the body's basic instructions. Although the genes currently being used in human genetic manipulation cannot be passed on to future generations, further experimentation may see the introduction of **germline gene therapy** as an attempt to reduce the likelihood of congenital disorders. Scientists are entering uncharted territory and many are worried that altering genetic material may cause unforeseen or irreparable effects to the developing foetus. Ethical concerns have arisen from this form of therapy as it has been argued that the foetus has no ability to accept or reject the therapy, and therefore may be having its basic human rights exploited.

Bioprospecting

6.2.4
Bioprospecting

Conducting tests to determine whether a specific plant or animal could be used to manufacture medicine or other products is known as **bioprospecting**. Bioprospecting may use the entire organism itself or involve the extraction of a gene or other compound from the organism. Bioprospecting has also influenced the discovery of some opioids, powerful pain relievers such as morphine and other drugs, and has recently been involved in the extraction of cannabis oil to make medicinal marijuana.

While the medical and economic benefits are clear, if not well managed, bioprospecting could lead to the exploitation and inevitable extinction of the species being used to develop the medicine. There are ethical concerns related to removing an animal from its natural habitat in order to carry out testing, particularly those that involve the removal of genes. Questions over the ethics of bioprospecting are also related to the ambiguous ownership of natural resources. Questions raised include the following.

- If a particular organism is found to host a valuable compound needed for medicine, do corporative representatives have the right to raid an entire ecosystem of the resource?
- How much of a resource can be taken from an ecosystem before it becomes detrimental to the environment?
- What should happen if the resource is found in polar regions such as Antarctica, which are controlled by multiple stakeholders?

While there is not one definitive answer to these questions, Figure 6.2.6 depicts the interrelationship between the stakeholders of a useful biological resource.

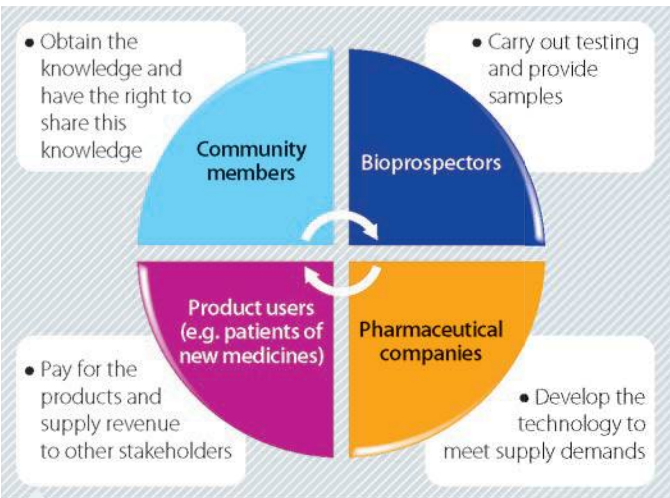

FIGURE 6.2.6 There are many stakeholders involved in the development and subsequent distribution of a product derived from a biological resource.

Protecting Indigenous cultural and intellectual property (ICIP)

While bioprospectors and pharmaceutical companies may only just be discovering the medicinal uses of natural resources, it is likely that local Indigenous people are already aware of the many assets of their environment. Applying knowledge of the land and the properties of its unique flora and fauna is something that Indigenous ancestors have been doing for thousands of years. However, taking natural products from land owned by Aboriginal people and using them to produce commercial products opens up a plethora of ethical concerns over the ownership of Indigenous intellectual and cultural property.

INQUIRING FURTHER

Investigate resources that have been a product of bioprospecting. Evaluate the importance of this resource and present your findings in an audio-visual format.

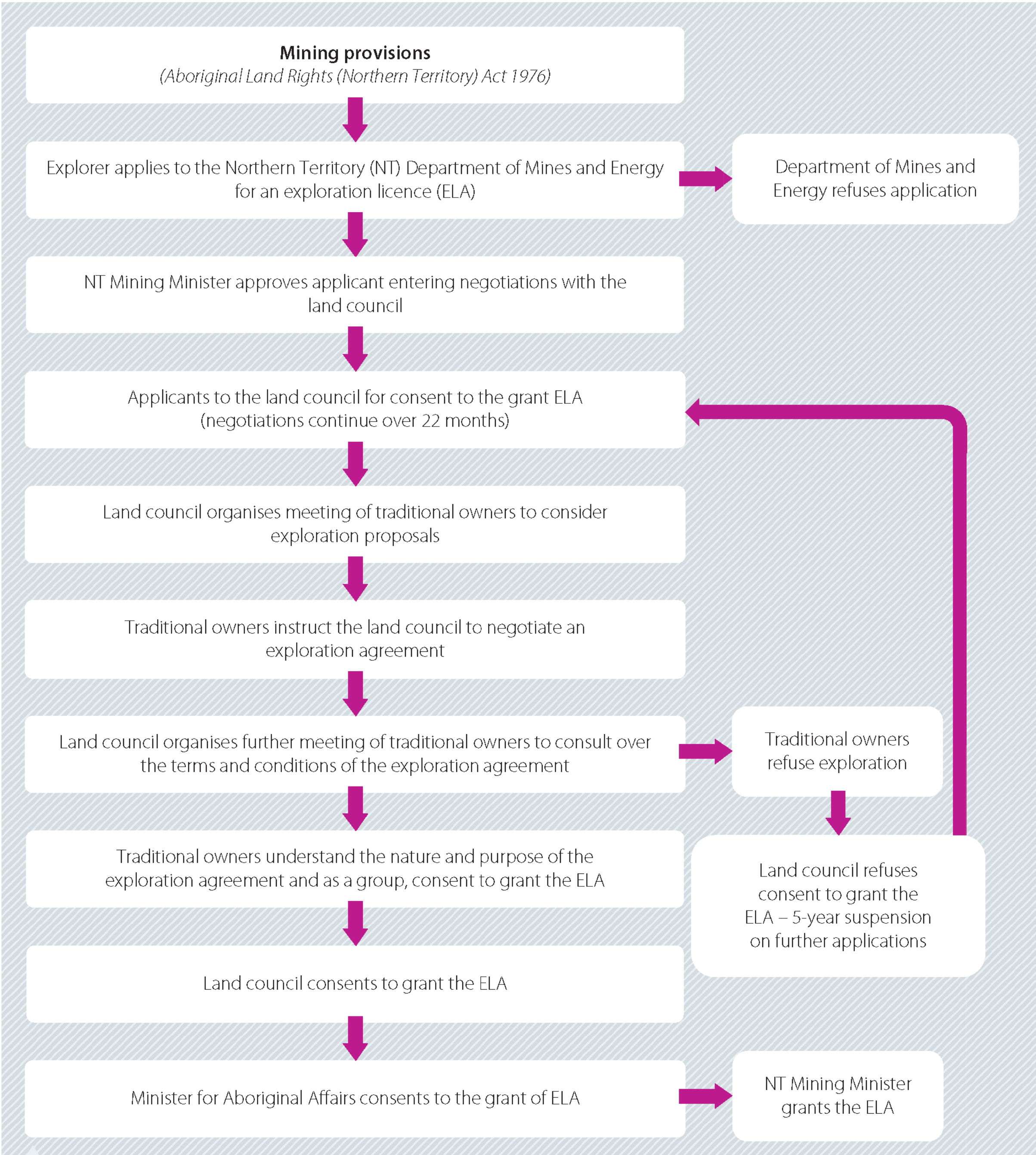

FIGURE 6.2.7 The process to obtain a mining exploration licence.

AAP Image/Joel Carrett

FIGURE 6.2.8 Many Indigenous communities are concerned that government plans to construct mines will disrupt the sacred land belonging to Aboriginal ancestors.

As community members share knowledge that has been passed down from their ancestors, it is unethical for this information to be exploited by big businesses. Regulations have therefore been established to protect Indigenous intellectual and cultural property. Legislation has been created to ensure all property remains under ownership of the traditional custodians of the land. Intellectual and cultural property includes artwork, folklore, vital medicinal plants, animals and minerals, literature, design, knowledge and performing arts.

Mining on Aboriginal land

Mining on sacred Aboriginal land sites has been a topic of interest for the last 50 years. Since the introduction of the *Aboriginal Land Rights (Northern Territory) Act* in 1976, regulations have consistently been refined to ensure that traditional Aboriginal landowners maintain control over their land. In regards to mining, the legislation has been put in place to ensure all permits are first approved by traditional owners through their local land council. Figure 6.2.7 demonstrates the many steps that must be undertaken to be approved for a mining exploration licence.

6.2.5 The *Aboriginal Land Rights (Northern Territory) Act* in 1976

INQUIRING FURTHER

Investigate areas around Australia where land has been restored to its traditional owners. Present your findings in a visual representation such as a annotated map.

Despite the tedious process to be granted approval, local communities still oppose the idea of exploiting land that holds historical value. As shown in Figure 6.2.8, many residents argue that disrupting the resting place of their ancestors is unethical.

Scientific codes of conduct

Codes of conduct allow scientists to operate under a uniform set of rules and regulations without crossing any major ethical boundaries.

Codes of conduct in biotechnology

Biotechnology is an area of medical technology that uses cellular processes to develop products to enhance and prolong our lives. The ethical concerns associated with manipulating 'natural' processes require this field of science to abide by strict codes of conduct. The Medical Technology Association of Australia works in conjunction with the federal government to oversee all processes associated with developments in medical technology to ensure that Australian research complies with international standards.

Stem cell research

Our body is made up of many different types of cells, each of which are specialised to carry out a particular function. Cells become specialised during in-utero development and once they have differentiated, they are unable to reverse. Stem cells are cells that have not yet differentiated in the embryo but have the potential to develop into many kinds of cells. Shown in Figure 6.2.9, stem cells can be extracted from a four- to five-day-old embryo and manipulated to differentiate into specific types of cells such as blood, skin or bone. This process is controversial, as removing the stem cells ultimately destroys the embryo, raising questions over the ethics of the technique.

Culturing differentiated tissue for experimental use allows scientists to determine the possible effects of new drugs or associated products to human tissue. As the process is carried out in a controlled

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environment in petri dishes, scientists can gain valuable information without adverse effects on one or more individuals.

Although the possible benefits of the technique are profound, the use of human embryos that have the potential to develop into human beings is hotly debated between scientific and other organisations. For this reason, stem cell research requires an international code of conduct and a strict governing body. The International Society of Stem Cell Research sets the current international standards for stem cell research. Their code of conduct outlines the rules and regulations for all phases of human embryonic stem cell research and includes the ethical, efficacy and safety principles that must be considered when carrying out research. It is then the individual responsibility of each country to ensure the relevant scientific organisations adhere to these guidelines.

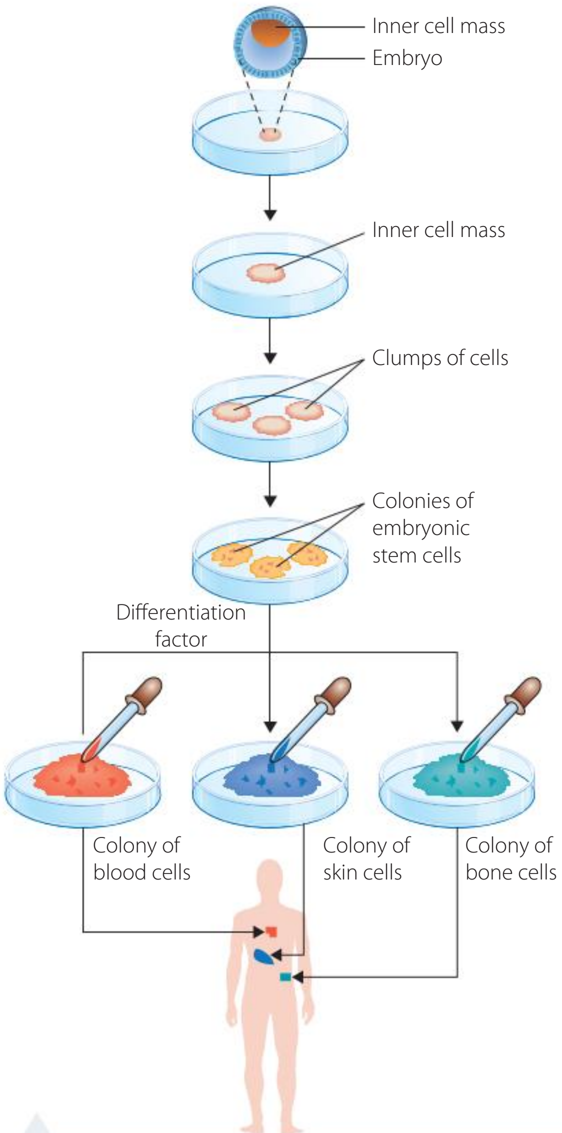

FIGURE 6.2.9 Stem cells taken from embryos can be cultured and differentiated to many types of human tissue. Removal of the embryo inevitably destroys it, which is why stem cell therapy remains controversial.

Surrogacy

Surrogacy refers to a reproductive technology where a woman carrying an embryo and birthing a baby is not the intended parent of the child. There are two main types of surrogacy: traditional and gestational (shown in Figure 6.2.10).

In traditional surrogacy, the woman who carries the baby has used her own egg and sperm from the father to make the embryo. Gestational surrogacy refers to the process of having an egg from the biological mother fertilised by sperm from the biological father using IVF and then that fertilised embryo is implanted into a different woman.

Surrogacy is sought after by parents who are unable to conceive for numerous reasons; including those women who are physically unable to carry a baby to full term, same-sex couples, older women and women with medical conditions.

'Surrogacy Matters: Inquiry into the regulatory and legislative aspects of international and domestic surrogacy arrangements' is the current document published by the Commonwealth government that outlines the laws and legislations of surrogacy in Australia. The document includes Australia's international obligations to a variety of offshore treaties including the Convention on the Rights of the Child, and anti-trafficking and organised crime treaties.

6.2.1 Stem cell research

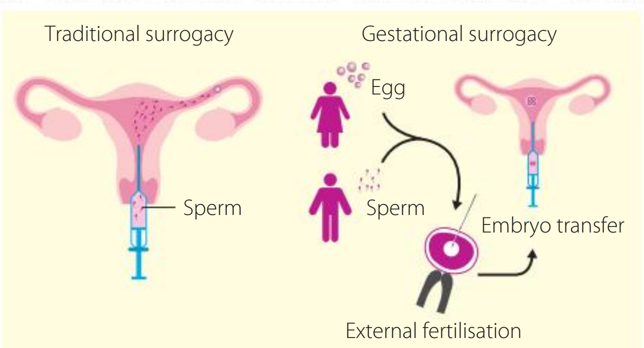

FIGURE 6.2.10 Traditional surrogacy involves the delivery of sperm into the surrogate. Gestational surrogacy involves the external fertilisation using sperm and egg from the biological parents and a transfer of the resulting embryo into a surrogate.

Organ transplantation

Organ transplantation is the process that involves removing an organ from a (usually deceased) person, and transplanting it to another individual. To be placed on an organ transplant waiting list, an individual must have exhausted all other treatment options and needs to undertake medical assessment to confirm their own organ is failing. In Australia, the most common organs needed for transplantation are the heart, lungs, kidneys, liver, intestine and pancreas.

To ensure all transplants from deceased donors are fair and equitable, the Australian medical community uses the following criteria to determine who receives the next available transplant.

- How well the organs match the person (e.g. blood type, size and so on)
- How long the person has been waiting for the transplant
- How urgent the transplant is
- Whether the organ can be made available to the patient in time

Allocation of transplants in Australia does not discriminate according to race, religion, gender, disability, social status, age or economic status.

Financial and societal pressures of organ donation

Organ donations can be from deceased or living donors. Living donors are usually a relative or close friend to someone who has end-stage kidney disease or liver failure. A living donor can choose to donate one of their two kidneys or a portion of their liver. However, the decision to undergo major surgery can lead to financial stress as recovery time can take up to 6 weeks. For those who have exhausted all of their leave or those who are not entitled to paid leave, this can mean taking 6 weeks of leave without pay.

Introduced as a two-year pilot in 2013, the 'Supporting Leave for Living Donors Program' was implemented in Australia to reimburse employers for any leave payments given to employees who have taken leave to undergo a live donation procedure. The program was reviewed and the decision was made by the Department of Health to continue funding the program for another two years (July 2015–June 2017), with an increase from 6 to 9 weeks of paid leave at the National Minimum Wage.

Black market organ transplantation

The scarcity of available organs for transplantation has been exploited by black market trade including organ trafficking and poverty-stricken individuals selling their own organs. In 2010, the WHO approximated that 10 per cent of total kidney transplants worldwide were obtained and performed through the black market. Recipients of the organs have been reported paying upwards of $200,000 for one organ, with the individual donors sometimes receiving less than 5 per cent of the money paid. Fortunately, the Australian 'DonateLife' initiative has seen a significant increase in individuals electing to donate organs after death. Figure 6.2.11 depicts a 76 per cent increase in organ donors over a six-year period, which has steadily increased each year since the introduction of the campaign.

While there is not a single international body governing organ transplantation, individual countries have their own regulations and policies to reduce the unethical transplantation of organs. In Australia, the NHMRC published their 2016 document, 'Ethical guidelines for organ transplantation from deceased donors'. The guidelines highlight the ethical practice and human rights related to transplantation as well as the criteria for eligibility, allocation and monitoring of the process.

Other countries once notorious for their organ black market, such as China, have recently put regulations in place to stop the on-demand execution of criminals for their organs. While critics are still debating the effectiveness of the regulations, China currently suffers an organ shortage, as many citizens believe that the body is a sacred entity that should be buried intact.

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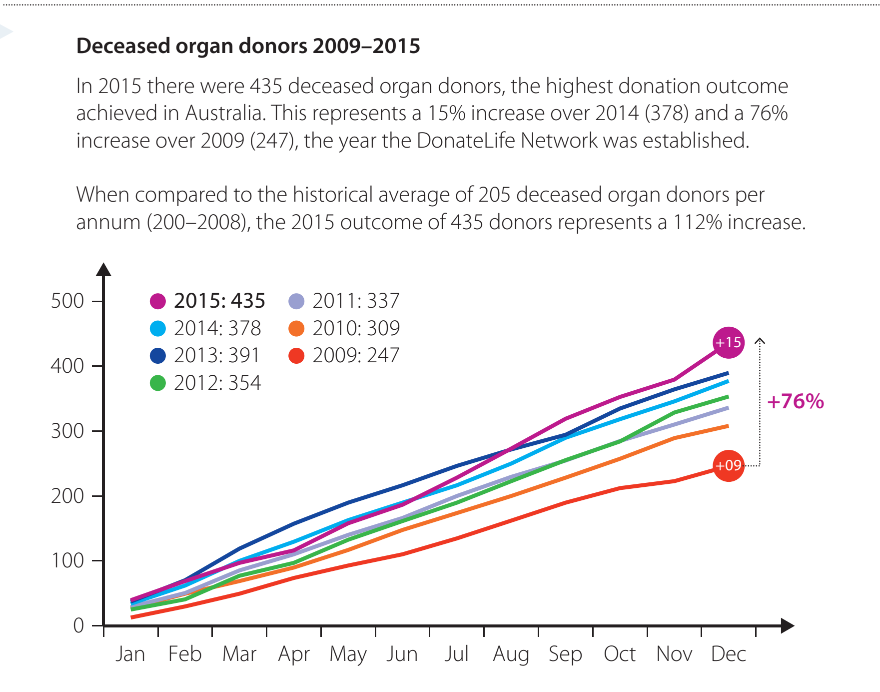
FIGURE 6.2.11 Deceased organ donors have steadily increased since the initiation of the 'DonateLife' Network.



Emerging technology in organ transplantation

To combat a flourishing black market, researchers are currently looking at alternatives such as organ creation using 3D printers. Shown in Figure 6.2.12, most of the current prototypes include joints and external structures such as ears, but scientists are working towards the technology being used to produce more complex structures.

INQUIRING FURTHER

Investigate current research in how 3D printing could be further used in medical technology. Present your findings in a portfolio with visual representations or models as an aid.

Facial transplants

How would you feel if you saw the face of a deceased relative on the body of a stranger? Facial transplants are a recent medical innovation that raise ethical concerns. The new medical procedure aims to provide victims of burns, trauma or genetic malformations with a more normalised appearance.

Getty Images/Bloomberg/Chris Ratcliffe

FIGURE 6.2.12 Using cells as 'ink', 3D printers are being used to develop human structures such as tongues, ears and joints including cartilage and bone.

AAP Image/Charlie Neibergall

FIGURE 6.2.13 After his mouth and nose were destroyed by a gun shot, Andy Sandness underwent 56-hour surgery to receive his donated face.

SECTION REVIEW 6.2

REMEMBERING

1 Identify two areas of scientific research that require regulation.
2 Define the term 'scientific ethics' using examples.
3 Name three examples of Indigenous intellectual and cultural property.

UNDERSTANDING

4 Describe the term 'code of conduct' in relation to scientific research.
5 Construct a table that outlines the positive and negative aspects of bioprospecting.
6 Draw a flow diagram that summarises the process of stem cell research.

APPLYING

7 Evaluate the importance of a code of conduct for transplantation of human organs.
8 Surrogacy can be either traditional or gestational. Compare the two methods of surrogacy and justify the use of a code of a conduct for each.
9 Using a code of conduct related to your everyday life (e.g. sport, school, work), justify the rules contained within them.
10 Why is it important to have regulations that protect Indigenous cultural and intellectual property?

ANALYSING

11 Research is currently taking place to try to remove the breast cancer-causing gene, BRCA, from a human embryo that cannot develop into a foetus. Justify the use of an unviable embryo and discuss the ethical implications if this research is trialled on a viable human embryo.

6.3 Influence of economic, social and political forces on scientific research

Scientific research and experimentation is a costly process that cannot be funded by scientific organisations alone. To complete their studies, scientists rely on funds from universities and the government along with grants from corporate bodies that have an interest in the concept being researched. Relying on external agencies for funding raises ethical concerns over the possibility for bias or a skewed representation in published data.

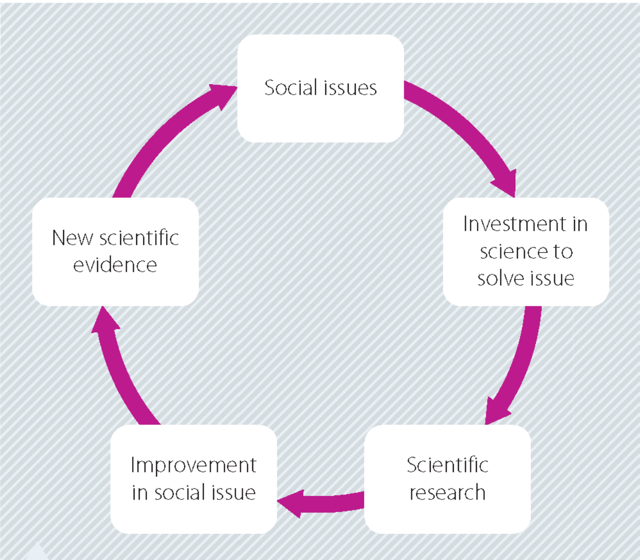


FIGURE 6.3.1 Scientific research is enacted as a response to improve social issues; however, the scientific evidence may determine a new social issue that requires further study.

Science and society

As shown in Figure 6.3.1, issues of society and scientific research are interlinked. Funding of social issues such as education, health, national security and agriculture rely on scientific research. Evidence from scientific surveys and fieldwork are used to devise sophisticated plans designed to reduce the burden of social issues.

Controversial investments – space exploration

Every year, billions of dollars are spent internationally on space exploration and intergalactic travel; but does all this investment benefit society in any way? Of course, observations of our solar system have helped scientists understand vital scientific principles. However, it is also argued that there are more pressing issues in urgent need of addressing on a global scale.

In 2016, NASA was assigned more than $6 billion dollars in the US government's budget. One of the recent uses of this money was on plans to determine whether there is liquid water present on Mars. Many argue that the billions of dollars spent on determining whether Mars has a water source that may be accessed thousands of years in the future could be better invested in working to fix current global issues, such as poverty and hunger in developing countries.

Table 6.3.1 outlines some of the points for and against investment in space exploration.

INQUIRING FURTHER

Conduct your own secondary investigation to gather more points for and against space exploration as an important social issue and use this information as the basis for a class debate.

INQUIRING FURTHER

Investigate how drug research and development has contributed to the economy. Present your findings in a research report.

TABLE 6.3.1 The prospect of space exploration being a 'waste of money' is ardently debated. There are many points both for and against its importance.

FOR	AGAINST
▪ Space exploration has the potential to solve current issues such as harvesting solar winds as an alternative energy supply ▪ Space exploration is important for the future of humankind as it may determine whether there is a possibility for humans to live elsewhere if our planet is no longer habitable ▪ Astronauts are capable of testing the fundamental principles of physics ▪ Space travel by tourists can be used to boost the economy ▪ Scientific knowledge is a valuable resource	▪ Scientists could be using their expertise to solve more pressing issues such as poverty and hunger ▪ The current needs of people on our own planet should take precedence over the potential of other planets ▪ There are so many areas of our own planet that have yet to be explored ▪ There have not been any direct benefits of space travel ▪ Space-related inventions such as equipment that functions at zero gravity are irrelevant to normal daily life ▪ Money is only invested in space exploration to 'show off' to other countries

Science and economics

Emerging scientific technologies must benefit human progress if they are to be invested in and produced on a mass scale. Scientific research in areas such as nuclear power, genetically modified foods, pharmaceuticals and robotics are related to their potential long-term benefits to the economy.

Science Photo Library/Martyn F. Chillmaid

FIGURE 6.3.2 The Flavr Savr tomato was developed following experimentation that involved silencing the genes responsible for ripening. The result was a tomato that could last up to 45 days without becoming over ripe. In this image, the two tomatoes shown on the far left were the control and the remaining four had the genes responsible for ripening silenced.

Genetically modified foods

Genetic modification of food involves inserting a favourable gene into the cells of the organism producing the product. Since the introduction of the first genetically modified (GM) food, the Flavr Savr tomato in 1994, GM foods have resulted in great economic benefits. GM foods are designed to improve yield, save costs on herbicides and increase the shelf life of fresh produce.

Potential of GM food – 'Golden rice'

Experts have proposed using GM foods as a way to improve malnourishment in developing countries where rice is a staple food, including Bangladesh, Vietnam and India. 'Golden rice', a GM food first harvested in 2004, is a genetically engineered species of rice that includes a gene responsible for expressing vitamin A. The rice was developed to try to prevent millions of deaths in developing countries from diseases related to vitamin A deficiency. At first, 100 grams of golden

Reuters/Erik De Castro

FIGURE 6.3.3 Although it is still being trialled and refined, golden rice is proposed to significantly reduce the deaths from diseases related to vitamin A deficiency.

rice supplied 5–8 per cent of the daily recommended intake of vitamin A. Continuous refinement and experimentation by scientists over the last decade has resulted in the development of new strains that supply up to 60 per cent for the same portion of rice.

Drones

A drone is an unmanned aerial vehicle that is used in situations where manned flight is too dangerous or expensive. The relatively inexpensive technology can perform roles once only possible from a helicopter or aeroplane. Drones have been used to assist the military since the early 2000s and have recently been applied in a number of different scenarios such as surveillance, mapping, storm forecasting, law enforcement, wildlife tracking and filming. Visual information collected from drones can be analysed and merged with 3D visual tools and predictive computer technology to generate maps such as that shown in Figure 6.3.4.

As shown in Figure 6.3.5, drones are also being developed as a tool to assist surf lifesavers patrol beaches from the air. The drones are fixed with cameras to identify dangerous conditions such as rips or the presence of a shark and also carry life-saving equipment that can be released to someone who may be at risk of drowning.

Reprinted from Trends in Parasitology, Vol. 30, Issue 11, November 2014, with permission of Elsevier

FIGURE 6.3.4 The ability to merge visual information collected by drones with elaborate computer technology is changing the way we can view Earth.

Getty Images/iStock/RuslanDashinsky

FIGURE 6.3.5 Drones have the potential to save millions of dollars spent on air surveillance.

Science and world health

Scientific research is vital to the maintenance of health and wellbeing. As risks to health are introduced, scientific research takes place to determine whether the risks can be better controlled.

Vaccination programs

As new diseases or viral strains are being discovered, the WHO constantly seeks new scientific research to determine whether a potential outbreak could be controlled through vaccination. For example, following a recent outbreak of the Ebola virus, scientific research resulted in the trial of an Ebola vaccine. In December 2016, the vaccine was deemed to effectively protect individuals from the virus and was made available for emergency use.

Historically, vaccination programs established by the WHO have seen the worldwide eradication of diseases, including smallpox. Discussed earlier in the chapter, eradicating a disease and maintaining eradication can be problematic and take over a decade to be successfully achieved.

Between 2008 and 2012, the highest number of pertussis (whooping cough) cases was recorded since national reporting began in 1991. With the highest rate of infection found to be in infants below 6 months of age and children 5–9 years in age, studies were conducted into the source of the infection. In half of the cases of infant whooping cough, family members and in particular, parents, were found to be the source of infection. Following these studies, Australia introduced free pertussis vaccinations to all pregnant women. Given in the third trimester of pregnancy, the newborn can be protected from the disease prior to receiving their 6-week vaccinations, as antibodies created by the mother in response to the vaccination cross the placenta. Additionally, healthcare authorities strongly recommend that all people planning to come into contact with a baby in their first 6 weeks of life have a booster vaccination.

Surgical procedures and devices

Overtime, scientific research to develop surgical procedures with minimal invasion has improved the likelihood of patients returning to a relatively normal quality of life following an operation. Modern surgical procedures improve wellbeing by:

- shortening post-operative hospitalisation
- reducing pain and recovery time
- causing less trauma to the body
- minimising risk of infection
- decreasing scar tissue.

Keyhole surgery

Keyhole surgery is a minimally invasive surgical procedure whereby surgeons perform an operation through small incisions (usually no longer than 1 cm). Shown in Figure 6.3.6, the procedure is performed using thin, long instruments fitted with a light source and a video camera that relays the information surgeons require to a screen in the operating theatre. The video camera eliminates the need for surgeons to open up the abdomen and therefore reduces the pain, discomfort and recovery time for the patient.

Getty Images/E+/vm

FIGURE 6.3.6 Keyhole surgery was developed in the early 20th century and as camera technology improved, so too did the quality of feedback to surgeons. Now, keyhole surgery is the preferred technique and is used whenever feasible.

Cataract surgery funded by the Fred Hollows Foundation

Fred Hollows was a New Zealand-born Australian ophthalmologist (eye doctor) who was awarded 'Australian of the Year', an Order of Australia Medal and an Advance Australia Award in recognition of his humanitarianism and contribution to world eye health. Starting with Indigenous communities in 1976, Fred Hollows began a revolutionary movement to reduce avoidable blindness in remote areas without adequate access to healthcare.

One of his initiatives, and perhaps his most famous, was to restore the sight of elderly community members in remote areas of developing countries by performing cataract surgery in bulk. The surgery involves replacing the damaged lens with an inexpensive device called an intraocular lens (IOL). Pictured in Figure 6.3.7, the silicone-based IOL performs the same function as the natural lens. Its low-cost design allows the 20-minute surgery to be completed by a trained ophthalmologist for as little as $25.

Following his death in 1993, the Fred Hollows Foundation continues his work in over 25 countries and has helped restore the sight of over 2 million people worldwide.

Getty Images/Cultura Exclusive

FIGURE 6.3.7 Intraocular lenses perform the same function as the eye's natural lens and are an easy way to prevent blindness caused by cataracts.

Water purification and wastewater treatment

Water is vital to life. It helps the body to regulate temperature, protects organs and tissues, lubricates joints, removes waste products, dissolves minerals and nutrients, helps carry oxygen and allows the body to make energy.

The amount of water currently available is the same amount of water that has sustained past generations and will continue to provide for future generations. It is therefore important that as world population increases, water in all forms can be recycled for future use.

Wastewater refers to water that has been previously used in: domestic, commercial or agricultural settings; surface or stormwater run-off; and in filtration. To ensure this water can be used again, it is treated in a wastewater treatment plant that restores it to a usable condition. As shown in Figure 6.3.8, the water must go through a series of processes to purify it.

Pre-chlorination

- Chlorine is added to raw wastewater to kill bacteria and other microorganisms

Flocculation

- Alum is added to coagulate fine particles to form heavy particles that will later settle (these particles are referred to as 'floc')

Sedimentation

- Water moves through large sedimentation basins
- The floc settles and the water above flows out to a series of filters

Filtration

- The water passes through a bed of sand and gravel which filters the water and traps any remaining particles

Fluoridation

- Fluoride is added (in some treatment plants) to reduce tooth decay

Calcium oxide

- Calcium oxide (also referred to as lime) is added to raise the pH to 8. This reduces the ability for the water to corrode plumbing material

FIGURE 6.3.8 Wastewater treatment plants transform raw wastewater into a form of water that can be used and ingested.

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LifeStraw device

Unfortunately, clean, safe drinking water is not readily available to all communities. LifeStraw is a device that has been designed to allow contaminated water to be drinkable through a simple filtration system. Stringently tested and refined through scientific experimentation, the LifeStraw is a light, portable device that can be partially submerged in contaminated water. The water is then sucked through a filtration system to deliver drinkable water.

Getty Images/AFP/Geraldo Caso

FIGURE 6.3.9 LifeStraw can be used to purify water in areas where clean water is not readily available

Political influences on scientific research

National budgets and the limited number of university grants in Australia influence the amount of money available to spend on scientific research. Although the overall goal of scientific research is to improve the health and wellbeing of Australians, financial pressures and competitive industries are undeniable influences on the allocation of money and resources to specific areas of study.

Marketing

Products that have been scientifically tested to work are preferred over those that have no evidence of their effectiveness. Undoubtedly, having scientific evidence to support a product is one of the most influential marketing techniques a company can use to promote its product.

Marketing in the pharmaceutical industry

The pharmaceutical industry is a competitive field. Many companies boasting similar products find themselves clutching at opportunities to prove that their product is more beneficial than their competitor's.

Before any pharmaceutical can be traded in Australia it must first pass stringent regulations that involves scientific research and testing. However, because of the competitive nature of the industry, some companies choose to invest in further studies independent of the compulsory tests they must carry out. This is done to obtain additional scientific data that highlight the necessity of the drug for the condition being studied or to gather results that reflect favourably upon their product.

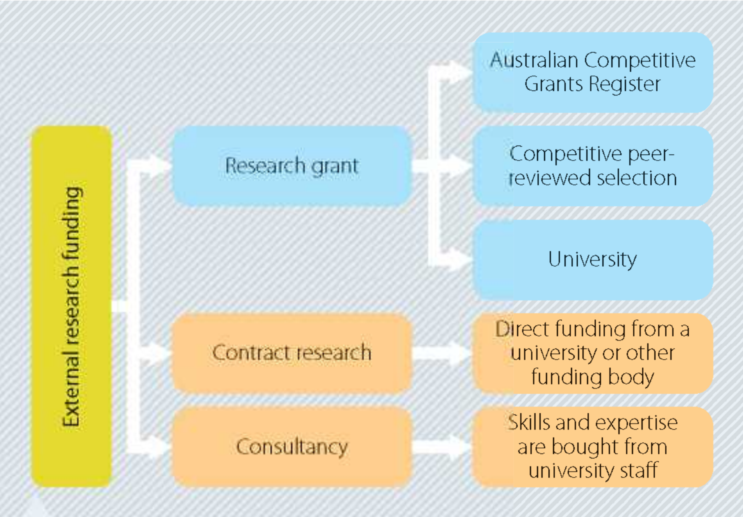

FIGURE 6.3.10 Funding for scientific research can be applied for under three main categories: research grants, contract research or through consultancy.

University research project budgets

The amount of study carried out in an area of science is dependent on the budget that area is allocated within a university. Additionally, the Australian Competitive Grants Register (ACGR) provides funding to projects that align with schemes funded by the Australian Commonwealth Government. When applying for research funding, there are three general pathways a scientist may take: research grants, contract research or consultancy. These are shown in Figure 6.3.10.

Government budgets

Scientific research that aligns with government initiatives are published on the ACGR. The register indicates the areas of research available for a government-funded research grant that are in accordance with the schemes that have been outlined as important in the national budget.

6.3.1 Australian Competitive Grants register

The areas allocated funding in the ACGR are a reflection of the social issues at a given time. For example, if there is financial pressure on the healthcare system from elderly patients requiring treatment and care for illnesses such as dementia and Alzheimer's, then there may be more money allocated in the budget to fund studies related to these diseases. As the government releases a new budget, these research priorities will change.

Benefit sharing using Indigenous cultural and intellectual property

ICIP is becoming increasingly valuable in modern science as a source to develop new pharmaceuticals, cosmetics and other products. Deeply rooted in culture and linked to social systems, ICIP is at risk of being exploited if it is not treated with respect when referenced in scientific research. By publishing ICIP, Indigenous Australians are sharing the benefits of their knowledge with society and thus, must be transparently involved in the research process.

Acknowledging the cultural and intellectual property of Indigenous Australians is a practice that must be upheld by all researchers who intend to use the knowledge of Indigenous Australians as a source.

When planning to integrate ICIP into scientific research, the research organisation, university or corporation must discuss the aim, strategies and management of the research project with the Indigenous community. A mutually-agreed contract that outlines the nature of the research and its potential benefits must then be drafted. The contract must be succinct and free of any ambiguity or information that could be misconstrued, especially when the ICIP contains sensitive material.

Personal, cultural and socioeconomic influence on scientific research

INQUIRING FURTHER

Conduct a secondary-source investigation into the current research on a diet of your choosing. Present your findings as a literature review.

Everyone has different values and priorities depending on their interactions and experiences with the world around them. In a society where there are so many opinions on the 'right' and 'wrong' way to go about our daily lives, people depend on scientific research to back up their claims.

Dieting in multicultural society

For over 100 years, the obsession with body image has led to the introduction of a range of diet plans claiming to produce the 'ideal body'. As ideals vary according to culture and societal norms at the time, so too does the goal of the diet itself. Some diets may aim to make a person lose fat, others are focused on building muscle mass or on increasing body fat. Regardless of their origin, the preoccupation with dieting has influenced scientific research aimed at supporting or falsifying the claims of specific diets.

For example, peer-reviewed research in to 'detoxifying' or cleansing diets has concluded that the current data from clinical trials conducted on such diets are flawed, with poor methodologies and small sample sizes. While there has been some evidence to suggest that certain foods have detoxifying properties, this data was obtained through animal testing and no such information has been collected in human trials.

Science Source

FIGURE 6.3.11 Boasting 'no ill effects', 'no exercise' and 'no danger', the consumption of jar-packed tapeworm eggs was a dieting craze introduced in the early 1900s.

Diets in history – the tapeworm diet

Initiated in England in the 1900s, the 'tapeworm' diet was marketed as a ground-breaking way to obtain the 'perfect' figure without having to reduce kilojoule intake. As the advertisement in Figure 6.3.11 shows, the diet involved eating tapeworm eggs from the jar or in pill form. Once the parasitic worm reached the intestine, it matured and absorbed the nutrients and fats ingested by the host, growing up to nine metres long. After reaching their desired weight, the host would then take a subsequent pill to remove the tapeworm from the digestive

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system, which was usually accompanied with severe abdominal cramps.

Following this radical diet, scientific research determined that the long-term ingestion of tapeworms was found to be associated with a range of diseases including dementia, meningitis and epilepsy. The diseases were as a result of cysticercosis, a condition where the tapeworm larvae bury into the bloodstream and are carried to the brain where they live as parasites in brain tissue.

Dieting across cultures

Diets also differ according to the dominant values of a culture. For example, in some areas of the South Pacific such as Fiji, Samoa and Nauru, being large was historically an attractive trait, suggesting wealth and access to resources. As depicted in Figures 6.3.12 and 6.3.13, recreational activities and traditional strength competitions may also encourage excess food to be eaten.

What is defined as an attractive female or male body is viewed differently according to a person's culture. While many westernised cultures have been accustomed to idolise slimness other cultures view additional weight as an indication of health and fertility. The anomalies in attractiveness between different countries can be problematic where extremely underweight or overweight individuals are favoured.

Socioeconomic status and dieting

Populations residing in areas of low socioeconomic status often do not acquire the education or have adequate access to the resources that allow them to make healthy nutritional decisions. If an individual is financially unstable or has limited access to foodstuffs, the need to fulfil hunger takes precedence over the nutritional value. Many low socioeconomic communities therefore survive on starch-based foods such as rice and potatoes that contain few vitamins. Scientific journals such as the *Journal of Nutrition* and the *International Journal of Food Science* are dedicated to researching the nutritional and health effects of dietary staples in different countries. This has led to the scientific development of foods such as golden rice to help reduce the deaths from diseases related to vitamin deficiency.

FIGURE 6.3.12 A UK pharmacy recently created a project that asked designers in 18 different countries to edit an original image to reflect the beauty standards specific to their country. The result showed the vast ways in which 'beauty' can be defined.

onlinedoctor.superdrug.com Shutterstock.com/Hugo Felix

FIGURE 6.3.13 The second part to the 'Perceptions of perfection' project highlighted similar differences in the 'ideal' male figure.

onlinedoctor.superdrug.com Shutterstock.com/Hugo Felix

SECTION REVIEW 6.3

REMEMBERING

1 Name two examples of genetically modified foods.
2 Identify one surgical device that has improved world health.
3 Name three ways in which minimally invasive surgery improves patient wellbeing.

UNDERSTANDING

4 Justify the use of drones as an economically beneficial technology.
5 Describe an example of benefit sharing in scientific research.
6 Evaluate the importance of scientific research to marketing.

APPLYING

7 Create a visual representation that outlines and describes the six steps of wastewater treatment.
8 Discuss the controversy related to investment in space exploration.

ANALYSING

9 Politics, time and budget priorities influence the direction of scientific research. Using a modern example, discuss how trends in scientific research are a product of government concerns.
10 'A low-carbohydrate, high-protein diet plan will help all Australians meet their goal weight'. Discuss this statement.

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CHAPTER REVIEW QUESTIONS

REMEMBERING

1 Identify the location of the world's most devastating nuclear reactor meltdown.

2 Define the process of bioprospecting.

3 Identify three areas of scientific research that require international codes of conduct.

4 Identify a culture where being overweight is attractive.

UNDERSTANDING

5 Describe the observations that led to the development of the smallpox vaccine

6 Outline two ethical issues related to genetic manipulation.

7 Why is it important that water is treated and purified before drinking?

8 Describe the process of stem cell research and why it raises some ethical concerns.

APPLYING

9 Use two examples to explain how the public image of science is influenced by past events.

10 Justify the importance of a scientific code of conduct in one named area of scientific research.

11 Evaluate the impact of minimally invasive surgery on human wellbeing.

12 How do large corporations and governments influence the direction of scientific research?

ANALYSING

13 Predict the positive and negative ways in which the introduction of cloning may influence the public image of science.

14 Using examples, analyse the necessity for regulation and ethical codes of conduct in the researching process of emerging scientific technology.

15 Discuss the following statement: 'Scientific research is guided by the emergence of scientific technologies and is independent from any socioeconomic, cultural or political influences'.

DEPTH STUDY
BIOLOGY

INVESTIGATING GENETIC MUTATIONS FROM IN-UTERO EXPOSURE TO NUCLEAR RADIATION

Suggested length: 12 hours including research and portfolio

Focus: Secondary-source investigation

WS 6.5.1 Secondary investigation scaffold

6.5.1 Genes to genome
6.5.2 Genetics home reference
6.5.3 What does radiation from a nuclear disaster actually do to our bodies?
6.5.4 Radiation levels

PORTFOLIO

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Syllabus statement: Investigating past scientific events such as nuclear reactor meltdowns and how it changed the public image of science in terms of mutations.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references:

- NHS: Health Education England, Genomics Education Program, Genes to Genome.
- US National Library of Medicine, *Genetics Home Reference*, 'Help me understand genetics'.
- *ABC News* (2016), 'What does radiation from a nuclear disaster actually do to our bodies?'
- The Chernobyl Gallery, Radiation Levels.

Investigation design

Outline the elements you are including in your portfolio as a table of contents. (Refer to Chapter 2 for further information.)

Method

The method is written as numbered steps. Each sentence must start with a verb. In secondary investigations, the method refers to the series of steps you plan to take to carry out the research.

Results

The results from a secondary investigation are a summary of the findings you have gathered from your research. In this case, the results may be visual representations, tables or graphs. Examples include how mutations occur, how mutagens affect DNA, the process of meiosis and information on the mutagen of your selected nuclear meltdown.

Validity and reliability

Remember that validity is related to the procedure and equipment used to perform your experiments, and reliability is associated with the repetition of the experiment obtaining similar results with minimal error. In secondary investigations, reliability refers to similar information being found in many reputable sources that have been recently published.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your aim. Include written explanations of your results and how these relate to the syllabus outcome/s you are investigating.

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DESIGNING A WATER PURIFICATION DEVICE AS A CHEMICAL SYNTHESIS PROCESS

DEPTH STUDY
CHEMISTRY

Suggested length: 14 hours, including research and construction of model

Focus: Primary investigation

6.6.1 Primary investigation scaffold

6.6.1 *Encyclopaedia Britannica* – Chemical synthesis

6.6.2 Clean water for developing countries

6.6.3 25 methods to purify water

MAKING A MODEL SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Syllabus statement: Designing a water purification device aimed at improving world health through the application of a chemical synthesis process.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references:

- *Encyclopaedia Britannica,* 'Chemical synthesis'.
- Dean Petrich (2017), Environmental alternatives, 25 methods to purify water.
- Pandit, A., Kumar, J. (2015), Clean water for developing countries, *Annual Review of Chemical and Biomolecular Engineering*.

Investigation design

Outline how you will design the final presentation of your investigation (see Chapter 2).

Method

The method is written as numbered steps. Each sentence must start with a verb. In this case, the method refers to how you carried out research and designed, constructed and tested your water purification device.

Results

Include visual representations of your design and tabulated and/or graphical data that depicts the effectiveness of your design.

Validity and reliability

Remember that validity is related to the procedure and equipment used to perform your experiments, and reliability is associated with the repetition of the experiment obtaining similar results with minimal error.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your aim.

DEPTH STUDY
PHYSICS

INVESTIGATING THE DEVELOPMENT OF NUCLEAR FISSION AND NUCLEAR FUSION AS ALTERNATIVE POWER SOURCES

6.7.1 Secondary investigation scaffold

Suggested length: 12 hours

Focus: Secondary-source investigation

6.7.1 Fission vs. Fusion – What's the Difference?

6.7.2 The bridge to fusion: four advanced nuclear fission technologies

6.7.3 Laws of conservation

SECONDARY-SOURCED INVESTIGATION SCAFFOLD

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Syllabus statement: Evaluating the importance of scientific research in nuclear fission and fusion to economic development and human progress.

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references:

- Duke Energy, Nuclear Information Center 'Fission vs. Fusion – What's the Difference?'.
- Svoboda, E. (2011), 'The bridge to fusion: four advanced nuclear fission technologies' *Popular Mechanics*.
- Nuclear Power, Laws of conservation.

Investigation design

Outline how you will design the final presentation (see Chapter 2).

Method

The method is written as numbered steps. Each sentence must start with a verb. In secondary investigations, the method refers to the series of steps you plan to take in order to carry out the research.

Results

The results from a secondary investigation are a summary of the findings you have gathered from your research. In this case, the results may be visual representations, tables or graphs. Examples include how nuclear fission and fusion occur, relevant laws of physics, how nuclear fission and fusion can be used to generate power.

Validity and reliability

Remember that validity is related to the procedure and equipment used to perform your experiments, and reliability is associated with the repetition of the experiment obtaining similar results with minimal error. In secondary investigations, reliability refers to similar information being found in many reputable sources that have been recently published.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your aim. Include written explanations of your results and how these relate to the syllabus outcome/s you are investigating.

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INVESTIGATING HOW TRADITIONAL MEDICAL TREATMENTS INFLUENCE THE DIRECTION OF SCIENTIFIC RESEARCH

DEPTH STUDY
INVESTIGATING SCIENCE

Suggested length: 12 hours, including research

Focus: Secondary-source investigation

WS 6.8.1 Secondary investigation scaffold

6.8.1 The role of traditional medicine practice in primary health care within Aboriginal Australia

6.8.2 Traditional Chinese medicine: potential for clinical treatment of rheumatoid arthritis

6.8.3 Research on traditional medicine; what has been done, and the difficulties and possible solutions

LITERATURE REVIEW

Syllabus outcome

Identify the syllabus outcome you will be investigating and write a summary of the outcome.

Syllabus statement: Investigating how traditional medical treatments in different cultural and socioeconomic settings has influenced the direction of scientific research

Aim

Write the aim as a sentence. Start the sentence with 'To' followed by a verb for example 'investigate', 'measure', 'test' and so on.

Secondary sources

List all the sources you have used in your investigation and cite them using the correct protocols.

See weblinks for suggested references

- Oliver, S. (2013), 'The role of traditional medicine practice in primary health care within Aboriginal Australia: A review of the literature', *Journal of Ethnobiology and Ethnomedicine*.
- Moudgil, K. & Berman, B. (2014), 'Traditional Chinese Medicine: potential for clinical treatment of rheumatoid arthritis', *Expert Review of Clinal Immunology*.
- Telles, S., Pathak, S., Singh, N. & Balkrishna, A. (2014), 'Research on traditional medicine; what has been done, the difficulties and possible solutions', *Evidence-Based Complementary and Alternative Medicine*.

Investigation design

Outline how you will design the final presentation (see Chapter 2).

Method

The method is written as numbered steps. Each sentence must start with a verb. In secondary investigations such as literature reviews, the method refers to the series of steps you plan to take in order to carry out the research.

Results

The results from a secondary investigation are a summary of the findings you have gathered from your research. In this case, the results may be tables and graphs comparing research from different sources.

Validity and reliability

Remember that validity is related to the procedure and equipment used to perform your experiments, and reliability is associated with the repetition of the experiment obtaining similar results with minimal error. A literature review usually comments on the reliability of sources by determining whether similar studies have similar results.

Discussion and conclusion

In the discussion and conclusion, analyse your findings to answer your aim. Include written explanations of your findings and how these relate to the syllabus outcome/s you are investigating.

ANSWERS

CHAPTER 3

SECTION REVIEW 3.1

Remembering

1
- Barry Marshall and Robin Warren discovered the link the between peptic ulcers and a bacterial infection.
- Jean Baptist van Helmont conducted experiments to try to determine where the mass of plants came from.
- Percy Spencer is regarded as the inventor of the microwave oven – he observed that large magnetrons had a heating effect on food nearby.

2
- Robin Warren initially observed that many of the biopsies from patients who had peptic ulcers were infected with the *H. pylori* bacterium. He worked with Barry Marshall to confirm this link and then to develop a new treatment for the ulcers.
- Van Helmont undertook careful measurements of the soil and the plant used in his investigation. While he was unable to correctly ascertain the way plants grew, his observations were precise.
- Percy Spencer made an accidental observation while working on magnetrons used in developing radar technology. A chocolate bar in his pocket melted while he was in the path of the microwaves. This observation led him to postulate that the technology could be used to heat food.

3 a Antibiotic treatment for peptic ulcers

b Microwave ovens

Understanding

4 The idea that a bacterium was the cause of peptic ulcers went against medical thinking at the time. Physicians assumed that the bacterium would not be able to survive within the environment of the stomach.

5 The role of gaseous exchange in plants had not yet been discovered. Van Helmont did not realise the additional mass could come from the air.

6 Percy Spencer followed the principles of the scientific method. He also read widely to fill gaps in his knowledge.

Applying

7
- Marshall and Warren proposed that the *H. pylori* bacterium was the cause of the majority of peptic ulcers. Their experiments confirmed this hypothesis.
- Van Helmont thought that plants grew by 'eating' soil. His experiment showed some decrease in the mass of the soil, but not enough to account for the increase in mass of the plant. He concluded that plants grew by assimilating, or drinking, water.
- Percy Spencer observed that microwaves heated food. He was eventually able to control this to develop the microwave oven.

8
- Marshall and Warren's idea that *H. pylori* was the cause of peptic ulcers went against the thinking of medical profession at the time, and many in the scientific community felt that the current treatments were effective enough. In most medical research fields, peptic ulcers were to not of high interest, therefore, it took a long time for other scientists to repeat Marshall and Warren's experiments and confirm their results.
- Van Helmont was able to show that a plant fed only water will still grow. Phenomena such as stomata had not yet been discovered, as it would be at least two hundred years before suitable microscopes would be invented.

SECTION REVIEW 3.2

Remembering

1
- Marshall and Warren conducted primary investigations, making tissue cultures out of biopsy samples and culturing them in a laboratory.
- Eratosthenes used a mixture of primary and secondary sources. He measured the angles at noon as his primary investigation, then used secondary information about the distance between the two cities as part of his calculations.
- Doppler conducted primary investigations – he used his own photographic plates to create images of his investigations, and then analysed them himself.
- Priestley conducted primary investigations; even going as far as breathing in the gas he had made.

2 Answers will vary, examples include:
- experimental testing – determine the boiling point of a liquid
- fieldwork – determine the number of lizards in a creek area
- locating and using information sources – researching information about stars in science textbooks
- conducting surveys – a survey might be used in cancer sufferers to attempt to draw links between patients to determine a cause of the disease
- modelling – a model of the atom can be used to demonstrate its parts and their relative position to each other
- simulations – are used to predict the effect that a 4° rise in atmospheric temperature may affect coastlines.

Understanding

3 Tissue culturing is important as it allows researchers to take cells out of a living organism and grow them under laboratory conditions. Researchers can then experiment without harming an organism.

4 Measurements were not standardised in ancient times, so there was likely to be errors in the measurement between the two cities.

5 Photographic plates needed complete darkness and long exposure time to get good results.

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Applying

6 His work involved sacrificing a lot of mice. He also used some mercury compounds that are dangerous to human health.

7 Galileo observed planets such as Jupiter through his telescope. This methodology was the only one he could use, as there was no secondary data available. The data were primary observations of Galileo. Galileo was considered a heretic, as his ideas contradicted the worldview of the Catholic Church at the time.

SECTION REVIEW 3.3

Remembering

1
- Make an observation
- Develop a question
- Create a hypothesis
- Design your experiment
- Perform your experiment
- Accept or reject the hypothesis

Understanding

2 In some scientific areas, such as astronomy and genetics, scientists analyse a large amount of data, trying to ascertain patterns. In astronomy, observations might come from many telescopes looking at the same objects from different points on the globe.

In genetics, a scientist may look for common genes that potentially cause disease, looking at hundreds or thousands of individuals' data. In these cases, a scientist or team will analyse the data from many sources.

Applying

3 Not all the equipment required may be available, and substitutes may not work as well.

SECTION REVIEW 3.4

Remembering

1 The methodology is the process used to undertake and complete your investigation. For example, when trying to ascertain the effect of sugar or salt on the boiling point of water, the best methodology would be a primary investigation.

A scientist trying to determine how climate has changed over the last 100 years would be unable to collect the data themselves, so they would analyse secondary sources of data, such as that provided by the Bureau of Meteorology.

2
- Independent variable – what is being changed in an experiment
- Dependent variable – changes as the independent variable changes.
- Sampling – obtaining information about a small subset of a larger group, and making extrapolations based on the information. Often used to determine species numbers in an area.
- Qualitative data – is when data can be described. For example, it feels hot in the room.
- Quantitative data – is data that can be described numerically. For example, the temperature is 30° Celsius in this room.

Understanding

3 Too much data may take too long to analyse.

4 Organising the data graphically may expose trends in the data that were not obvious when just looking at the numbers.

5 Risk assessments are vital in helping to ensure an investigation is conducted safely. To 'identify' involves the investigator determining all potential hazards. They then 'assess' to determine the likelihood of the risk occurring, and how dangerous this risk might be. If a risk is deemed to be a high chance of happening with a chance of injury, then it might be pertinent to change investigative method. It is important to 'control' risk to make sure you work with participants or use equipment with the least amount of risk possible.

6
- While working individually, you do not have to negotiate to do something in a certain way – you make the decisions. Working solo might also make it easier to concentrate.
- Working in teams means different members of your group might bring in unique skills for the investigation, and you may be able to discuss the best ways to conduct the investigation or analyse the results.

Applying

7 Different groups may have different views on what can be used to further an investigation. For example, many people disagree with the use of embryonic stem cells as they hold human life sacred. Others may believe that all living creatures have the right to not be experimented on.

Priestley's experiments involving oxygen resulted in many mice dying of asphyxiation after being put into sealed containers. Today, this would be seen as a cruel and unnecessary experiment.

8
- Technological advancement has seen many scientific ideas change dramatically.
- The telescope allowed Galileo to see object orbiting Jupiter, proving the Earth wasn't the centre of all objects in the universe.
- The development of the cathode-ray tube eventually led to the development of electron microscopes which gave unique insights into the subatomic world.
- The increase of processing power in computers has allowed for the development of complex computer simulations. They have given people a glimpse into many of the potential futures that may occur as the effects of global warming worsen.

9 In the case of Marshall and Warren, their investigation allowed a simple treatment to be used for a debilitating condition. Prior to their research, patients with ulcers had to be treated for extended periods. Their research allowed

people to be cured with a short course of antibiotics, an advantage to society.

Spencer's research had a positive effect on the environment, as microwave ovens use less electricity than conventional electric ovens, reducing the amount of energy consumed.

CHAPTER REVIEW

Remembering

1 A scientific theory is an explanation of a phenomenon based on evidence. Two examples are the theory of plate tectonics or germ theory.

2 Ulcers are caused by a bacterium, *H. pylori*, which is able to live in the human gut. A simple course of antibiotics will remove the bacterium and cure the patient.

3 Jan Baptist van Helmont was a Flemish doctor and chemist who is credited with the first use of the word gas, and who also did many experiments on the digestion of food. He is best known for his five-year experiment where he merely watered a willow plant, but observed significant growth.

4 Percy Spencer was an American physicist and inventor who developed the microwave oven based on work he had done on radar arrays for the American military.

5 Accurate measurement of angles and the ability to solve mathematical problems.

6 Doppler was studying the spectral patterns from binary star systems.

7 Priestley discovered one of the components of air, which we now know to be oxygen.

8
- A primary investigation is an experiment where the individual or team collect their own information.
- Fieldwork means any investigation done outside the controlled situation of a laboratory.
- A secondary-source investigation is where the individual or team analyse the results of other scientists' investigations to extrapolate new information.
- Surveying is a sampling technique where the opinions of a group are determined.
- Modelling is a way of studying a phenomenon by studying a representation of the phenomenon. Examples of models include diagrams, physical replicas, mathematical models, analogies or simulations.
- Simulation is a way of studying a concept by assessing how different factors affect a phenomenon. For example, in climate science, scientists create computer models of ecosystems and then modify the variables to determine how these changes may affect the climate.

9 The scientific method is an organised approach to solving a scientific problem. Scientists follow this method as it provides a logical way to conduct investigations and makes it easy for others to replicate and confirm their results.
There are many examples of investigations that do not follow the basic scientific method. In biology, some scientists spend time observing the interactions of primates in their natural habitat. A well-known example of this is the work of Dian Fossey, who studied mountain gorillas. Geologists use similar techniques when observing rock formations or the behaviour of volcanoes.

10
- Methodology – the process by which an investigation is conducted. For example, conducting an investigation.
- Aim – what you are trying to prove in your investigation.
- Hypothesis – an educated guess as to what you think your investigation will show.
- Materials – the equipment and substances you will need to complete your investigation.
- Method – the steps taken to conduct your investigation.
- Risk assessment – a process to follow to identify risks and then put strategies in place to mitigate any potential hazards.
- Reliability – repeating an experiment to obtain similar results with minimal error.
- Validity – ensuring the test is fair and that is tests your hypothesis.
- Independent variables – the variable that is deliberately changed in an investigation.
- Dependent variables – what changes when the independent variable is changed; what is being measured.
- Controlled variables – all other parts of an investigation that must be kept the same to ensure validity and reliability.

11 Two ways of improving accuracy are using equipment with higher degrees of precision and conducting more experimental trials.

12 Primary data is data collected directly by the individual or team conducting the investigation, while secondary data has not been collected directly.

13 Three ways to collect data are:

a Using direct observation

b Using data-logging equipment

c Conducting surveys or questionnaires

14 A scientific report summarises what was found during the investigation and backs up the findings with evidence and data.

Understanding

15 Answers may vary. One answer could be: Marshall and Warren found a link between peptic ulcers and the bacterium *H. pylori*. The accepted idea at the time was that it was impossible for bacteria to survive in the stomach.

16 Barry Marshall swallowed the *H. pylori* samples, developing a peptic ulcer a short time later. He believed he was justified in taking this risk because he could take a course of antibiotics to destroy the bacteria.

17 Van Helmont was trying to determine where a plant's mass came from. The assumption at the time was that the mass came from plants assimilating soil. Van Helmont showed that only a miniscule amount of soil mass had decreased.

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He assumed that the increase in the plant's mass must have come came from water, as that was the only thing he had added.

The notion of gaseous exchange in plants had not been discovered, so he was unable to factor in the use of gases within the plant's structure.

18 Instruments of measurement from the time were not entirely accurate. In addition, Eratosthenes had to do the mathematics without the aid of a calculator.

19 An investigation must have all factors constant to ensure that the validity and reliability are maintained.

20 A scientist must get enough data to be able to make an accurate conclusion, but not too much data to make it difficult to analyse the results or that they waste time and resources.

21 When working individually, a scientist may be able to work efficiently and with minimal distractions; however, if they have questions or want to talk something over, it may take time to find someone.
When working in groups means you can make use people with specific skills. One person maybe quicker at a task, such as data analysis, while others can continue with different elements of the investigation.

22 It is often easier to ascertain trends in the data looking at a graph than by looking at tables of numbers.

23 The purpose of any scientific investigation is to find an answer to a problem. The results are an integral part of the evidence supporting the hypothesis.

24 The investigation is reliable if it can be tested with consistent results. If you are correctly testing your hypothesis then it is valid.

25 It allows scientists to clearly explain their results. It allows scientist to communicate ideas to each other.

Applying

26 Answers will vary. A suggested answer could be: Professor Fiona Wood used cell cultures of skin to develop a product to spray skin cells onto patients who had suffered severe burns.

27 It was sometimes difficult to get accurate measurements. In the case of Eratosthenes, if he missed his measurement of the angle, he would have to wait a year to be able to make the next measurement.

28 Many of the laborious tasks in astronomy, such as sitting in the dark exposing photographic plates, is now done remotely using computer technology. Computer can also be used to quickly find differences in the images.

29 Investigations, such as those done by Priestly, involving animals are tightly controlled via ethics panels. An ethics panel decides whether the experiment is cruel towards the animal, or whether the harm or death of the animal is worth doing. In the case of Priestly it would most likely have been deemed unethical.

Jenner's experiment of infecting a small boy with two disease strains would not be considered ethical as the boy, James Phipps, was healthy and had a high chance of dying if the vaccination did not work as expected. While Phipps and his family were well rewarded with land from Jenner, the risk of death would prevent the experiment being approved.

30 A literature review can give a scientist some insight into the areas of research that other scientists have conducted. It may show areas that require future research.

Analysing

31 Modern inventions such as the microwave have made household chores faster and more efficient.

Some might argue that this has led to cooking more processed food, which has influenced the obesity epidemic affecting western society. Others may argue that this convenience has provided families with more leisure time and made it easier to prepare healthy food.

32 Answers will vary, an example is below.
In the 20th century, the US and USSR space programs were expensive scientific programs. However, as well as enabling space exploration, these expensive programs also led to the development of technologies such as wireless communication and the Global Positioning System. In addition, many of the innovations in microprocessors came from the need for small electronics on space craft.

As well as advancing science in general, fundamental research on the Large Hadron Collider may lead to technologies we have not even thought of yet.

CHAPTER 4

SECTION 4.1

Remembering

1 Technology is the application of knowledge to create a device with practical purposes. Examples could include the telescope, the computer or the telephone.

2 Answers will vary; suggested answer:

Writing was one of the first ways to communicate ideas and transfer information. Ancient cultures, such as the Egyptians, used rolls of papyrus to record information about laws, harvesting and taxes and to communicate strategy during wartime. Later, paper replaced papyrus and the postal system was created to distribute information. In the 20th century, the invention of computer and the Internet changed communication systems, which led to today, where we send and receive communication globally via email and other platforms, such as social media and instant messaging.

3
- Gross: caused by mistake when using the instrument and recording data.
- Systematic: instrumental – caused by a fault in the instrument.
- Systematic: environmental – caused by external conditions affecting the instrument; for example, changes in temperature, humidity and light intensity affecting the instrument or its results.

- Systematic: observational – caused by errors in observations or readings.
- Random: caused by sudden changes in experimental conditions, which are out of control of the operator.

Understanding

4 Temperature affects the reaction rate in a chemical reaction because the increase in energy in the system increases the number of collisions between the particles.

5 Charles' law states that for a constant volume of gas in a sealed container, the temperature of the gas is directly proportional to its pressure. That means the more pressure there is in the container the higher the temperature.

6 Average speed is measured because the speed of an object changes over a distance due to friction or other forces applied to the object. Instantaneous speed is the speed of the object in that instant.

Applying

7 Low temperatures reduce the collisions between particles in biochemical processes, so the processes slow down or stop altogether. Another aspect of cool conditions is that living tissue can freeze, burst and die.

Desert plants have many evolutionary adaptations to overcome the effect of extreme temperatures, such as:

- enzymes that adapt to catalyse chemical reactions in temperatures over 40°C, providing resistance to high daytime temperatures
- structural adaptations, such as spikes, which reduce water loss, allowing cells to avoid dehydration
- the ability to retain water in a gel-like state, which helps some plants survive temperatures as low as −40°C
- the ability to produce anti-coolant substances to avoid freezing.

8 The aerodynamics of the boomerang and its size, length and wing area are the keys to understanding its speed and the distance travelled. To increase speed and therefore cover more distance, the following aspects should be considered:

- Gyroscopic motion: As the boomerang spins, the wing going over the top creates more lift, and at the same time creates drag. Lift and drag are two important variables to control to improve speed and manage air resistance.
- The boomerang flight is perpendicular to the boomerang plane; this is important in throwing the boomerang as an overhand throw, not a sidearm toss. This reduces air resistance.
- Keep in mind Newton's third law of motion: 'For every action force there is an equal and opposite reaction force'.

SECTION REVIEW 4.2

Remembering

1 Answers will vary; for example, science has helped develop many technologies that improve society, while technological developments improve the ability to collect evidences to support or disprove scientific principles, theories, models and laws.

2 Impact is defined as a marked effect or influence on someone or something. One example would be that the use of digital technologies has influenced the way science is conducted in communication, medical and engineering fields.

3 Aboriginal and Torres Strait Islander communities use native plants for medicinal purposes. They create infusions to be consumed as a tea or applied in compresses, and make ointments for skin conditions. For example, the snake vine can be tied around an affected area to relieve pain or quandong seeds can be mashed into a paste and applied topically on burns.

Understanding

4 The collection of evidences as data is the key to support or disprove the application of a scientific principle. For example, using satellite imaging and sonar digital technologies to collect evidences about how the continental plates are moving over time supports the theory of plate tectonics.

5 Newton's laws have important applications in new technologies and design. For example, transport safety. Thanks to Newton's laws, today's cars are built to absorb the forces of impact and protect the passengers. Applying the principles of inertia and action-reaction crumple zones, seatbelts and airbags reduces the impact of forces in accidents.

6 Collecting information about the uses of medicinal plants can be a challenge for the pharmaceutical industry because the same plant can be used for different medicinal purposes in different communities. This is because plants are affected by seasonal availability and geographical distribution.
Other challenges are caused by the language barrier and the need to respect sacred knowledge that may not be able to be discussed widely.

Applying

7 To create Bt cotton, the following scientific principles and technologies were applied:

- genetic engineering techniques – DNA hybridisation technologies
- knowledge about DNA structure
- knowledge of cell theory and cell replication
- tissue culture technologies.

Those technologies, in conjunction with scientific knowledge, were used to develop Bt cotton, which has changed the cotton industry. Bt cotton has reduced the use of pesticides, improving the environmental conditions of the crop and reducing the impact of pesticides on the food chain.

8 High above the Earth's atmosphere, the Hubble telescope has collected evidences to support theoretical principles about the universe using digital cameras and spectrometers, which feature multi-wavelength filters. The theoretical principles include the existence of black holes, star distances, galaxy and star formation and understanding of the age of the universe.

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Thanks to the information collected by the Hubble telescope, astrophysicists have enhanced their understanding and proved principles with concrete evidences and data analysis.

9 To collect the plant from Country and Place, local elders and communities have to be contacted and a meeting has to be arranged to discuss:

- intention to use the plant as medicine
- the collection area
- implications if the plant grows in a sacred or respected area
- the intellectual property of the knowledge about preparing the plant for medicinal purposes

Finally, a written agreement between all the stakeholders should be signed.

CHAPTER REVIEW

Remembering

1 Technology is the application of knowledge to create a device for practical purposes in any area of research.

2 Technologies can limit scientific advances when the technology used in collecting data and evidences to support the scientific principle is not appropriate, or does not collect accurate measurements.

Technologies can enhance science when they help researchers collect data and evidences with limited or no error, and the measurements are precise and accurate. Technologies can also help in processing large amounts of data that would be unwieldy to process manually.

3 The difference between analogue and digital is the way the information is collected and recorded. In analogue technologies, the wave is recorded or used in its original form, while with digital technologies, the wave is sampled at some point and turned into a combination of binary numbers and stored in a device.

4 Identify the type of errors when using technologies and give examples.

ERRORS		DEFINITIONS	EXAMPLE
Gross		Caused by a mistake in using instruments or meters, calculating measurements or recording results	A person or operator reading a pressure gauge writes 1.10N/m^2 instead of 1.01N/m^2
Systematic	Instrumental	Occurs due to a fault in the measuring device	A data logger is measuring temperature in the range of 100°C instead of the range of 30°C
	Environmental	Occurs due to some external conditions of the instrument (pressure, temperature, humidity or magnetic field)	The humidity levels during the measurements has changed because of the wind conditions
	Observational or parallax error	Occurs due to incorrect observations or readings in the instruments	Reading 35 mL from the measuring cylinder instead of 32 mL
Random		Caused by a sudden change in experimental conditions	Unexpected change in temperature or fluctuation in voltage

5 The developments of technologies over the years has led to advances in science, its theories and laws and consequently has driven new developments and created new needs in society. At the same time, new understandings and more deep knowledge in scientific principles, theories, models and laws helped the development and improvement of the technologies.

Understanding

6 New technologies play an important role in the analysis of data and creation of models for future interpretation and correlations of data to predict and diagnose phenomena. Technologies influence all branches of science to a level that science is somewhat dependent on technology and the relationship between the two is difficult to separate. In simple terms, it is now difficult to see the division between science and technology in any research.

7

TECHNOLOGY	DIGITAL	ANALOGUE
Advantages	• More precise • Compatible with other digital systems • Integrated networks • Immediate recorded information	• Low cost • Uses less bandwidth • Sometimes more accurate • No need to synchronise communication systems
Disadvantages	• Might be expensive • Can amplify sampling errors • Digital communications require greater bandwidth • Detecting digital signals requires synchronised communications system	• The effects of random noise can make signal loss and distortion impossible to recover • Observational errors

8 Answers will vary, based on student example.

9 Note: students can choose any example here, it is important that the discussion is related to the science first into the technology second. Suggested answer:

The development of technologies in the production of glasses and contact lenses to improve vision is linked to the understanding and knowledge of the laws of reflection and refraction.

The law of reflection says that the angle of incidence is the same as the angle of reflection.

Law of refraction or Snell's law: the incident ray, the refracted ray and the normal to the interface, all lie in the same plane.

Different media (water, air, glass, Perspex, plastics) have different refractive indexes and this will influence the type of glasses or contact lenses created to correct vision.

Today's glasses and contact lenses (and other optic devices) are based on those principles. New materials and new technologies are also important when producing optical materials but the technology starts with the laws of reflection and refraction.

10 Aboriginal Australians and Torres Strait Islanders use traditionally made infusions to drink as teas to treat upset stomachs or body aches and ointments and saps are placed on infected cuts and abrasions. Bush medicines are collected and prepared from well known local plants. However, communities may use the same plant for different purposes depending on seasonal availability and geographical distribution.

11 Bioharvesting from Country and Place to produce medicinal drugs has ethical implications for local Aboriginal and Torres Strait Islander communities. Many Country and Place areas are sacred or have a significant meaning for the local Aboriginal or Torres Strait Islander community and the knowledge about the use of native plants as traditional medicines is considered Indigenous cultural and intellectual property. Therefore, it is very important that if a native plant is collected from Country and Place, the local Aboriginal and Torres Strait Islander community is consulted and the implications of that harvest is discussed.

Applying

12 Students can design any simple experiment here. Points to be addressed in the answer include:

- list of technologies – data loggers, digital thermometers or traditional thermometers
- risk assessment – identify the hazard and explain how to overcome the risk.

13 $V_1 = ?$

$V_2 = 180\ \text{cm}^3$ to $\text{dm}^3 = 0.18\ \text{dm}^3$

$T_1 = 40°\text{C} + 273 = 313\text{K}$

$T_2 = -3.0°\text{C} + 273 = 270\text{K}$

$$\frac{V_1}{T_1} = \frac{V_2}{T_2}$$

$$V_1 = V_2\left(\frac{T_1}{T_2}\right)$$

$V_1 = 0.18\ \text{dm}^3 \times (313\ \text{K}/270\ \text{K})$

$V_1 = 0.209\ \text{dm}^3\ \text{H}^2$

14 Due to the increase in pressure diving deeper in the ocean, the volume of air reduces. However, the volume of air in the tank does not change as the diver descends because the air in the tank is pressurised.

15 $P_1 = ?$

$P_2 = 2.00$ atm

$V_1 = 8$ L

$V_2 = 20.3$ L

$$P_1V_1 = P_2V_2$$

$$P_1 = P_2\left(\frac{V_2}{V_1}\right)$$

$P_1 = 2.00\ \text{atm} \times (20.3\ \text{L}/8\ \text{L})$

$P_1 = 5.06$ atm

16 d = 500 m
t = 12 min

12 min to sec = 720 sec

S = d / t

S = 500 m / 720 sec

S = 0.69 m/s

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17 As shown in the hypothetical table below, the speed has affected the distance travelled by the spear in the same time frame.

SPEED (m/s)	TIME (sec)	DISTANCE (M) (d = s x t)
27	30	810
35	30	1050
48	30	1440

Analysing

18 a Effect of temperature on plant growth

Temperature: measured with a data logger or digital thermometer

Plant growth = e.g. plant height measured with a laser meter

b Effect of pressure on oil extraction

Pressure = digital pressure gauges

c Effect of wind speed on racing car design

Wind speed = aerodynamic motion and forces sensors, slow motion cameras

Justification: digital technologies are more reliable, precise and accurate when collecting data because they are calibrated for that specific purpose and reduce the systematic and gross errors.

19 Scientific principles include:

- Radioactive decay
- EM spectrum waves – gamma rays
- Atomic and quantum theories

20 Answers will vary.

21 Aboriginal people beat the resin out of the grass, then cleaned it and heated it over fire to create a sticky black substance. The resulting resin hardened as it cooled. It was strong enough to bind rock to wood, so it was used to create tools such as spears, woomeras and axes.

Synthesising

22 a Suggested answer: 3D printing and 3D scanner printer

b Suggested answer:

- Properties of materials
- Light properties (structured and modulated)
- Energy transformations: light to electrical
- Analogue to digital data conversions
- Computer science: miniCAD programs

c Suggested answer: The understanding in materials' molecular structures and properties (biomaterials and inorganic materials), how light properties (reflection and laser) is used to 'read' and create an image, and the application of the law of conservation of energy is applied in the energy transformations from light to electrical signals interpreted in the CAD programs are the key scientific principles for 3D scanners to collect the information and create a device for the client.

23 Suggested questions for the interview:

- What Aboriginal communities live in this area?
- What plants are collected for medicinal purposes in the past?
- How were those plants collected and prepare to be used as medicines?
- Who can collect those plants and prepare the medicines? Are there any restrictions?
- Are the collection practices still valid today?
- What kind of rituals were practiced to release the person from the illness?
- Were infants and adults given the same treatments for similar illnesses?

Evaluating

24 Suggested debate structure – create groups in the classroom that take the issue under the following discussion areas:

- positive facts
- negative facts
- general public opinion
- scientific opinion
- solutions.

25 Suggested answer: Technology has impacted the way society works and relates. Information and communications technology has expanded knowledge across the world and has closed the gap between ideologies and opinions. We learn more every day from others and we share more of our information and knowledge with others too.

The cartoon may refer to the fact that humans have not change our 'raw' emotions: fear, love, sadness, fight or flight attitudes, aggression and compassion. Technologies may help us to instantly access pictures of our loved ones from the other side of the world, but our emotions about them are still the same as they were a million years ago.

Note: this can be a very interesting debate topic in the classroom; students can create flyers to place around the school to change students' attitudes towards cyberbullying and use of social media.

CHAPTER 5

SECTION REVIEW 5.1

Remembering

1 One way scientists can inadvertently bias a sample is by selecting it based on convenience, as this may limit the kind of data collected. This is called convenience sampling. Another form of bias could come from using data from participants who volunteer for the investigation. This is known as voluntary response sampling.

Understanding

2 When a sample size is too small, there is an increased chance that the data may be swayed in one direction or another simply through random chance. Increasing the sample size decreases that likelihood that random chance will sway the

results and a more normal distribution is more likely to be obtained.

3 The confidence interval is the distribution of values for a given measure or treatment. The example from Figure 5.1.5 demonstrates a set of samples that measure weight, some of these samples have a wider spread in the distribution of the measurements recorded and others have a much smaller spread. The samples that have a smaller distribution can be viewed as more reliable than values with a larger spread.

Applying

4 A proportion of consumers make food choices based on how healthy and safe they perceive a food to be. However, there is considerable debate about whether or not genetically modified organisms (GMOs) are safe to consume. The empirical scientific evidence strongly suggests that the vast majority of GMOs are safe to consume; however, some in the health food industry dispute these claims, saying GMOs are not natural and, hence, dangerous. Some companies use GMO-free branding in the hope of capturing the attention and product loyalty of consumers that identify more readily with those who are anti-GMOs.

Consequently, this type of branding does little to inform the consumer about the product's safety and instead feeds into consumer's established biases.

5 The sample size required to investigate the question would need to be very large and span participant age ranges from 0 to 85 years. The researchers would need to group the participants into subsets of age, such as:0–4, 5–9, 10–14, and so on, up to 80–85. This would total at least 17 subset groups.

To get reliable results for each subsets and reduce the chance of random error, each subset should have at least 20 participants, though around 40 would be preferable. This would to ensure a good confidence interval or spread around the mean.

Having more than 60 participants for each subset is unlikely to add to the reliability of the data. Thus, to get reliable results for this investigation you would likely need between 340 and 680 participants ranging in age between 0 and 85 years of age.

SECTION REVIEW 5.2

Remembering

1 A placebo is a tablet or treatment that has no recognised active ingredient or affect. In medical investigations, placebos are given to patients acting as a control in the investigation.

Understanding

2 The scale of the graphs in Figure 5.2.9 can significantly influence the way people interpret the information. The scale in the first graph strongly emphasises the differences in the preferences of the people that participated in the investigation while the scale in the second graph reduces the emphasis. The objectives of the investigator may influence the decision about which graph will be used to show the results.

3 In a double-blind trial to test the effects of a cholesterol treatment, the person administering the treatment does not know which patient is receiving the real drug or the placebo. This reduces the likelihood that the person administering the treatments could consciously or unconsciously bias the results whether through their body language or in their perception of results e.g. by recording reduced symptoms of heart disease in a patient receiving the drug when in reality there was little difference in the symptoms.

The use of double-blind trials increases the validity of the results obtained, which meaning increased confidence that the results are actually due to the cholesterol drug.

Applying

4 The image Kawan selected for use in his memory test could sway the results and unfairly advantage some individuals over others because of the type of objects that the people were being asked to recall. A person who works at a desk for work or study is probably very familiar with the objects in the picture and can easily name them or even guess that they were in the picture simply by recalling what is on their own desks.

A person who does not regularly work at a desk may find some objects unfamiliar. They may have difficulty remember the names of the objects and may not be able to guess what else would be likely to be there.

An image that displayed items that all participants were likely to be familiar with or that showed a random collection of unrelated items would be more likely to produce a result that is not biased.

5
- Select at least 20 people to participate in the investigation, these people should have a similar lifestyle to ensure that they are being exposed to similar types of bacteria every day.
- Randomly divide the participants into two equal groups. The first group will wash their hands, while the second group will not as they are control.
- Collect 30 agar plates for the investigation. Ten plates should be sealed without even opening them, these will be the agar plate control, to ensure they were not contaminated prior to treatment.
- Ten plates should be exposed to the participants in the treatment group who have washed their hands with soap prior to wiping their finger on the agar. The final 10 are for the control group, in which participants wipe their finger on the agar without washing their hands. All plates are sealed and then left to incubate.
- The sealed control plates are then checked to ensure no contamination has occurred. If the plates are contamination free, you can then compare hand washing plates with the control group that did not wash their hands to determine the effectiveness of hand washing with soap to reduce the number of bacteria.

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SECTION REVIEW 5.3

Remembering

1 A correlation is often seen when one or more dependent variables, that may or may not be related, show a similar or proportional relationship with an independent variable. Causation is a relationship in which the independent variable is known to have an effect on the dependent variable.

Understanding

2 In the Hawthorne studies, the investigators unknowingly managed the people in their study differently from the way they were normally managed by the factory overseers. The investigators gave the people on the factory floor more autonomy and input into how they performed their job. This inadvertently increased the productivity of control group despite the fact that they did not have extra lighting. The finding of this investigation has since been used as an example of how the presence of investigators and the changing circumstances that their presence creates can influence the outcome of an investigation.

Applying

3 Besna's investigation did not take into account the effect that vegetation could have on the amount of soil erosion. Besna's investigation could be improved by conducting the study on the second, vegetated hill. By doing this, Besna could ascertain if it was slope alone that caused soil erosion or if it was a combination of slope and lack of vegetation.

By conducting the second investigation Besna would be able to get a more complete understanding of the factors that influence soil erosion and subsequently make more informed recommendations and decision regarding erosion.

SECTION REVIEW 5.4

Remembering

1

LANGUAGE	THEORY	LAW
Scientific	An explanation that has empirical evidence to support it	That a given natural event will occur under a specified set of circumstances
Common	Having an idea or explanation that may or may not have supporting empirical evidence	The rules by which something should comply, but exceptions can be observed or the law may change over time

2 The halo effect is where an individual (or group) is perceived in a positive manner, which can influence and bias thinking on a given subject or issue simply because the person are viewed positively. This results in others being more likely to trust what the person says without requiring empirical evidence to support the claims.

An example of this may be when a trusted public figure recommends a miracle product and consumers purchase the item not because of its demonstrated efficacy but because the public figure endorsed it.

Understanding

3 Scientific investigations and publications often use complex language and describe processes that are not always understood by people without scientific backgrounds. For this reason, good scientific journalism will use language and images that are accessible to a general audience, without distorting the significance or applicability of the research findings.

Good reporting also realistically outlines a study's limitations and highlights unresolved issues or questions to ensure that the general public are fully informed and can make sound decisions based on evidence.

4 Tobacco companies generate profit through cigarette sales. Public health measures are based on empirical evidence that demonstrates that cigarette smoking has long-term health effects, such as contributing to lung cancer and heart disease. As well as shortening and limiting the quality of people's lives, these health effects cost significant amounts of taxpayer money to treat through the public health system. As such, public health officials advocate for policies and programs, such as plain packaging, that minimise the chances of someone taking up cigarette smoking and encourage them to quit, improving the individual's long-term life expectancy and decreasing the burden on the public health system.

However, if fewer people smoke cigarettes, this means a fall in sales and less profit for tobacco companies. It is therefore in the tobacco companies' interest to oppose measures such as plain packaging to protect the profitability of the tobacco company.

5 Many scientific fields use complex terminology that can be difficult for the average person to understand. Atomic physics is one field that can require years of training and experience to fully understand its terminology and processes. This can result in the public's perception that complex terminology and processes give a discipline its legitimacy.

This perception of the legitimacy of complex terminology and processes can be co-opted by pseudoscientists who develop their own complex terminology and processes to portray the illusion that their field of 'science' has undergone a rigorous vetting through the analysis of empirical evidence similar to fields like atomic physics. Pseudoscientists can deceive people who lack scientific literacy and do not understand how scientific ideas are subjected to rigorous debate based on the empirical evidence, a process that is lacking in the pseudosciences.

Applying

6 There are a number of ways that the authenticity of a media article can be cross-checked against the scientific research. First, you can check if the original article is linked to or mentioned, as well as the name/s of the investigators and the institution it comes from. You can also check whether the writer uses neutral or emotive language used to persuade the reader, whether they provide appropriate statistics that do

not bias the interpretation of the findings and the use, or lack, of qualifiers that urge caution when interpreting the results or findings. By looking for these features in a media article you can make a reasonable assessment of the authenticity of the media article and the claims it is making.

7 The growing demand that research authors identify their employment status comes from a growing awareness of how conflicts of interest can sway or bias the interpretation of investigations findings. This has come about because scientists working in a given industry; for example, the pesticide industry, are not excluded from publishing their findings in journal articles.

However, whether consciously or not, the scientist may be inadvertently biased in favour of the industry they work for. By publishing their employment status, readers are aware of any potential conflicts of interest and can subject such studies and findings to closer scrutiny.

SECTION REVIEW 5.5

Remembering

1 It costs money to conduct scientific research, and those funding the research want to ensure the money spent is used productively. To gauge this, they take note of the number of research articles that a scientist is publishing in journals. This is known as 'publish or perish' where a scientist that is deemed to not publish frequently enough may lose their job or not be considered for a grant and hence 'perish'.

Understanding

2 Peer review benefits from the fact that scientists who are well respected and well versed in particular research areas can critically analyse the research presented to them and judge its suitability for publication. However, presently there is considerably more research papers submitted for publication than peer reviewers can reasonably keep up with. Consequently, a portion of papers are reviewed by scientists who lack experience so the research publication may be compromised.

3 The reproducibility crisis a where the number of research papers being published cannot be reasonably cross-checked by reproducing the investigation and/or that insufficient replication is being done before publication.

Replication is a primary means of verifying the findings of fellow scientists. A paper that is reproducible has good supporting evidence, while those that cannot be reproduced can be questioned. Being unable to sufficiently replicate published research compromises the reliability of the scientific process.

Applying

4 a Kolya would need to submit a research proposal to his institution to ensure that he was capable of doing the research, had all the equipment needed and it meet ethical standards.

b Once this was approved, Kolya could then conduct the investigation.

c On completing the investigation, his research institution may then approve the investigation, make recommendations to improve the quality of the investigation or withdraw their support. Though not strictly required, Kolya should only proceed with institutional support.

d Kolya can then submit his research for publication. It will undergo an initial review by the publisher before being sent off for peer review. At both of these stages Kolya could be asked to revise his paper or have his paper rejected as not meeting requirements.

e Once Kolya's paper is accepted, it will be published, and then can be looked at by the broader scientific community. At this point, his research is subjected to replication – if his findings cannot be replicated, questions will arise and Kolya will need to address these or make amendments to his research to satisfy the broader community. In rare instances if these adjustments cannot be made, calls may be made to have his research retracted as fraudulent.

5 The incentive structure of scientific research institutions demands that scientists regularly publish their research or 'perish', that is, lose their job. This can result in scientists submitting research papers that are misleading or even fraudulent in order to protect their job or reputation.

One measure to detect fraudulent research is the post-publication peer-review process where scientists reading the article can submit a critique of the paper, questioning the research techniques or findings. If enough questions are raised, then the paper can be reviewed and a decision made as to whether or not to retract it.

Another method is to more strongly regulate open-access journals by establishing a regulatory body to verify that journals meet publication standards. Journals that fail to meet these standards can then be vetted and rejected. Both of these measures could help to improve the reliability of the scientific research material that is being published.

CHAPTER REVIEW

Knowledge

1 When a person or organisation makes a claim to truth they are asserting that what they are saying or proposing is a true representation of reality. However, it must be recognised that such claims are made according to that individuals or organisations interpretation of the cause and effect of the phenomena.

2 Bias is the tendency to misrepresent or misinterpret an observed phenomenon. One example is cognitive bias were an individual interprets data in a way that aligns with their established belief system rather than considering alternative perspectives and other ways of interpreting the data.

3 One example where correlation has been mistaken for causation is when an observational study found a correlation between hormone replacement therapy and reduced incidence of heart disease. It was then assumed that hormone replacement therapy could reduce the risk of heart disease in

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women. Further studies, however, found that women that had a higher socioeconomic status and could afford a better diet and maintained an exercise regime were also more likely to take hormone replacement therapy leading to the correlation of reduced risk of heart disease. Later double-blind trials actually found that there was a slight increase in risk for heart disease when taking hormone replacement therapy.

4 Iridology is a pseudoscience that claims that a person's health and emotional wellbeing can be diagnosed by looking at the patterns and colours of the iris of a person's eye. Astrology is a pseudoscience that claims that a person's past, current and future life circumstances can be explained by the position of the planets in the solar system at the time that they were born.

5 Fake or predatory journals typically require payment before publication and have poor accountability and transparency processes. They will often solicit new and inexperienced research scientists to publish their work. The editing and the peer-review process of these journals is usually poor or non-existent.

Comprehension

6 The terms used in scientific language typically have a definition or meaning that is clearly stated and agreed upon by the scientific community. This means that the terminology in science tends to remain much more stable over time. However, common language does not have to adhere to these conventions and consequently words may change and adapt with greater frequency over time. As such, a word used in science may have an alternative or different meaning than in common language.

7 Scientists can minimise the chances of statistical bias in three ways:

a In the data collection phase, they can ensure the samples selected for the study are not biased by making sure the sample size is adequate and/or that the equipment and surveys accurately measure what they are supposed to measure.

b They scan avoid bias in the analysis of the data, by selecting the right techniques to interpret the data regarding what is happening in the sample population.

c Finally, they need to ensure the statistics are presented fairly, particularly when using graphs, as these can lead the reader to interpret the results in a particular way, often in the way the author wishes.

All of these biases can be minimised by having peers cross-check and review the statistics at each stage and by publishing the methods used to generate the statistics.

8 The incentive for organisations to ignore the findings and advice of science often centres on the conflict between the need to generate profit and the desire to comply with scientific findings. This places the companies in a position of conflict, often their factories and business practices are set up in a particular way, and changing this will cost a significant amount of money. Companies will often ignore or even discredit the findings of scientists in order to avoid the costs of change.

9 The numerology chart in Figure 5.6.1 uses some unfamiliar symbols to make it difficult for others to interpret their meaning and understand their purpose, thus requiring a 'trained' professional to act as a mediator to be able to interpret the cause and effect that is claimed.

10 Answers will vary. Suggested answer: some people refuse to believe evidence about a scientific issue if it clashes with their own beliefs, while others have been taken in by misleading scientific articles in the past and are therefore sceptical about scientific evidence.

Application

11
- Ronald will need to set up at least four treatments for the investigation, the first tomatoes grown without any fertiliser at all; this treatment will act as a control group. The second treatment will be tomatoes grown in a nitrate fertiliser, and the third tomatoes grown in a phosphate fertiliser. The last treatment will grow the tomatoes in a 50-50 combination of phosphate and nitrate fertiliser. Ronald could incorporate other sets in this investigation if he decided to investigate ratios of fertilisers such as 3:1 and 1:3 nitrate and phosphate fertilisers.
- Each treatment will require a sample of tomato plants. Different tomato plants should be used to ensure that the results are not biased by testing just a single variety. Five varieties should be able to produce a result with a reasonable confidence level, though more could be used if space allowed. For each variety, Ronald should have a minimum of 30 individual plants for each treatment to ensure a satisfactory confidence interval. This means he will need 120 plants of each of the five varieties of tomato plant he plans to test, so 600 plants in total.
- Ronald could then set up his investigation, ensuring that all the plants were grown in under the same conditions e.g. the same potting medium, the same temperature and humidity, the same amount of water and sunlight. The only difference should be in the fertiliser they are treated with.
- Ronald could then determine the productivity of the tomatoes for each fertiliser treatment by measuring in grams the mass of the tomatoes produced during harvest.

12
- An advertiser can give the impression that the food they are promoting is healthy in a number of ways.
- They can identify imagery that people associate with being healthy and safe. In the vast majority of cases these are images of undisturbed natural landscapes and whole foods. A compilation of these types of images, including sunshine, green grasses, trees, animals and an open sky, as well as bundles of harvested whole foods can be used on the packaging to attract the consumer's attention and connect the product with the idea that it is healthy and natural.
- Another way is to build an association in the consumer's mind between the product and an individual who is perceived as healthy. For this, a fitness expert, chef or food critic with a reputation that they use healthy, natural foods can be used to trigger the halo effect in consumers. In this way, the consumer associates the product with foods and

lifestyles that are perceived as healthy. This decreases the likelihood that the consumer will question the claim that the food product is healthy.

13 Peter's results could have been affected by a variation of the Hawthorne effect. When the other students came to watch, the participants in the investigation became aware they had an audience and possibly became anxious about how they would be perceived. This created a bias in the results that Peter recorded. Peter would be able to obtain less biased results by repeating his experiment in a place where other students would not be able to watch or observe his participants. By doing this, he can reduce their anxiety and obtain a more accurate readings.

Analysis

14 The tobacco industry was established before science determined that cigarette smoking was contributed to diseases, such as lung cancer and heart disease, and that nicotine was addictive. So by the time these findings were made, the tobacco industry was already very profitable. To act on the evidence that was presented by the scientific community, the tobacco industry would need to slow or stop producing a product that was the sole source of profit for the companies' shareholders. Consequently, tobacco companies have either denied or downplayed the effects that cigarette smoking has on health in order to continue selling cigarettes.

Similarly, the asbestos mining industry ignored health and safety warnings from the scientific community. Protecting miners from the harmful effects of breathing asbestos dust would have required a radical overhaul of mining operations, shutting down mines for months to install ventilation and ensure all workers had personal protective equipment. Their failure of the industry to protect their workers despite evidence from the scientific community that it was necessary to protect the miners' health means that a number of mining companies have now been sued by former miners suffering from asbestosis.

15 Double-blind trials are specifically designed to eliminate or reduce the chance of the participants and the investigator influencing the findings. Because the person(s) administering the treatment is not aware which participant is in which group, the chances of observer-expectancy bias is reduced. The findings of double-blind investigations are considered to be much more reliable and valid than other types of investigations that do not reduce bias as effectively.

16 The meme suggests that people are allowing their political stance on a scientific issue to be determined not by the evidence that has been presented to them but by a cognitive bias. For example, people who identify as being politically conservative are more likely to agree with conservative politicians who reject climate change, while people that identify as being politically progressive are more likely to agree with progressive politicians who accept climate change. This meme is asking people to make a judgement on climate change based on the evidence and not their political affiliation.

Synthesis

17 The quote acknowledges that the phenomenon of 'publish or perish' is a genuine issue in the scientific community. It goes on to discuss ways in which a young scientists need to develop the skills and strategies to become successful over the long term. The quote suggests that young scientists start mastering the process of writing and editing papers in order to get as many papers published as soon as possible in. By doing this, it is implied that young scientists will be able to survive the publish or perish phenomenon in the scientific community and have much more successful careers over the long term.

18 The discrepancy in the treatment of the teenage boy and the woman is most likely to have been the result of stereotyping or observer-expectancy bias. It is very likely that the treating doctor expected that teenage boys often hurt themselves while doing activities like skateboarding and that it is not often serious, while a professional woman who rarely undertakes risky activities would need to be evaluated more carefully. Additionally, the woman may be more likely to be able to effectively negotiate with the medical industry than the teenage boy.

To overcome such bias, the doctors and nurses could have an established set of procedures that require set diagnostic procedures to be performed when a patient presents with a particular condition. In this case it would be that any patient presenting with an injured limb as a result of a fall must have an x-ray to eliminate the possibility that the limb is fractured.

Evaluation

19 The confidence intervals shown in the graph indicate the spread of the results obtained from the different sampling locations between 1951 to 1997 and 1998 to 2014. The confidence intervals of the 1951 to 1997 data show a small spread where temperature varied only slightly with the mean temperatures shift of 0.075 to 0.1 degrees per decade. The 1998 to 2014 data show a large variation in the spread of temperatures recorded over that time; however, the mean temperature shift was between 0.05 to 0.1 degrees per decade – a mean that is not remarkably different from the previous period.

If the graph were displayed without the confidence intervals, then it may have been possible to argue that there was no significant difference in the mean temperatures over time, however, including the confidence intervals means that the reader must consider that temperatures have become more extreme yet are producing similar means. By including the confidence intervals, climate scientists can illustrate that the warnings that temperature will become more erratic and extreme as a result of climate change has validity.

20 As part of the pressure to publish or perish, some research scientists who feel threatened submit fraudulent papers and subvert the peer-review process in order to make it look like they are successfully publishing. This behaviour has resulted in over 100 articles that have been retracted because of fraud.

The scientific community is working to counteract the publication of such articles in a number of ways.

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- First, by making the publication process more transparent and introducing post-publication peer review. This enables members of an entire scientific field to critique a paper and eliminate the possibility of fake or biased peer review.
- Second, journal review websites can be built to inform people about which publications use good accountability and transparency measures in their peer-review and publication processes. This puts pressure on journal publishers to meet a minimum standard or risk being boycotted by the scientific community.
- Third, awareness campaigns can be used to inform research scientists, particularly young scientists, of ethical requirements of the scientific community, the consequences for committing fraud and ways and means of detecting fraud.
- Finally, non-profit organisations can act with the support of the scientific community to set publication and ethical standards for scientists and journal publishers to ensure that the scientific community and general public can trust the research findings being published.

SECTION REVIEW 6.1

Remembering

1 Answers may vary, but could include any of:
- relocation costs
- pressure on healthcare system
- loss of income for plant workers and beneficiaries of agriculture
- accumulation of radioactive compounds in food sources.

2 Answers may vary but could include any of:
- smallpox
- measles
- mumps
- rubella
- whooping cough (pertussis)
- hepatitis B
- diphtheria
- tetanus
- pneumococcal disease.

3 Damming is the process of blocking a river or stream using a large wall, usually made from rock or concrete. Reasons for damming include: to supply water for households and agricultural irrigation, providing a place for recreational activities and generating clean, renewable energy in a controlled manner.

Understanding

4 While testing was being carried out on the RMBK 1000 nuclear reactor, workers at the plant disabled the automatic shutdown mechanism. When the reactor became unstable, it was unable to shut down, which resulted in increased pressure and eventually the destruction of the nuclear core. This caused two large explosions that released radioactive products into the atmosphere.

5 Answers will vary but may look similar to:
- Observation: Jenner noticed that milkmaids exposed to cowpox did not exhibit symptoms of the condition.
- Experimentation: Jenner extracted pus from the cowpox pustule and inserted it in to an incision made on eight-year-old James Phipps. Jenner then exposed James Phipps to smallpox and observed no symptoms of the disease.
- Submission: Jenner presented his findings to the Royal Society in the United Kingdom but he was rejected after they claimed lack of sufficient evidence.
- Experimentation on other children: Jenner replicated his experiment with other children (including his own) and experienced consistent success.
- Development of vaccine: Jenner developed the vaccine to prevent smallpox.

6 Answers may vary but may look similar to:

	CAUSE	EFFECT
Benefits	Dam acts as a reservoir	• Provides households and agricultural pursuits with a source of water • Provides a recreational site for water-based activities such as water-skiing and boating
	Source of hydroelectricity	• Generates clean energy (no greenhouse gases) in a controlled manner
Limitations	Alteration of free-flow	• Organisms may not be able to cope with the change in characteristics of the ecosystem (i.e. chemical composition, dissolved oxygen, water flow) • Loss of biodiversity
	Disconnection from other waterways	• Prevents migration of some fish species • Possible overpopulation of organisms lower in the food chain • Loss of biodiversity
	Blocking of waterways	• Prevents naturally occurring sediment from accumulating downstream • Prevents maintenance of natural deltas, floodplains and wetlands

Applying

7 Edward Jenner's work with vaccines played an important role in the development of modern medicine and healthcare. His early technique that involved extracting pus from cowpox pustules and injecting it into an incision was the first known vaccination technique. Jenner even coined the term vaccine from the Latin 'vacca' meaning cow. While his studies were initially rejected, some 200 years later the idea of exposing individuals to a weakened or synthetic form of an antigen is recognised

by modern medical professionals as the most efficient way to initiate the body to carry out an immune response.

8 Answers will vary.

9 Answers will vary.

Analysing

10 Answers will vary.

SECTION REVIEW 6.2

Remembering

1 Answers may vary but could include any two of:

- genetic modification
- surrogacy
- organ transplants
- bioprospecting
- stem cell research.

2 Ethics are the external rules relating to right and wrong that have been developed by social systems and governed by legal guidelines. For example, genetic modification of sex cells has the potential of creating 'designer babies' where parents may choose to include certain genes and get rid of others. For this reason, Australia has legal guidelines derived from scientific ethics that prevent parents obtaining genetic modification of sex cells for their unborn children.

3 Answers may vary but could include any three of:

- artwork
- folklore
- medicinal plants
- literature
- design
- performing arts
- traditional knowledge.

Understanding

4 Codes of conduct provide a uniform set of rules that ensure scientific research does not cross any ethical boundaries and that it complies with international standards.

5 Positive and negative aspects of bioprospecting:

POSITIVE	NEGATIVE
• Use of natural resources to solve social issues • Potential to cure disease • Less pressure on healthcare system	• Over-exploitation of resources • Endangerment/extinction of species • Ethical concerns • Ownership difficulties if the resource has multiple stakeholders

6 The flow diagram should include the following information:

- Stem cells are extracted from the inner cell mass of a four- or five-day-old embryo.
- The inner cell mass is grown under laboratory conditions until there are colonies of embryonic stem cells.
- Stem cells are separated into different groups.
- Different differentiation factors manipulate the stem cells to become a specific type of cell (i.e. blood cell, skin cell and so on).
- The cultured cells are transferred to the relevant area of the body.

Applying

7 Scientific codes of conduct are vital to regulate organ transplantation. Because there are different circumstances surrounding each patient who requires an organ, the code of conduct outlines certain criteria outlined to determine who gets priority when an organ becomes available. These criteria include how long the patient has been waiting, how urgently the organ is required, how well the patient matches the available organ and whether the organ can be delivered to the patient in time.

The code of conduct is also important as it ensures that potential recipients are not discriminated against according to age, race, gender, socioeconomic status, religion or disability.

8 There are two types of surrogacy; traditional and gestational. While both surrogacy methods involve a woman that is not the intended mother of the child, they differ in the process in which this occurs. In traditional surrogacy, the surrogate uses her own egg and the sperm of the biological father to reproduce. In gestational surrogacy, the eggs are removed from the biological mother and fertilised externally by the sperm of the biological father and then the embryo is implanted in to the surrogate. Codes of conduct are vital in this process as they ensure that the surrogacy is being carried out with the best interests of the child in mind and that the surrogate is not exploited. The code of conduct also complies with anti-trafficking and organised crime treaties.

9 Answers will vary.

10 Indigenous Australians have been aware of the many assets of the Australian environment long before bioprospectors and pharmaceuticals companies have been operating. To honour the history, knowledge and cultural values of Indigenous Australians, it is important that their intellectual and cultural property remain protected. As traditional custodians, Indigenous Australians have the right to all property, and codes of conduct help ensure that companies do not exploit this property to gain economic advantage.

Analysing

11 BRCA is a hereditary gene that has been found to affect a person's chances of developing breast cancer. Scientists may be able to be remove the gene from an embryo before the embryo develops into a foetus. Currently, this research is carried out on unviable embryos. Using an unviable embryo removes ethical concerns as it eliminates the possibility of ending the life of a potential human being in the process of research. If this research was carried out on a viable embryo, it would raise a number of ethical concerns. While some may argue that using a viable embryo would give a more reliable indication of whether the research was successful and could be used on more individuals, others may argue that the research would be destroying potential lives. Viable embryos

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represent life and it is often debated that they should only be used to assist with reproduction.

SECTION REVIEW 6.3

Remembering

1 Answers will vary but could include:
- Flavr Savr tomato
- Golden rice.

2 Answers may vary but could include Fred Hollows' intraocular lens or the cochlear implant.

3 Answers may vary but could include three of:
- reduces scar tissue
- shortens post-operative hospitalisation
- reduces pain and recovery time
- decreases trauma to the body
- minimises risk of infection.

Understanding

4 Drones are economically beneficial as they can perform the same operations as vehicles designed for manned flight, such as helicopters or aeroplanes, at a fraction of the cost. Drones are inexpensive to manufacture compared to manned flight vehicles and can complete a task in a fraction of the time. Drones are also economically beneficial as they do not require a 'pilot,' can access dangerous locations with less risk and do not require fuel to run.

5 Benefit sharing using Indigenous cultural and intellectual property is valuable as it allows large companies draw on the knowledge of Indigenous Australians when developing new medicines. In turn, those knowledgeable Indigenous Australians are involved in the decision-making process to ensure valuable resources are not being exploited.

6 Scientific research is an important way of marketing a product as it indicates the product is backed by scientific evidence. When a product has been 'scientifically tested,' it can be marketed as both safe and effective. This is particularly true in the pharmaceutical industry where companies can spend thousands of dollars to fund research on their product.

Applying

7 Answers will vary.

8 There is controversy surrounding the costs of space exploration as it can be argued that exploring space does not benefit society in any way. While it is suggested that space exploration will solve future issues, the billions of dollars spent could be better spent on more pressing issues such as poverty and hunger. Other arguments against space exploration include the irrelevancy of equipment that functions at zero gravity, the lack of direct benefits from space travel and importance of current issues.

Analysing

9 Answers will vary.

10 Answers will vary.

CHAPTER REVIEW

Remembering

1 The Chernobyl disaster happened in Ukraine.

2 Bioprospecting involves conducting tests to determine whether an organism could be used to create a product.

3 Answers may vary, but could include cloning, stem cell research, surrogacy, genetically modified foods and organ transplantation.

4 Countries of the South Pacific (any one of Fiji, Samoa, Nauru).

Understanding

5 Edward Jenner observed that milkmaids exposed to cowpox did not show symptoms of smallpox.

6 Ethical concerns related to genetic manipulation include the unforeseen or irreparable effects altering genetic material could cause to the developing foetus and lack of ability for the foetus to consent to the treatment.

7 Water needs to be purified to ensure that bacteria and other pathogens are removed before people drink it. Treating water with calcium oxide reduces the potential for the plumbing to corrode.

8 Stem cell research involves extracting stem cells from a four- to five-day-old embryo and then culturing them to differentiate into specific cell types. Once the stem cells have differentiated, they are implanted into the part of the body that requires them. Ethical concerns arise from stem cell research as it involves the destruction of viable embryos that have the potential to develop into life.

Applying

9 Answers may vary.

10 Answers may vary.

11 Minimally invasive surgery is contributes positively to human wellbeing; it has a number of advantages over invasive surgery including reduced recovery time, less scarring, less risk of infection and less trauma. Each of these factors allows individuals to return to their normal functioning quicker, which positively contributes to mental and physical wellbeing.

12 Large corporations and governments influence the direction of scientific research as they are responsible for funding scientific studies. For example, if there is a pressure placed on the healthcare system from elderly patients with dementia, the government may allocate more funding for scientific research in this area. Conversely, if there is no interest or advantage to large corporations or governments, then funding is unlikely.

Analysing

13 Answers may vary.

14 Answers may vary.

15 Answers may vary.

GLOSSARY

A

abdominal part of the body containing the stomach and intestines

accuracy level to which a measurement, calculation, or specification conforms to the correct value or a standard

activation energy minimum level of energy for a substance to be activated to react chemically

active ingredient substance/s present in a plant that is biologically active and it can be extracted for medicinal purposes

aim purpose of the investigation

atom from the Greek word 'atomos' meaning cannot be divided

average speed total distance travelled over time

B

bias when personal opinion affects how a person weighs the validity of evidence

binary star a pair of stars in orbit around each other

bioprospecting conducting tests to determine whether an organism could be used to manufacture a product

biopsy taking samples of tissue from a patient and testing these samples in a laboratory; this technique is commonly used to test if cells are cancerous

Boyle's law the product of the volume and the pressures for a fixed mass of a gas at constant temperature, is constant

C

calibrated to have correlated the readings of an instrument against that of a known standard to ensure the accuracy of the instrument

capture-recapture a method to estimate the population size by trapping them in a small area, releasing them and then extrapolating the total population

carcinogen a chemical known to cause cancer

catalysts chemicals that increase the reaction rate by lowering the activation energy

causation where a change in one variable affects the other variable; also referred to as cause and effect

Charles' law for a constant volume of gas in a sealed container, the temperature of the gas is directly proportional to its pressure

chronic an illness that continually re-appears or is experienced for a long time

circumference the distance around a circle

confidence interval a value, with an associated margin of error, that indicates the range in which a random sample from the population is likely to fall into for a given measure or treatment

confidence level expressed as a percentage likelihood that a repeated investigation on a random sample will produce a comparable result

conflict of interest a situation in which two parties or groups have incompatible objectives. If such parties have an unequal balance of power, then one party may use their power for personal benefit

contradiction a statement or depiction that is inconsistent and does not adhere to logic when compared to one or more other statements or depictions

control experimental set-up where the independent variable is not applied

control group the group in an investigation that is used as a benchmark in comparison to a second group that receives a prescribed treatment

controlled variable factor that is kept constant during the experiment/investigation

convenience sampling a sample that is used in an investigation primarily because it is the most readily available sample that the investigator can access

correlation connection between two or more things, or a measure of how things are related

D

data numerical or observational facts collected together as evidence for analysis

data collection gathering of qualitative or quantitative measurements for the purpose of statistical analysis

data logger electronic or digital device that records data either with a sensor or digital aid

denatured an enzyme that has been altered by heat, acidity or some other effect

dependent variable factor measured in the investigation

double-blind trials an experimental technique in which neither the participants nor the researcher in contact with them are aware of who is receiving the treatment and who gets the control

E

ecological relating to the interactions of species within an environment

efficacy the ability of a product or process to produce a desired result

element primary constituent of matter that can undergo chemical reactions

empirical data information collected by observations or measurements during an investigation

enzymes catalysts that assist biochemical reactions in organisms

error measure of the estimated difference between the observed or calculated value of a quantity and its true value

estimation a rough calculation of the value of something

ethical whether what is being done conforms to good standards of behaviour

ethics rules established by social systems that govern 'right' and 'wrong'

evaluation make a judgement based on evidence

extrapolation extension from a range of plotted data to infer new values from the known ones

F

fertiliser a substance added to soil to aid in plant growth

fieldwork investigation conducted outside the laboratory

friction a force of resistance when two surfaces rub against each other

G

gas a fluid state of matter that fill all parts of a given container because the particles move freely

gastrointestinal tract organ system from the mouth to the anus which is involved in digestion of nutrients and excretion of waste products

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germline gene therapy the process where DNA is transferred to the cells that produce reproductive cells

H

halo effect a psychological phenomenon where a person is perceived more favourably because of an initial positive perception of that person

hypothesis educated guess tested through experimentation to answer the inquiry question; states the relationship between the independent and dependent variables

I

ideology a set of beliefs and ideas, both conscious and unconscious, that an individual or group of individuals, have in relation to the way the world works. Also referred to as a worldview

incentive a structure or thing that encourages and motivates someone to behave in a given manner

incubation period the period of time between initial exposure to an infection and the appearance of symptoms

independent variable factor deliberately changed during an investigation to obtain data

innate bias the tendency for an individual to draw a flawed inference because of the assumptions and experiences that have influenced them and the mental 'short cuts' the brain makes when making an observation

inquiry question driving force of the research; can be investigated scientifically

insecticide resistance a micro-evolutionary process whereby insect populations become increasingly resistant to the effects of an insecticide

interpolation estimating new data points within the range of data points

J

justification support an argument

L

Large Hadron Collider particle accelerator that propels subatomic particles (hadrons) at high speed

line of best fit trendline that best fits the plotted data, it goes through the centre of the plotted data

log book journal taken during the investigation where all data, observations, results, inquiries and conclusions are registered

lymphocytes a white blood cell with a single, round nucleus

M

mean a central tendency within the range of a data set, calculated by adding all the values in a data set and dividing by the number of values

median the central value within the range of a data set; a value that is generally determined by having an equal number of values from the data set on each side. (larger data samples and group frequencies make this calculation more complex)

medicinal plant a plant with pharmaceutical properties possessing an active ingredient that can be extracted for medicinal purposes

method experimental steps to follow to collect data and test the hypothesis of an investigation

methodology a way of going about an investigation

microwave a form of electromagnetic radiation with wavelengths between 1 metre and 1 millimetre

mode the most common value recorded within the range of a data set

model two- or three-dimensional representation or description of a process, system or idea

moral a judgement about whether what is being done is good or bad

N

nuclear fission a nuclear reaction where energy is released from splitting atoms

O

observer-expectancy effect an effect in which an individual making a judgement on the presented data is inadvertently biased by their own preconceptions of the subject to be judged

open access a journal that allows scientific researchers to pay to have their paper published a class of open-access journals that solicit money, often from inexperienced research scientists that want to get their paper published, but do not enforce the recognised cross-checking processes such as peer review to ensure scientific rigour

P

peer review process in which experts review and critique the work and research of others in the same field

peptic ulcer a break in the tissue of the digestive system, mainly in the stomach, that causes pain, among other symptoms

pharmacological the characteristics and properties of a drug that make it medically effective

pitch a property of sound waves; high-frequency sounds have a high pitch, while a lower-frequency sound has a low pitch

placebo a medicine or procedure that has no therapeutic effect

post-publication peer review a process of peer review that is done after the publication of the research paper that utilises the flexibility of online media

primary data data you have collected yourself

pseudoscience a practice that portrays itself as a science, often through complex terminology and processes but does not meet the criteria for contributing to the greater knowledge and/ or burden of evidence for science

publish or perish a phenomenon in academic disciplines where academics need to regularly publish or risk losing research funding or their job

Q

quadrat a process by which a small area is examined to estimate the population of a species within a larger area

qualitative data descriptive data collected as evidence during an investigation (e.g. images, observational sentences)

quantitative data numerical values collected as evidence during an investigation (e.g. calculations are usually part of the analysis, not data collection measurements)

R

radar an acronym for RAdio Detection And Ranging (or RAdio Direction And Ranging), which is a system used to detect the presence of objects over long distances

radiant heat heat transfered by electromagnetic waves

reaction rate speed at which a chemical reaction occurs

red/blue shift when spectral lines move towards the red or blue end of the visible spectrum

reliability extent to which an observation and/or measurement can be repeated under the same circumstances and produce similar results

replicable able to be repeated

reproducibility crisis a phenomenon where the number of research papers being published cannot be reasonably cross-checked by reproducing the investigation and/ or that insufficient replication is being done before publication

reputable to be seen as well respected and trusted

respiration process by which organisms produce energy

retracted the removal of a published paper/ book by the journal editors as a result of misconduct, such as fraud

risk assessment evaluation of the risks of an investigation

S

safety hazard expected risk during an investigation

sample bias is the tendency to under or over represent a particular group within the sample population

sample size number of observations or replications in an experiment

scientific investigation an organised approach to solving a scientific question

scientific theory an explanation of an aspect of the world that can be tested

secondary data data collected by other people and published

species group of living organisms with similar characteristics that can interbreed

spectral pattern when light is viewed through a spectrograph, the parts of the spectrum have distinct spectral lines that represent the various chemical elements

stereotyping the process of classifying someone (or something) on the basis of superficial characteristics and attributing generalisations to all individuals that fit within the bounds of that classification

summer solstice longest day of the year; that is, when the most amount of sun is seen

survivor selection a research phenomenon where not all participants who begin a longitudinal study complete it. For this reason, incomplete data on participants is removed to maintain the integrity of the study

T

technology practically applying knowledge to create a device for practical purposes in any area of research

terminology the specialised terms and words used within a particular field or profession that have a technical definition within this context

tissue culture a group of living cells grown under laboratory conditions

treatment variation of the independent variable

true a depiction of a phenomena that conforms to or reflects reality

true value measurement with no errors

U

uncertainty interval (±) around the measured value compared to the true value

V

vaccine a weakened form of an antigen (or a synthetic substitute) that initiates an immune response to stimulate the production of antibodies and provide immunity to the targeted disease

valid extent to which a report or investigation contains accurate data, inferences and conclusions

variable measurable factor that can be changed or maintained in an experiment/ investigation

vector an organism that transmits a disease from one organism to another

vested interest a situation where a person or group would benefit from influencing circumstances to favour their position

voltage force pushing electrons around the circuit

voluntary response samples a sample (most commonly of people) that is investigated because they are willing to take part in the investigation

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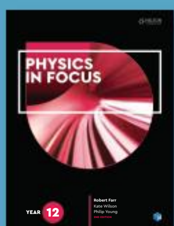

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ISBN 978-0170411264