GET

LEVEL 4

AET

Natural Sciences

CLASS TEXT & STUDY GUIDE

Liesl Sterrenberg, Grace Elliott, Helena Fouché, Retha Louw, Norman Davies & Silvana Scarola

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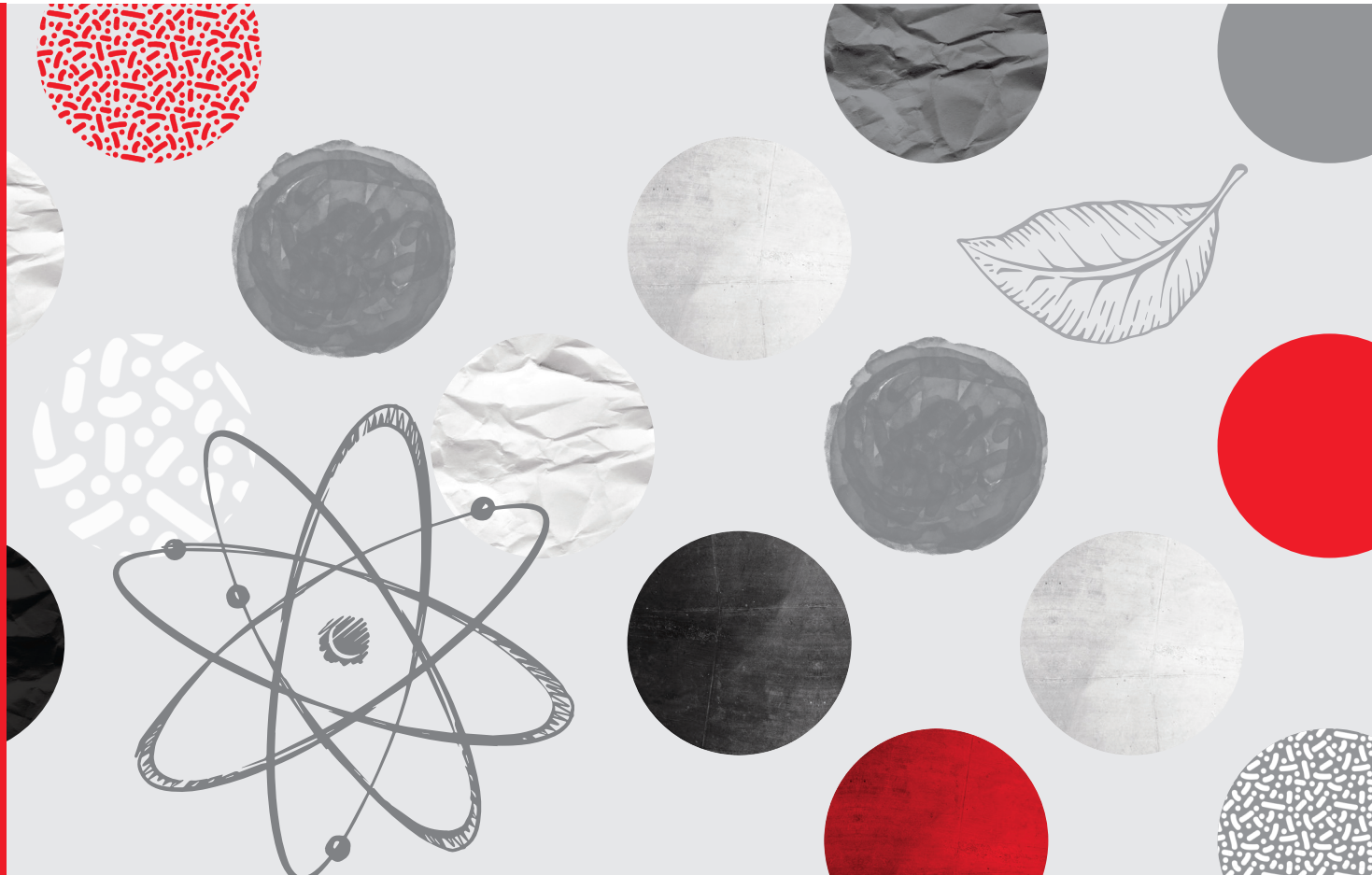

THE ANSWER SERIES *Your Key to Exam Success*

Natural Sciences

Liesl Sterrenberg, Grace Elliott, Helena Fouché
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THIS CLASS TEXT & STUDY GUIDE INCLUDES

1. Notes
   - Life and Living
   - Matter and Materials
   - Energy and Change
   - Planet Earth and Beyond
2. Questions per Module
3. Detailed Answers (in separate booklet)

E-book available

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ABOUT THIS PUBLICATION

The Answer Series proudly offers this new publication in *Natural Sciences*. This handbook and study guide was written by a team of authors according to the National Curriculum and Assessment Policy Statement (CAPS) for Natural Sciences. Their extensive experience and expertise have contributed to this new addition in our highly successful series.

WHO IS THE ANSWER SERIES?

The Answer Series is an educational publishing company based in Cape Town that specialises in producing study guides for high school learners throughout South Africa. Established in 1975, we are constantly expanding our range of study guides and updating the content to stay abreast of curriculum changes.

The study guides are designed to enrich the understanding of learners and provide essential exam technique and practice. Learners can work independently, or the study guides can be used in the classroom. Written by subject specialists, they provide invaluable support for all learners who want to achieve success in their studies.

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OUR SUBJECTS

Mathematics • AP Mathematics

Mathematical Literacy • Physical Sciences

Life Sciences • Agricultural Sciences

Natural Sciences • EMS • Accounting

Business Studies • Economics

Consumer Studies • Geography • History

Afrikaans 1ste Addisionele Taal • English 1st Additional Language

English Home Language

The Answer Series

THE PUBLISHER

CONTENTS

UNIT STANDARDS MAP

US 7507

Demonstrate an understanding of the concept of science

		SO1	SO2	SO3	SO4	SO5
	SKILLS		X		X	X
LIFE and LIVING	TOPIC 1		X	X		X
	TOPIC 2	X				X
	TOPIC 3					X
	TOPIC 4					X
	TOPIC 5			X		X
MATTER and MATERIALS	TOPIC 3					X
	TOPIC 4					X
	TOPIC 6					X
ENERGY and CHANGE	TOPIC 3					X
	TOPIC 4					X
	TOPIC 5					X
	TOPIC 6					X
EARTH and BEYOND	TOPIC 2					X
	TOPIC 5		X			

US 7508

Conduct an investigation in Natural Sciences

		SO1	SO2	SO3	SO4
	SKILLS	X			X
LIFE and LIVING	TOPIC 1		X	X	
	TOPIC 3	X			
	TOPIC 4		X		X
	TOPIC 5		X	X	X
MATTER and MATERIALS	TOPIC 3		X	X	X
	TOPIC 4		X	X	X
	TOPIC 5		X	X	X
	TOPIC 6		X	X	X
	TOPIC 7		X	X	X
ENERGY and CHANGE	TOPIC 1	X	X	X	X
	TOPIC 2		X	X	
	TOPIC 3	X	X	X	X
	TOPIC 4	X	X	X	X

US 7509

Apply basic concepts and principles in Natural Sciences

		SO1	SO2	SO3	SO4
	SKILLS	X	X		X
LIFE and LIVING	TOPIC 1	X	X		X
	TOPIC 2	X			X
	TOPIC 3	X		X	X
	TOPIC 4	X	X		X
	TOPIC 5	X	X	X	X
MATTER and MATERIALS	TOPIC 1	X		X	X
	TOPIC 2	X	X		X
	TOPIC 3	X	X		X
	TOPIC 4	X	X		X
	TOPIC 5	X	X	X	X
	TOPIC 6	X	X	X	X
	TOPIC 7	X	X	X	X
ENERGY and CHANGE	TOPIC 1	X	X	X	X
	TOPIC 2	X	X	X	X
	TOPIC 3	X	X	X	X
	TOPIC 4	X	X	X	X
	TOPIC 5	X	X		X
	TOPIC 6	X			
	TOPIC 7	X	X		
EARTH and BEYOND	TOPIC 1	X			X
	TOPIC 2	X	X		X
	TOPIC 3	X			
	TOPIC 4	X			X
	TOPIC 5	X	X	X	X

US 7511

Analyse how scientific skills and knowledge contribute to sustainable use of resources

		SO1	SO2	SO3	SO4
MATTER and MATERIALS	TOPIC 2				X
	TOPIC 3		X		X
	TOPIC 4	X	X	X	
	TOPIC 5		X		
	TOPIC 6			X	
ENERGY and CHANGE	TOPIC 3				X
	TOPIC 5				X
	TOPIC 6	X	X	X	
EARTH and BEYOND	TOPIC 2		X	X	
	TOPIC 3	X	X	X	
	TOPIC 4	X		X	

US 7513: Assess the impact of scientific innovation on quality of life

		SO1	SO2	SO3	SO4
LIFE and LIVING	TOPIC 1	X			X
	TOPIC 3	X	X		
MATTER and MATERIALS	TOPIC 3	X	X		
	TOPIC 4		X		
	TOPIC 5				X
	TOPIC 6	X	X		
ENERGY and CHANGE	TOPIC 3	X	X		
	TOPIC 4	X			
	TOPIC 5	X	X		
	TOPIC 6	X	X		
	TOPIC 7			X	
EARTH and BEYOND	TOPIC 3	X	X		

WHAT IS NATURAL SCIENCES?

Natural Sciences is the scientific study of natural phenomena in the physical world; and looking for explanations to questions based on observations. Scientific investigation explores ideas, and involves formulating hypotheses and designing or conducting experiments to test these hypotheses.

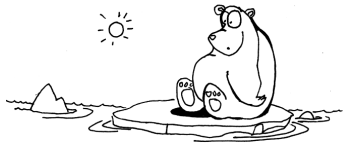
Natural Sciences is organised into 4 **Knowledge Strands** that are covered in **4 Modules** in this study guide:

Module 1: **Life and Living**

Module 2: **Matter and Materials**

Module 3: **Energy and Change**

Module 4: **Planet Earth and Beyond**



AIMS IN NATURAL SCIENCES

Specific Aim 1: **'Doing science'**

Learners should be able to complete investigations, analyse problems and use practical processes and skills in evaluating solutions.

Specific Aim 2: **'Knowing subject content and making connections'**

Learners should have a grasp of scientific, technological and environmental knowledge and be able to apply it in new contexts.

Specific Aim 3: **'Understanding the uses of science'**

Learners should understand the uses of Natural Sciences and indigenous knowledge in society and the environment.

ASSESSMENT

Assessments including **Tests, Tasks** and **Exams** should include the three **Specific Aims**.

Questions should include different levels of difficulty: **low order**, **middle order** and **high order** questions.

The specific **Verbs** used in different types of questions are listed in the table below.

Different cognitive levels for all 3 Specific Aims	**Knowing science**	**Understanding science**	**Applying scientific knowledge**	**Evaluating, analysing, synthesising scientific knowledge**
Proportion (%) of **low/middle/high order** questions	**Low order questions 40%**	**Middle order questions 45%**		**High order questions 15%**
Verbs used in questions	▪ State ▪ Name ▪ Label ▪ List ▪ Define ▪ Describe ▪ Identify	▪ Explain ▪ Compare ▪ Rearrange ▪ Illustrate ▪ Give an example ▪ Calculate ▪ Generalise ▪ Determine ▪ Discuss ▪ Tabulate	▪ Predict ▪ Apply ▪ Use knowledge to demonstrate ▪ Solve ▪ Implement ▪ Judge	▪ Select ▪ Differentiate ▪ Analyse ▪ Infer ▪ Suggest a reason ▪ Interpret ▪ Discuss ▪ Categorise ▪ Classify

ACTION VERBS

The most common action verbs used in assessment tasks are explained in this table.

ACTION VERB	EXPLANATION
analyse	separate, examine and interpret
apply	use scientific knowledge/theory to explain phenomena
calculate	a numerical answer is required – in general, you should show your working, especially where two or more steps are involved
categorise	arrange items in categories/groups based on similar features
classify	group things scientifically based on common characteristics
compare	point out or show both similarities and differences between things, concepts or phenomena
define	give a scientific statement or clear meaning of a term, rule or law
describe	state in words (using diagrams where appropriate) the observable points of a structure/process/phenomenon/investigation
determine	calculate or discover the answer by examining evidence
differentiate	use differences to qualify categories
discuss	consider all information in an orderly sequence to reach a conclusion
explain	give a clear, detailed account to interpret and spell out data/ observations/measurements in the form of a cause-effect or statement-reason sequence
identify	name the components or items
implement	put a plan into effect or an idea into practice
infer	conclude or take an educated guess based on observations
judge	form an opinion based on examination of evidence
label	identify on a diagram or drawing
list	write a list of items, with no additional detail
mention	refer to relevant points
name	give the name (proper noun)
predict	make a statement in advance about the outcome of an investigation
state	write down information, laws or definitions without discussion
suggest	offer an explanation or a solution
tabulate	draw a table and indicate the answers as direct pairs

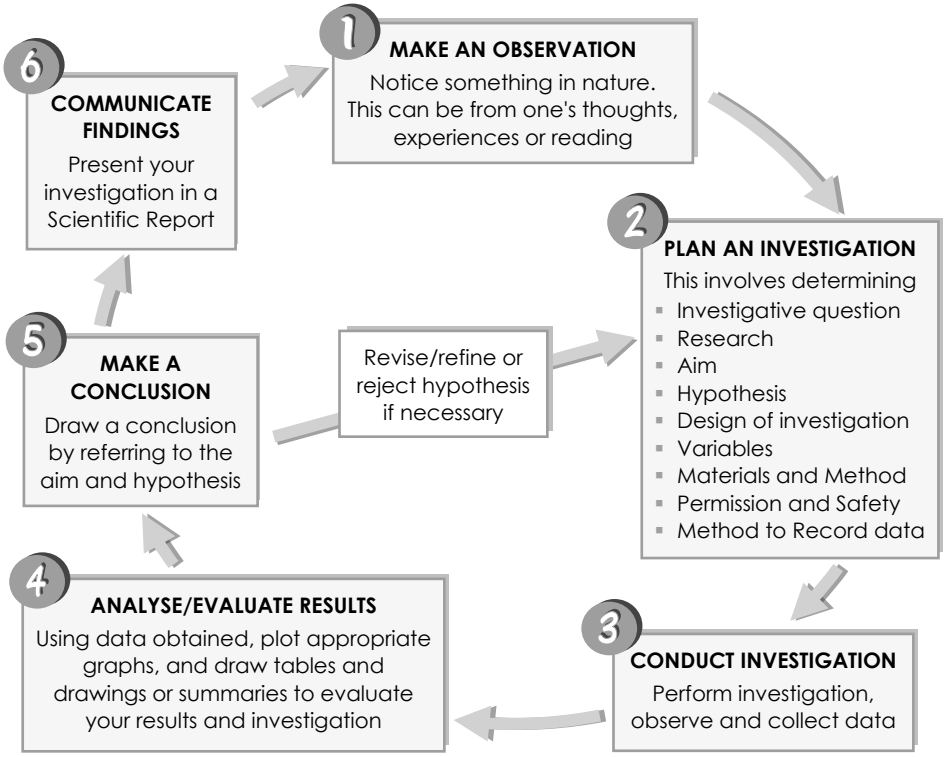
SKILLS

US 7507	US 7508
SO 2 – AC 1-2	SO 1 – AC 1-3
SO 4 – AC 1-4	SO 4 – AC 3
SO 5 – AC 2	
US 7509	
SO 1 – AC 1-3	
SO 2 – AC 1, 3	
SO 4 – AC 1-4	

SCIENTIFIC INVESTIGATION

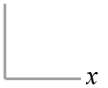
STEPS OF THE SCIENTIFIC METHOD

The scientific method is an ongoing process that involves various steps.



If there were errors in the methodology or the results are invalid, it may be necessary to re-establish your variables or method and repeat the investigation.

IMPORTANT TERMINOLOGY TO REMEMBER

Term	Definition
Scientific method	The scientific method is a process by which scientific knowledge grows. Observing a phenomenon, conducting background research in order to become educated on the subject, asking a question, planning an investigation, hypothesising and predicting the outcome of the investigation, testing the hypothesis by carrying out a scientific procedure, analysing and evaluating results, drawing up conclusions and finally communicating the findings.
Investigative question	Any scientific investigation starts with a question that you want to answer. It should contain the **independent** and **dependent variables** and must be written as a question. It ends with a question mark '…**?**'
Aim	The aim states what you intend to investigate. It is the '**why**' behind the experiment. It is written as a statement that includes both the independent and dependent variables. The aim usually begins with '**To investigate...**', '**To show...**' or '**To determine**'. *The **aim** also informs the **hypothesis**.*
Hypothesis	○ A possible **prediction** and/or **explanation** of the **relationship** between **two variables** ○ It always states both variables (independent and dependent) ○ It provides an explanation for an observation and is supported through experimentation ○ It is an educated statement of the predicted outcome of an investigation ○ It must be testable ○ It should be impersonal or 3rd person: 'If …, then …'
Variables	A variable is a characteristic, number, or quantity that **increases** or **decreases** over time, or takes different values in different situations
Controlled/ fixed variables	○ **Factors** that could change in an experiment but are **controlled** or kept **constant** so that the results are considered valid ○ They are always kept the **same** to ensure that results are only due to changes in the independent variable ○ They are always specific and written in full to indicate their quality or quantity, e.g. 'the same volume of water' not just 'water'
Independent variable	○ The factor that is being investigated – it causes a change in the dependent variable ○ The factor that is **manipulated** (determined/ changed) by the investigator ○ It causes a change in the dependent variable ○ It is recorded on the horizontal ***x*-axis** of a graph 
Dependent variable	○ The **effect**/result of the independent variable being changed/manipulated ○ The factor which is **measured** (counted/observed) by the investigator ○ It is recorded on the vertical **y-axis** of a graph *Always state the independent and dependent variables as provided in the **aim** or **hypothesis** of the investigation.* 
Experimental control	○ An additional experiment which is identical to the experiment, except the factor/variable being tested is excluded, i.e. no treatment is given to a control group ○ The purpose of a control is provide a comparison with the experiment results ○ It confirms that the independent variable caused the results and not an unknown factor
Method	○ The way in which the experiment or investigation is carried out ○ It is written in numbered steps and recorded in the third person – like a set of instructions ○ The last step should always be: 'Record the results in a table' ○ Instructions must be detailed enough for another scientist to repeat it exactly
Results	○ Data that is collected from the experiment that will either support or refute (disprove) the hypothesis ○ It can be quantitative (numerical, e.g. 50, 70, 90) or qualitative (descriptive, e.g. green/milky/loudest) ○ It is recorded in the form of tables, graphs, diagrams, photographs, video/audio recordings, tallies, specimens, observations
Analysis/ interpretation	○ Writing the results out in words ○ Identifying maximum and minimum values ○ Identifying data that does not fit the pattern, i.e. anomalies/outliers ○ Describing result patterns/trends

Evaluation (discussion)	○ Suggesting reasons for the patterns/trends observed ○ Suggesting reasons for the anomalies (outliers/results that don't 'fit') ○ Evaluating your method: was it fair? reliable? accurate? valid? How could you improve in each of these areas? ○ Discussing the worth of the experiment and what the results could mean for society/school/you
Conclusion	○ Links the results directly to the aim and can either support or refute (disprove) the hypothesis ○ States a new, but linked, hypothesis that may be investigated as a result of your results – this is known as 'further work' *A hypothesis is not* right *or* wrong. *Science is constantly changing, therefore we can only* ***accept*** *or* ***reject*** *a hypothesis.* 

PLANNING AND CONDUCTING AN INVESTIGATION

Differentiate Between the Planning and Conducting Phases of an Investigation

○ Planning requires decision-making. Anything that can be described in a sentence that begins with 'Decide to ...' is a planning step.

○ Conducting means to implement (to do) something.

Planning *involves decisions that are made* ***before the investigation****.*

Conducting *involves decisions that are made* ***after planning*** *and* ***part of the investigative method****.*

Before starting any investigation, we need to **plan** how it will be done. **Planning** steps for a typical investigation include:

○ determining **who/what** the sample will be (age/gender/species/etc. of participants)

○ determining the size of the **sample**

○ determining **when** the investigation will take place (time frame)

○ determining **where** the investigation will take place (location)

○ obtaining **permission** from the participants

○ determining how we will measure and record our **results** (selecting apparatus)

○ determining the **variables** - especially the variables that must be controlled to make it a **valid** investigation

After the planning phase, then decisions can be implemented as part of the investigative method. This is called the **conducting** phase.

ENSURING MEANINGFUL RESULTS

The following aspects must be considered to ensure your results answer the investigative question and are meaningful.

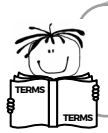
1 validity 2 reliability 3 accuracy

NOTE

Although ***validity*** *and* ***reliability*** *are the most important aspects,* ***accuracy*** *is included with a brief explanation to ensure a comprehensive list of aspects that ensure meaningful results. Fair testing and precision are other aspects that also affect the validity and reliability of results, but they are not discussed in this curriculum.*

1 Validity

Validity refers to **experimental method/scientific process** and if it appropriately addresses the aim of the investigation,
i.e. a test is valid if it measures what it claims to measure.



V*alidity* tests: ***HOW*** *the experiment is performed.*
Remember *the* ***V****:* ***HOW*** *are* ***V****ariables controlled?*

To ensure that results are valid:

○ test only **one variable** (the independent variable) at a time

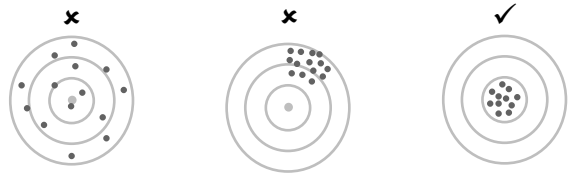
○ identify the controlled/fixed variables and keep them constant

○ choose an appropriate design for the experiment

An experimental **control group** contributes to the validity of an investigation. It eliminates the effect of other variables. The **control** has exactly the **same set-up** as the experiment except the **factor being investigated is excluded**, i.e. no treatment is given to the control group.

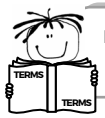
Validity *may be illustrated in throwing darts.*

The centre 'bull's eye' is what you aim to achieve in the experiment. If darts (results) are off the target – the results are not valid / less valid. If darts are all near the target/centre/bull's eye – then the results are considered ***valid****.*



Low validity ***Low validity*** ***High validity***

2 Reliability



reliability: the degree of the consistency and repeatability of an experiment

A **reliable** experiment has results which can be obtained **consistently**.

To ensure that results are reliable:

- **repeat** the experiment and obtain consistent and significant results (within an acceptable margin of error)
- increase the sample size to ensure a more accurate **average** that can be generalised to a larger group with more certainty
- take **many readings** and use the average
- select a **random sample**

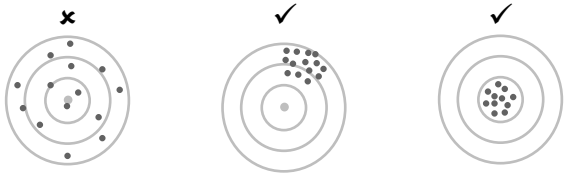
NOTE

Reliability:
Remember the ***R's***
- ***R****epeat the investigation*
- ***R****aise the sample size*
- *Readings - take more*
- ***R****andom sampling*

An experiment with 100 plants is reliable. But an experiment with 200 plants is ***more reliable****.*

Ensure that other researchers will be able to perform exactly the same experiment, under the same conditions, and generate the same results. Consistent results from the same experiment will reinforce the findings of the experiment and ensure acceptance of the hypothesis by the wider scientific community.

Reliability *may be illustrated in throwing darts. If darts (results) consistently hit the same number and are close together, this is considered a* ***reliable result****. If darts hit different numbers / a wide range of numbers, this would be considered an unreliable result.*



Low reliability ***High reliability*** ***High reliability***

Check the ***context*** *of questions on* ***reliability*** *and* ***validity****. If the question refers to:*

'what was ***already done*** *in the investigation'*

- *the* ***past***
  → the answer will be provided in the question
- *the* ***future***
  → the answer must be determined from the data provided

'what ***should be done*** *in the investigation'*

3 Accuracy

Accuracy refers to the care taken by the investigator in making measurements.

To ensure that results are accurate:

- use appropriate apparatus
  i.e. use a measuring tape, not a ruler, to measure a person's height
- make sure apparatus is correctly calibrated
  i.e. 1 gram on a scale is actually 1 gram on any calibrated scale

NOTE

Validity *and* ***reliability*** *are often asked in exam questions.*

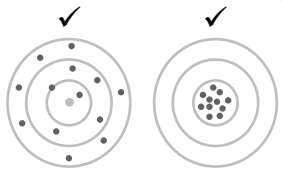
Accuracy *is not often referred to, as it is taken for granted that the investigator will take care in making measurements.*

SKILLS

Human error in misreading measurements as well as **faulty apparatus** contribute to inaccurate results.

Accuracy *may also be illustrated in throwing darts.*

If darts (results) are off the target – the results are inaccurate – they are not the true value. If darts are all near the target/centre/bull's eye – then the results are considered ***accurate****.*



SUMMARY

To ensure meaningful results:

- only change the independent variable (**validity**)
- repeat as many times as possible, or increase your sample size, and take an average (**reliability**)
- ensure your equipment is properly calibrated and there is no human error in the testing (**accuracy**)

Precautionary Measures

In every investigation there are steps that must be taken to ensure that the **design** of an investigation is correct. These include:

- safety measures to protect samples/subjects
- ethical studies to ensure investigation is legally and morally acceptable
- results that are recorded accurately

WORKED EXAMPLE OF SCIENTIFIC INVESTIGATION QUESTION

A scientific investigation was conducted with 20 cyclists to determine whether caffeine can increase stamina. The investigators followed this procedure:

- The cyclists were given the first cup of coffee (without caffeine) to drink.
- They then had to cycle for as long as possible at the same speed.
- They cycled around a 400 m track on level ground.
- They were given a second cup of coffee (with caffeine) to drink before the second cycling session.

The table below shows the average time the cyclists were able to cycle after drinking decaffeinated coffee (coffee without caffeine) and drinking coffee with caffeine.

Type of coffee	Average duration of cycling (minutes)
250 ml decaffeinated coffee	82
250 ml caffeinated coffee	123

HINT

Always keep a highlighter at hand when reading this type of question. Then you can underline the ***aim****,* ***variables****,* ***sample size*** *and other important information to simplify the answering of questions.*

1. How large was the sample for this experiment? (1)

20 ✓ cyclists

This refers to how many individuals were used in the experiment. Read the introduction.

2. State the question that the scientists were trying to answer through the investigation. (2)

Does drinking coffee containing caffeine increase stamina? ✓✓

An investigative question must have both variables. Use the ***aim*** *in the introductory sentence to state the investigative question.*

3. Suggest a possible hypothesis for this investigation. (2)

Drinking coffee with caffeine increases stamina in cyclists. ✓✓

Any statement that predicts the outcome of the investigation and includes both variables will be accepted.

4. Identify the:

4.1 independent variable (1)

4.2 dependent variable as well as how it was measured (2)

Amount of caffeine ✓ present.

*This is the variable that is manipulated. It will be different in each group. It is taken from the **aim**: 'to determine whether **caffeine** can increase stamina'*

- *stamina ✓*
- *by measuring the average duration of cycling ✓*

*Note the 2 parts of this question. The dependent variable is in the **aim** of the investigation: 'to determine whether caffeine can increase **stamina**.' But stamina is **quantified** by measuring the average duration of cycling.*

5. Provide **three** ways in which the scientists ensured the validity of this experiment. (3)

- *The same group of cyclists was used in both tests ✓*
- *They used the same track for both tests ✓*
- *The same amount of fluid/coffee was given in each case ✓*
- *They cycled at the same speed ✓ in both groups*

*The question asks for **three** ways, so only the first three answers will be marked, regardless of whether the 4th or 5th answers are correct.*

*This question is stated in the **past**, so look at what has **already been done** in the investigation. Remember that validity relates to constant variables. Re-read the experimental setup to identify these variables.*

6. Provide **one** way in which the scientists ensured the reliability of their experiment. (1)

- *20 cyclists were used / large sample size ✓*
- *The average duration of cycling ✓ was measured in each group*

*The question requires **one** way, so only the first answer will be marked, regardless of whether the 2nd or 3rd answers are correct.*

*This question is stated in the past, so look at what has **already been done** in the investigation. Remember the '**R**s for **r**eliability: **R**aise the sample size and **R**epeat the experiment.*

7. What is the relationship between caffeine consumption and the stamina of the cyclists? (2)

The stamina increased ✓ with the use of caffeine ✓ (the average duration of cycling increased with the use of caffeine)

The conclusion is always drawn from the aim or hypothesis of the investigation. Do not only refer to the data in the table.

8. Explain the purpose of giving the cyclists decaffeinated coffee to drink during the investigation. (2)

- *Decaffeinated coffee serves as the control ✓*
- *to eliminate any other factor ✓ that may cause an increase in stamina / to compare the results to*

*The setup where the independent variable is removed, is called the **control**. It acts as a 'baseline' to compare the results and to observe the real effect of the independent variable.*

9. The cyclists were not told whether or not the coffee they drank contained caffeine. Explain why the cyclists were not given this information. (2)

- *If they know ✓ whether caffeine was ingested or not*
- *it could have influenced/increased/decreased their performance ✓ **OR***
- *The participants may think they have more stamina ✓*
- *which could have influenced/increased/decreased their performance ✓*

This question tests the understanding of how other variables could have influenced the outcome of the experiment. If the participants had knowledge about the caffeine in the coffee, the experiment would have been less valid, as the results would have been influenced by that variable.

10. The procedure does not indicate how much time passed between each cycling exercise. Explain why this is an important factor to know. (2)

- *With too little time in between the two tests, the participants could be tired ✓*
- *which makes the investigation less valid ✓ **OR***
- *The participants must be equally rested ✓ for both tests*
- *to ensure the validity ✓ of the investigation **OR***
- *The cyclists could be more warmed-up for the second test ✓*
- *which makes the investigation less valid ✓*

This question tests the understanding of how other variables could have influenced the outcome of the experiment. If the tests were conducted closer together, the experiment would have been less valid, as the results would have been influenced by that variable.

REPRESENTING DATA

Criteria for presenting data:

1 Tables

- **Heading**
  - clearly states what the data represents
  - includes both the **independent** and the **dependent variables**
  - e.g.: A table to show the relationship between the *independent variable* and the *dependent variable* over a period of time

REMEMBER

*The **independent variable** is the variable that you control and may change during the experiment.*

*The **dependent variable** is the variable that is measured during the investigation and affected by the change in the independent variable.*

- **Rows** and **columns** are labelled with the relevant variable and the **unit** in brackets.
  - The independent variable is on the top / left side of the table / 1st column.
  - The dependent variable is on the bottom / right side of the table / 2nd column.
- If the independent variable is numerical, the values are arranged from the lowest to the highest.

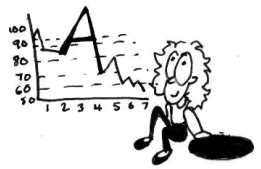
E.g. Measuring the changes in temperature over time.

Time (s)	10	20	30	40	50	60	70	80	90
Temperature (°C)	12	16	20	30	45	50	40	35	20

Independent variable — **Dependent variable**

Time (s)	**Temperature (°C)**
10	12
20	16
30	20
etc.	

2 Graphs



- **Variables**
  - **independent variable**
    - labelled on the ***x*-axis**
    - values are manipulated (determined/controlled) by the investigator
  - **dependent variable**
    - labelled on the **y-axis**
    - data is measured by the investigator

NOTE

***Independent** variable – **x**-axis = manipulated variable*

***Dependent** variable – **y**-axis = measured variable*

- **Axes**
  - each axis must be labelled with the relevant **variable**
  - ***x*-axis** – independent variable
  - **y-axis** – dependent variable
  - appropriate **units** must be included after the variable name, e.g. Time (s) or Mass (kg)
  - axes must have the correct **scale** to maximise the space available
  - graphs should be large enough to read data easily i.e. approximately 10 lines or larger
- **Scale**
  - non-continuous data must be spaced at equal intervals on each axis
  - continuous data uses a scale that starts at 0 and increases at equal intervals
  - each variable has its own independent scale
  - the scale should maximise the space available on the axes
- **Heading**
  - all graphs must have a heading
  - clearly states what the data represents
  - includes both the independent and the dependent variables and the relationship between them

Line Graph

A line graph shows continuous **quantitative** (numerical) **data**, e.g. time, distance, mass, etc.

STEPS to draw a LINE GRAPH

1. Identify the independent and dependent **variables** from the data provided
2. Draw a set of **axes** (***x***-axis: independent variable & **y**-axis: dependent variable) with **labels** and **units**
3. Choose a **scale** for each axis with equal intervals that include lowest/highest values
4. **Plot points** where values from each axis meet on the graph

NOTE

*Data points are plotted using a cross (**x**) or a small dot (⊙) where the value from the dependent variable (y-axis) meets the value of the independent variable (x-axis).*

5. Use a ruler to join the dots with **straight lines** or 'line of best fit' between the dots
6. Provide a **heading** that includes both variables and the relationship between them

NOTE

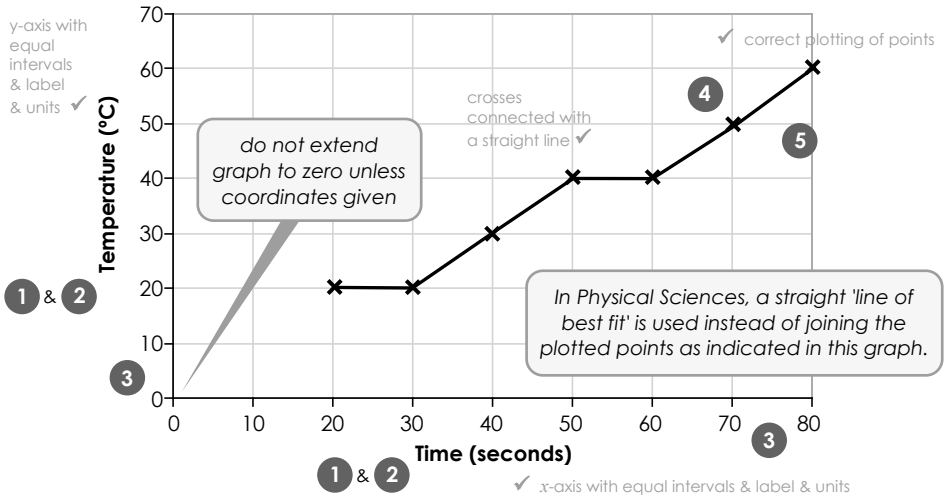
Read values off a graph by drawing a perpendicular dotted line from the known point on the relevant axis to the graph, then another perpendicular dotted line from the graph to the other axis. Read the value where this line intersects the second axis.

NOTE

Take note of mark allocation on the graph ✓

✓ heading with both variables

6 Line graph showing the relationship between temperature and time in a chemical reaction



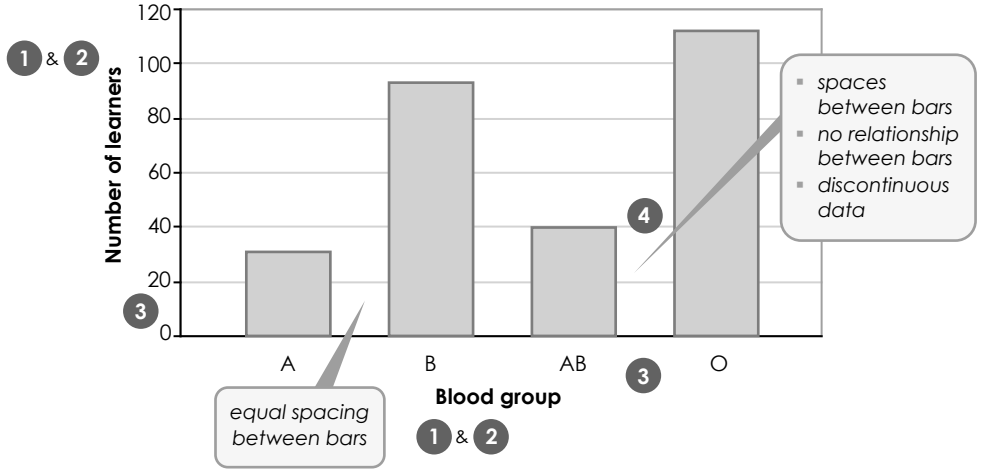
Bar Graph

A bar graph shows discontinuous **qualitative** (non-numerical categories) **data**, e.g. types of food/areas/months, etc.

STEPS to draw a BAR GRAPH

1. Identify the independent and dependent **variables** from the data provided
2. Draw a set of **axes** with **labels** (no units):
   - ***x***-axis: independent variable with **qualitative data**
   - **y**-axis: dependent variable with **quantitative data**
3. Choose a **scale** for each axis with regular intervals that include lowest/highest values
4. Data is plotted as **blocks/bars/columns**, not points.
   - There are **spaces** between each bar because the data on the *x*-axis is **discontinuous**
   - Each bar must be the same width
   - Spaces between each bar should be the same width
5. Provide a **heading** that includes both variables and the relationship between them

5 A bar graph illustrating the number of learners with each type of blood group



NOTE

continuous data *can be represented by any value in an interval, e.g. temperature or height*

discontinuous data *can only be represented by separate values in distinct categories or groups, e.g. different chemicals in fertiliser*

SKILLS

Histogram

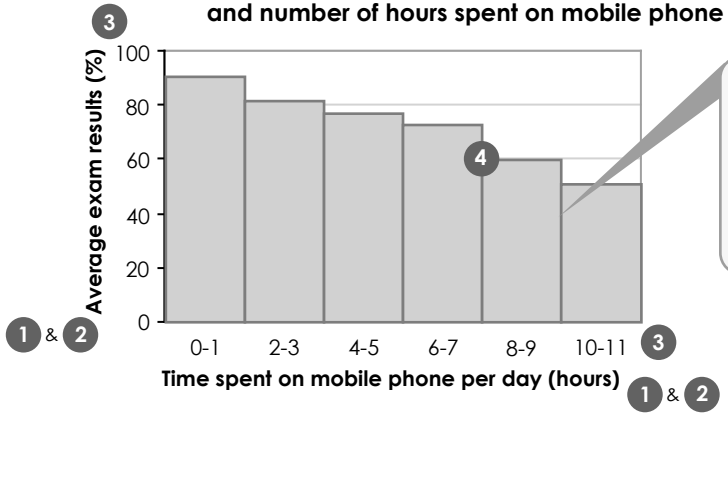
A histogram shows **groups of quantitative** (numerical) **data** on a continuous scale.

- Data is grouped into categories of **continuous data**, e.g. 0-5, 5-10.
- Categories start with the smallest value on the left to the largest on the right.

STEPS to draw a HISTOGRAM

1. Identify the independent and dependent **variables** from the data provided
2. Draw a set of **axes** with **labels** (no units):
   - ***x***-axis: independent variable with **quantitative data**
   - **y**-axis: dependent variable with **qualitative data**
3. Choose a **scale** for each axis with regular intervals that include lowest/highest values
4. Data is plotted as **blocks/bars/columns**, not points.
   - Bars should be equal in width.
   - Bars touch each other with **no spaces** in between because the data on the *x*-axis is **continuous**
5. Provide a **heading** that includes both variables and the relationship between them

A histogram to show the relationship between average exam results and number of hours spent on mobile phone per day (5)



Pie Graph/Chart

- A pie graph shows data as a **part** or **percentage** of the **whole**.
- Pie graphs are used for **discontinuous** data.
- Pie graphs can be used instead of bar graphs where there are six or less parts/**sectors**.
- A circle represents 100% of the total = 360° with sectors that represent the size of each of the parts.

STEPS to draw a PIE CHART

1. Calculate the sum of all the values (total)
2. Convert the value of each sector to degrees by dividing by the sum total and multiplying by 360°:

$$\textbf{degrees} = \frac{\textbf{value of sector}}{\textbf{sum of values}} \times \textbf{360°}$$

NOTE

e.g. $\frac{25 \text{ beetles}}{750} \times 360° = 12°$

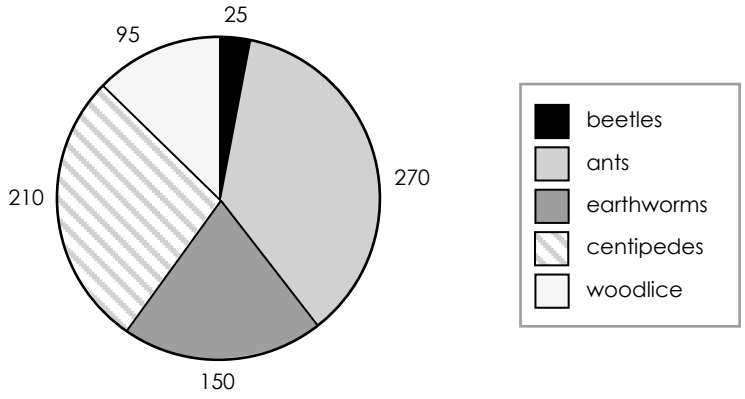
360° is the total number of degrees in a circle

3. Use a compass to draw a circle
4. Draw a line from the centre to the edge of the circle (radius) and use a protractor to measure the degrees for each sector
5. Shade all the sectors differently
6. Include a key OR label each sector to indicate the value/percentage of each sector on the graph
7. Provide a **heading** that includes both variables and the relationship between them

NOTE

In exam questions, always show your calculations for a pie graph.

A pie chart to show the relationship between types of animals in a soil sample



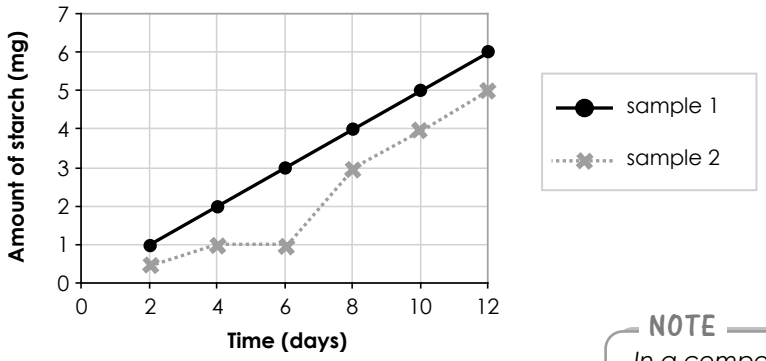
When to use which graph?

Line:	Both variables are numerical, e.g. time
Bar/pie:	Independent variable is a category (qualitative/non-numerical) and **discontinuous**, e.g. colour, countries, languages, types of responses
Histogram:	Independent variable is a category (quantitative/numerical) of **continuous** data, e.g. length, temperature, sound, age groups

Compound Graphs

- Two dependent variables are plotted on the same set of axes.
- They are distinguished by using a solid and broken line (line graph) or different shadings (bar graph).
- There is a **key** to describe each set of data.

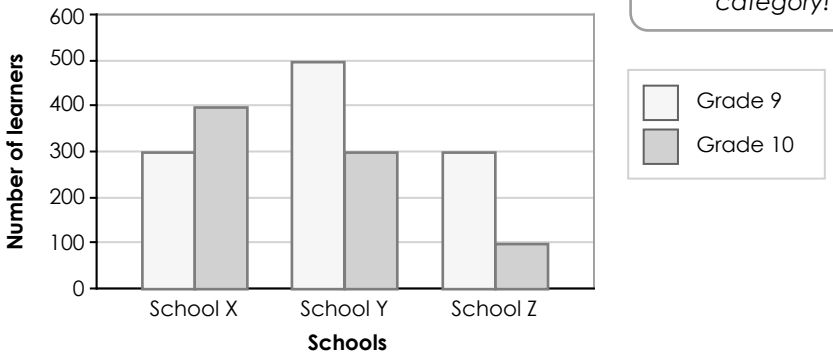
A line graph showing the relationship between the amount of starch produced over time in two different leaf samples



NOTE

In a compound bar graph the spaces are between each category!

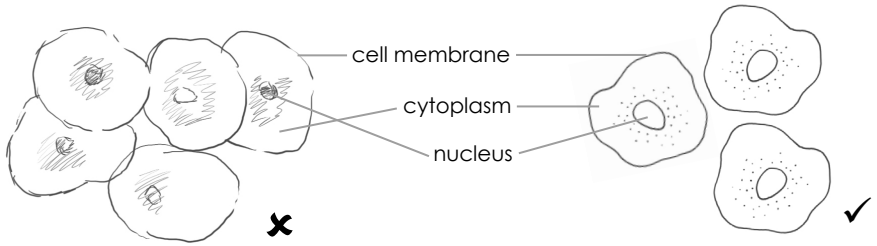
A bar graph showing internet use by Grade 9 and Grade 10 learners in different schools



Biological Drawings

Drawings are used to record an image of a specimen.

- **DRAW WHAT YOU SEE!** Do not include what you think you should see.
- Drawings must be large enough to see all labelled parts clearly.
- Draw in pencil ONLY.
- Always use distinct, single lines when drawing – no 'sketching'.
- To illustrate darker areas on a specimen, use stippling or dots.
- Do not shade in any area of your drawing.
- All drawings must have the following:
  - **Heading**
    - a full, clear and concise title that describes the drawing
  - **Magnification**
    - indicate the magnification (scale) at which the specimen was observed, e.g. 400X
  - **Labels**
    - always include labels of the important features of the specimen
    - label lines should be drawn in ink and with a ruler
    - label lines should not cross
    - labels may be written on both sides of the drawing
    - label lines should end at the same point so that labels are aligned below each other



Incorrect drawing format

Diagram of animal cell (100X)

Correct drawing format

Diagram of animal cell (100X)

MODULE 1 LIFE and LIVING

TOPIC 1 CELLS AS THE BASIC UNITS OF LIFE

US 7507; 7508; 7509; 7513

TOPIC 2 SYSTEMS IN THE HUMAN BODY

US 7507; 7509

TOPIC 3 HUMAN REPRODUCTION

US 7507; 7508; 7509; 7513

TOPIC 4 CIRCULATORY AND RESPIRATORY SYSTEMS

US 7507; 7508; 7509

TOPIC 5 DIGESTIVE SYSTEM

US 7507; 7508; 7509

LIFE and LIVING

US 7507

Demonstrate an understanding of the concept of science

	SO1	SO2	SO3	SO4	SO5
TOPIC 1		X	X		X
TOPIC 2	X				X
TOPIC 3					X
TOPIC 4					X
TOPIC 5			X		X

US 7508

Conduct an investigation in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 1		X	X	
TOPIC 3	X			
TOPIC 4		X		X
TOPIC 5		X	X	X

US 7509

Apply basic concepts and principles in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 1	X	X		X
TOPIC 2	X			X
TOPIC 3	X		X	X
TOPIC 4	X	X		X
TOPIC 5	X	X	X	X

US 7513

Assess the impact of scientific innovation on quality of life

	SO1	SO2	SO3	SO4
TOPIC 1	X			X
TOPIC 3	X	X		

TOPIC 1: CELLS AS THE BASIC UNITS OF LIFE

US 7507: SO 2 – AC 1-3; SO 3 – AC 1,3; SO 5 – AC 1-2
US 7508: SO 2 – AC 1-2; SO 3 – AC 1,3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 1-2
US 7513: SO 1 – AC 1-4; SO 4 – AC 3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Describe the development of science in the microscope and cells
- Illustrate the significance and understanding of cells in life
- Devise and implement a procedure to investigate cell structure
- Demonstrate the correct use and setup of a microscope
- Apply knowledge and skills to familiar and unfamiliar phenomena
- Explain the application of knowledge of cells in stem cell research

Resources

- Class text & study guide
- Microscopes
- Practical equipment p. 12
- Practical equipment p. 13

TOPIC 2: SYSTEMS IN THE HUMAN BODY

US 7507: SO 1 – AC 1; SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Identify and describe the different organ systems
- Illustrate the significance of organ systems in the identification of diseases
- Define concepts and principles relating to organ systems
- Apply knowledge and skills to familiar and unfamiliar phenomena

Resources

- Class text & study guide

TOPIC 3: HUMAN REPRODUCTION

US 7507: SO 5 – AC 1-2
US 7508: SO 1 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 3 – AC 1-3; SO 4 – AC 1-3
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Understand and illustrate the effect of harmful chemicals on the foetus
- Understand and illustrate the usefulness of contraceptive methods
- Formulate a scientific hypothesis
- Define concepts and principles relating to the reproductive system
- Implement a plan to investigate a phenomenon or problem
- Gather and interpret relevant data
- Explain and describe the impact of harmful chemicals and contraceptives on the quality of life

Resources

- Class text & study guide

TOPIC 4: CIRCULATORY AND RESPIRATORY SYSTEMS

US 7507: SO 5 – AC 1-2
US 7508: SO 2 – AC 1; SO 4 – AC 3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Understand the causes of health issues associated with circulation and respiration
- Conduct a heart dissection
- Understand ways of representing data
- Define concepts and principles relating to circulation and respiration
- Demonstrate the effect of exercise on the heart rate
- Apply knowledge and skills to familiar and unfamiliar phenomena

Resources

- Class text & study guide
- Practical equipment p. 46
- Practical equipment p. 50

TOPIC 5: DIGESTIVE SYSTEM

US 7507: SO 3 – AC 1; SO 5 – AC 2
US 7508: SO 2 – AC 1; SO 3 – AC 1,3; SO 4 – AC 3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Explain and understand the requirements of different diets
- Illustrate the significance of understanding nutritional value of food in life
- Investigate food samples for the presence of nutrients
- Understand ways of representing data
- Define concepts and principles relating to digestion
- Interpret scientific evidence and apply knowledge and skills

Resources

- Class text & study guide
- Practical equipment p. 58

TOPIC 1 CELLS AS THE BASIC UNITS OF LIFE

US 7507: SO 2 – AC 1-3; SO 3 – AC 1,3; SO 5 – AC 1-2
US 7508: SO 2 – AC 1-2; SO 3 – AC 1,3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 1-2
US 7513: SO 1 – AC 1-4; SO 4 – AC 3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Describe the development of science in the microscope and cells
- Illustrate the significance and understanding of cells in life
- Devise and implement a procedure to investigate cell structure
- Demonstrate the correct use and setup of a microscope
- Apply knowledge and skills to familiar and unfamiliar phenomena
- Explain the application of knowledge of cells in stem cell research

UNIT 1 CELL STRUCTURE

The cell is the basic **structural and functional unit** of all living organisms. It is a **building block** that contains all the structures needed to perform the processes associated with life.

CELLS – STRUCTURAL AND FUNCTIONAL UNITS

Seven Basic Characteristics of Life

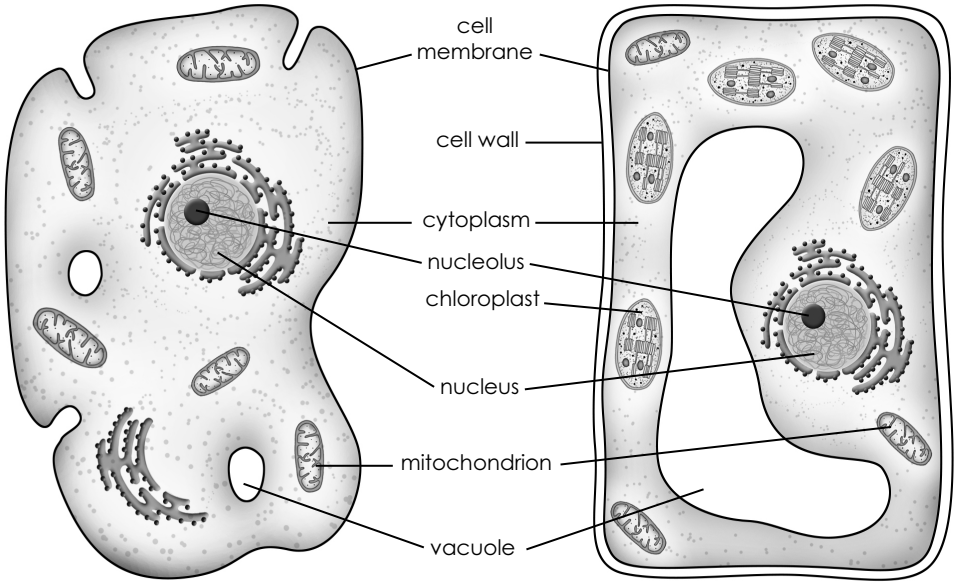
- **M**ovement – the cell moves in response to stimuli
- **R**espiration – the cell uses food and oxygen to release energy
- **S**timuli response – the cell responds to changes in the environment
- **G**rowth – the cell increases in size
- **R**eproduction – the cell divides to form new cells
- **E**xcretion – the cell removes waste
- **N**utrition – the cell takes in food for energy

NOTE
*You can remember these characteristics using the acronym **MRS GREN.***

Cells are microscopic, simple in structure, but complex in organisation. Plant and animal cells have a **cell membrane** that controls entry and exit of substances and surrounds a jelly-like **cytoplasm,** and specialised structures called **organelles** that perform specific functions. There are many different organelles, but we will only study a few in this section.

Organelles

- nucleus – controls cellular activities
- mitochondria – converts food and oxygen into usable energy for the cell
- vacuoles – provide storage and support for the cell
- chloroplasts – convert light energy into food for the cell



Structure of an animal cell **Structure of a plant cell**

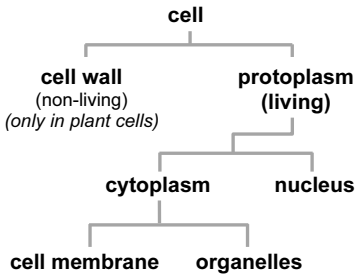
NOTE
*You must be able to **draw** and **label** diagrams of plant and animal cells.*

COMPONENTS OF PLANT AND ANIMAL CELLS

All cells are made up of **living material** called **protoplasm**. Protoplasm includes the liquid **cytoplasm**, the **nucleus** and other **organelles**.

NOTE

*All cells and their components are specifically adapted to perform their function. Each **adaptation** should always be explained with reference to **structure** as well as **function**.*



Cell Wall

- It is a tough, fibrous, **non-living** structure that surrounds the protoplasm.
- It is present only in plant cells.
- It is composed of **cellulose**.

Unlike animals, plants do not have skeletons for support. Thus cell walls are essential to provide shape, strength and support to plant structures.

Cell Membrane (Plasma Membrane)

- It forms a thin outer **boundary** for the contents of the cell.
- It controls the movement of substances in and out of the cell – it is **selectively permeable.**
- In plant cells, it is surrounded by a rigid cell wall for additional support.
- Substances move by **diffusion** and water moves by **osmosis** across the cell membrane.

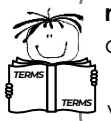
osmosis: the movement of water from a high water potential to a low water potential through a membrane

in a cell 'factory'

*The **cell membrane** represents the **gates** in a factory. It controls the entry/exit of substances in/out. Useful substances are allowed in while unwanted substances are blocked.*

Cytoplasm

- It is the jelly-like fluid matrix inside the cell membrane.
- It is the **medium** in which chemical reactions occur, e.g. digestion.
- Substances are dissolved or suspended in the cytoplasm.
- Food is stored in the cytoplasm, e.g. starch granules.
- It maintains the shape of the cell.



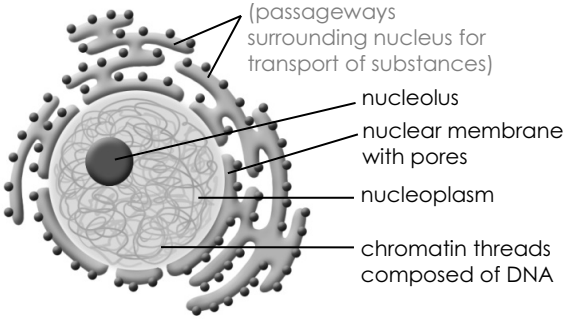
metabolism: all chemical reactions within a cell

in a cell 'factory'

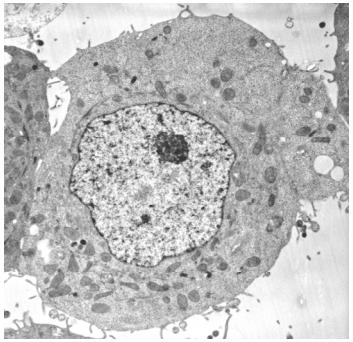
*The **cytoplasm** represents the **factory floor** in a factory. It is the site of all cellular activities. Products are assembled and prepared here for 'shipping' out.*

Nucleus

- It is a dark, round/oval structure in the cytoplasm.
- It is enclosed by a **nuclear membrane**.
- It contains fluid called **nucleoplasm**.
- A small dark body called the **nucleolus** is visible in the nucleoplasm.
- The nucleus controls all the activities of the cell.
- It carries the **inherited characteristics** on **DNA** (deoxyribonucleic acid) which is coiled to form chromatin threads in the nucleoplasm:
  - DNA contains all the **coding** for the **structure and functioning** of a cell, e.g. shape of eyebrows, length of small finger, colour of eyes, etc.
  - this DNA coding is arranged in units called **genes** and occurs in the nucleus of every cell in the body of an organism
  - DNA causes **variation** within a species, i.e. the differences between individuals:
    - e.g. height in humans, length of flower petals, colour patterns in cows
    - each individual's **DNA** is **unique** as it is a combination of DNA from both parents



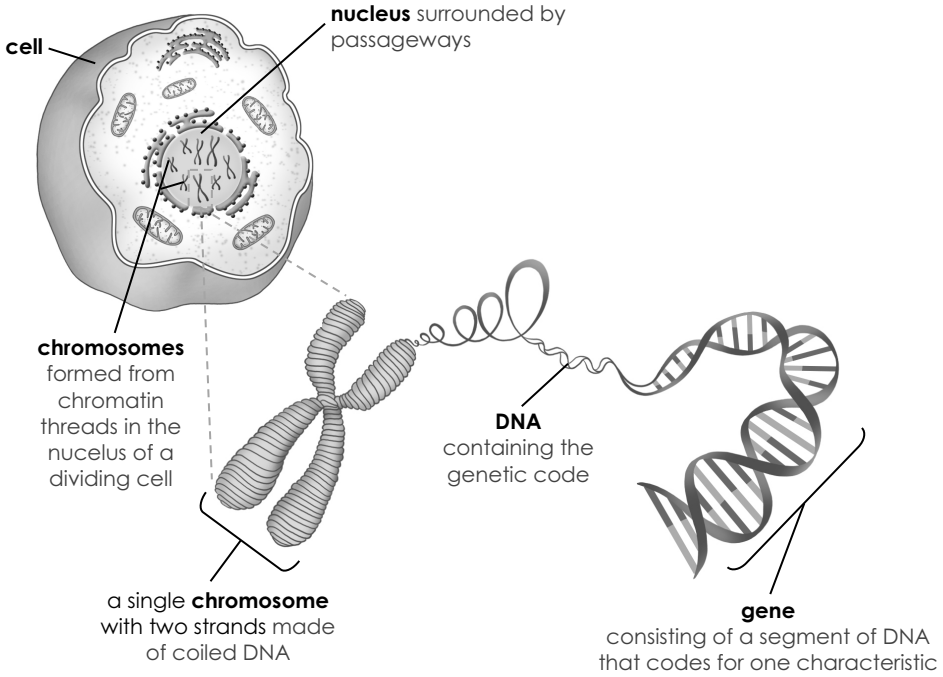
Structure of a nucleus



Photomicrograph of a nucleus in a cell

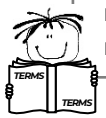
in a cell 'factory'

*The **nucleus** represents the **control room** or **headquarters** in a factory. It controls all activities of the cell. It stores the master copy plans, determines which products are made and when to make another 'factory'.*



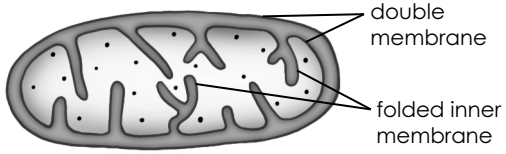
Mitochondrion

- It is a cylinder-shaped organelle with a double membrane.
- The inner membrane is folded to increase surface area for chemical reactions.
- It is the site of **respiration**
  - the process that **releases energy** from food, e.g. glucose
  - uses oxygen
  - releases carbon dioxide



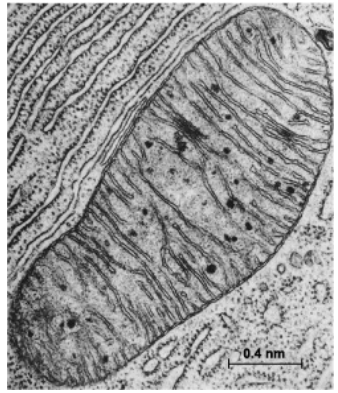
mitochondrion: singular
mitochondria: plural

respiration: *see p. 21 for more details on the process*



in a cell 'factory'

*The **mitochondrion** represents the **power plant** in a factory. It transforms energy in fuel (food) into accessible forms of energy.*



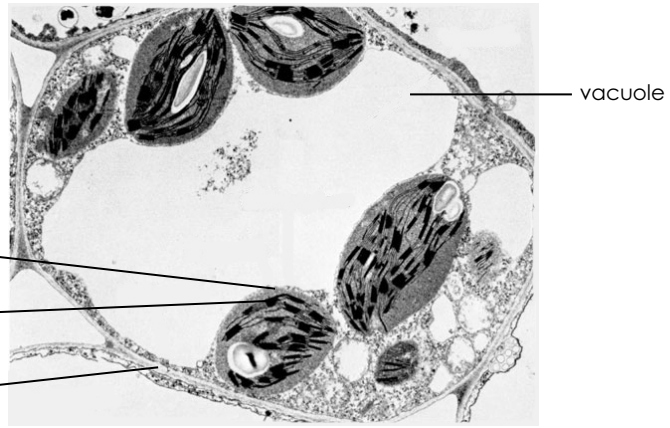
Photomicrograph of a mitochondrion in a cell

Vacuole

- It is a fluid-filled sac in the cytoplasm.
- It is enclosed by the **tonoplast** – a **selectively permeable membrane**.

selectively permeable membrane: a membrane that controls the movement of substances in/out of the cell

- It is filled with fluid called **cell sap**.
- Plant cells have larger vacuoles that provide **support**, **storage** and **shape** for the plant cell.
- Animal cells have smaller vacuoles called **contractile vacuoles** that regulate the water balance.



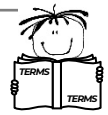
Photomicrograph of a vacuole in a plant cell

in a cell 'factory'

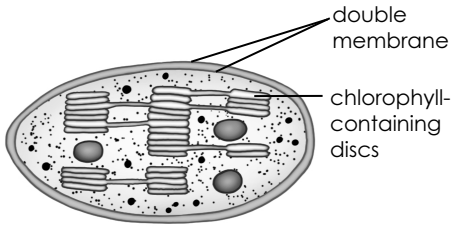
*The **vacuole** represents the **storage room** in a factory. It stores raw materials for production as well as food and waste material.*

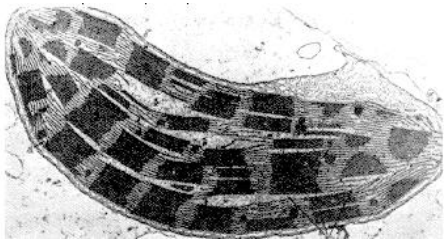
Chloroplast

plastid: an organelle that contains pigment or food



- It is an oval-shaped, green organelle called a **plastid**.
- Occurs in all photosynthesising parts of the plant, e.g. leaves.
- It is surrounded by a double membrane and filled with fluid.
- It contains discs with a green pigment called **chlorophyll** for **photosynthesis**.
- It converts light energy from the sun (radiant energy), water and carbon dioxide to carbohydrates (e.g. glucose) for food.





Photomicrograph of a chloroplast in a plant cell

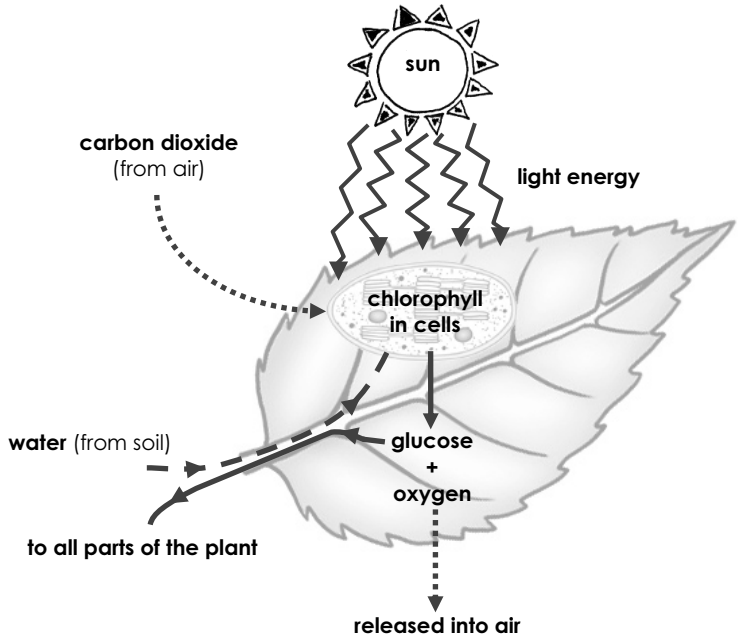
in a cell 'factory'

*The **chloroplast** represents the **solar panels** or the **kitchen** in a factory. It traps energy to make food/fuel.*

SUMMARY

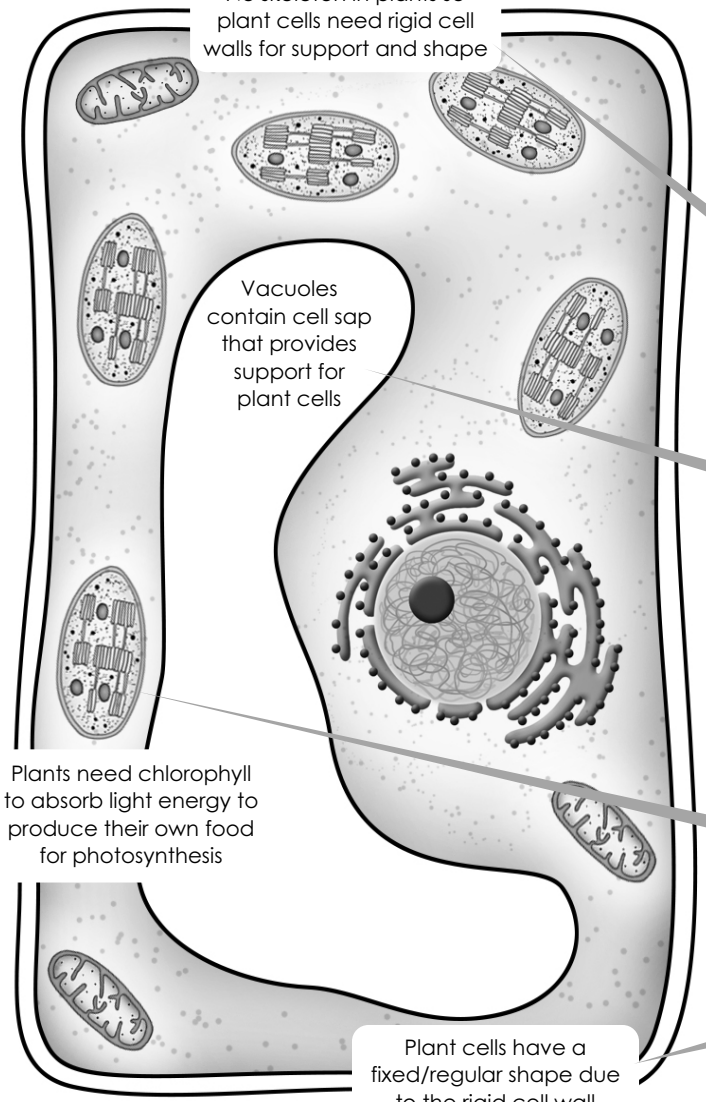
SUMMARY OF PHOTOSYNTHESIS

THE PROCESS THAT OCCURS INSIDE A CHLOROPLAST



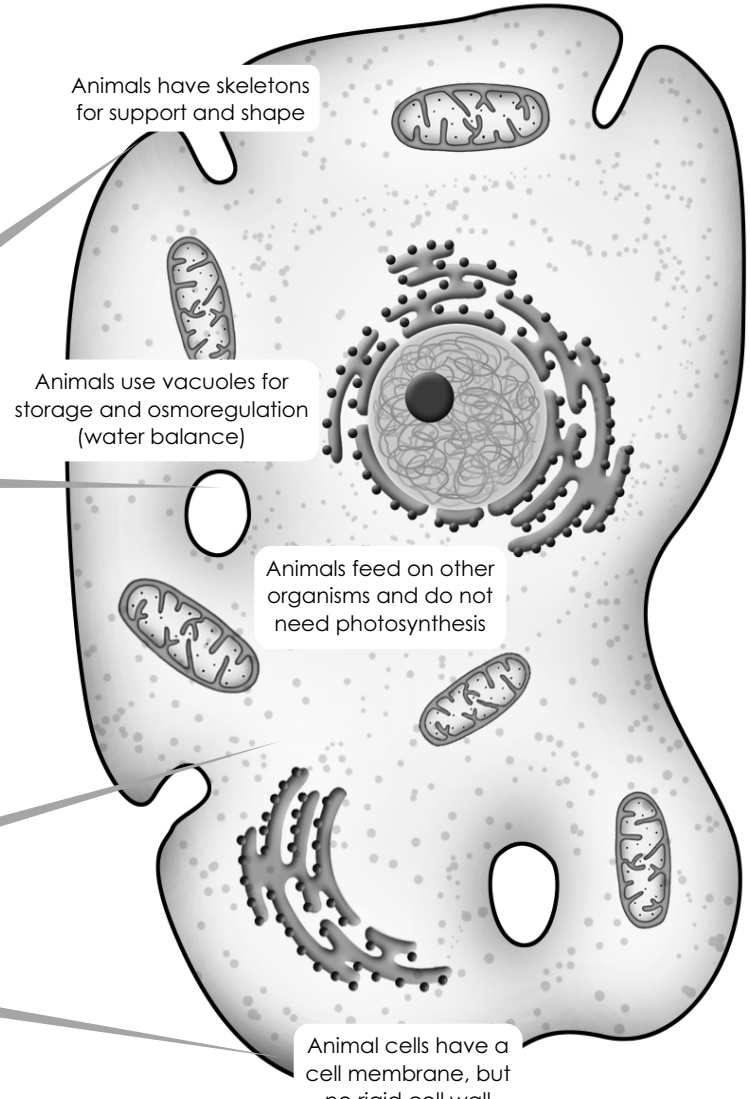
UNIT 2

DIFFERENCES BETWEEN PLANT AND ANIMAL CELLS

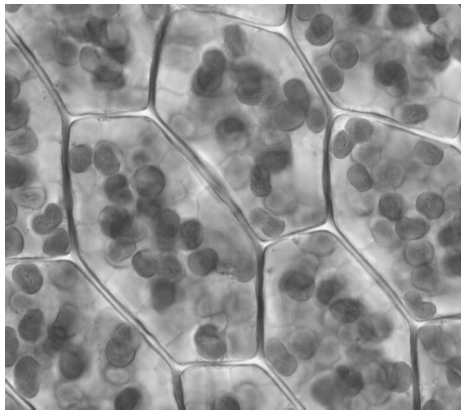


Structure of a simplified plant cell

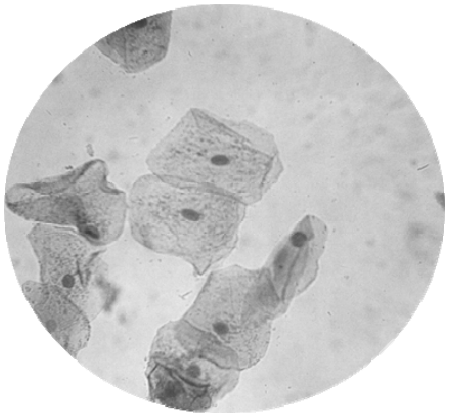
PLANT CELLS	ANIMAL CELLS
cell wall present made of cellulose	cell wall absent
large vacuole present	small vacuoles are temporary or absent
plastids e.g. chloroplasts present	plastids e.g. chloroplasts absent
fixed/regular shape	irregular shape



Structure of a simplified animal cell



Photomicrograph of plant cells
leaf cells showing chloroplasts and rigid cell walls



Photomicrograph of animal cells
cheek cells showing irregular shape

photomicrograph: a digital image (photograph) of an object viewed through a microscope

UNIT 3

CELLS IN TISSUES, ORGANS AND SYSTEMS

Although all cells have many structures and functions in common, they are not the same. They develop differently in size, shape and structure in order to perform specific functions. This process of cells 'becoming different' is known as **differentiation** or **specialisation**. Cells develop particular characteristics to adapt to their specific environment and function, e.g.:

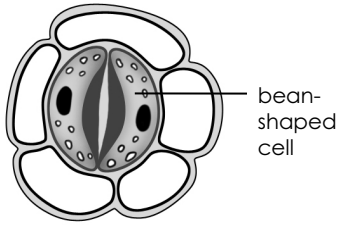
- blood cells transport gases
- nerve cells conduct impulses
- muscle cells contract and relax

ADAPTATIONS OF PLANT AND ANIMAL CELLS

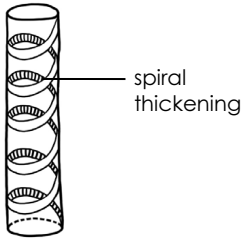
Specialised plant and animal cells have specific adaptations for their role in their environment. Some examples are described below:

NOTE
Adaptations *always refer to* ***structure*** *and* ***function****.*

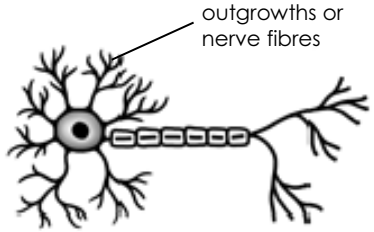
ultrathin cells line the lungs to allow for **easy diffusion** of gases



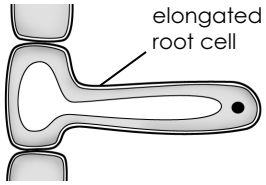
bean-shaped cells in the leaf surface have **thick inner walls** to control opening/closing of a pore for **gaseous exchange**



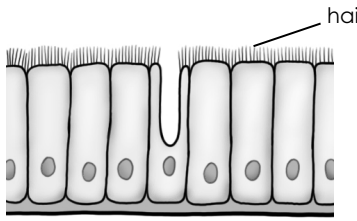
spiral thickening strengthens the walls of an empty plant cell (xylem vessel) for the upward **transport of water**



many, long outgrowths of a nerve cell for optimal **transmission** of **nerve impulses**



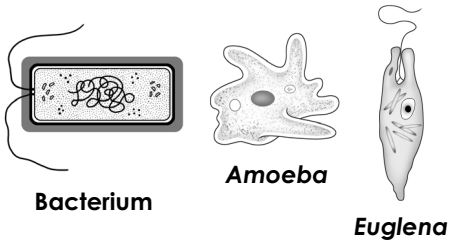
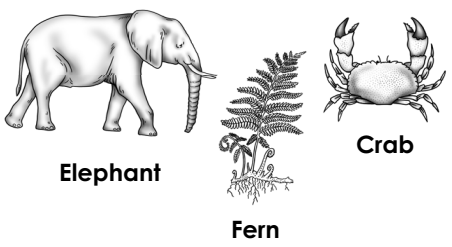
finger-like extension of a root cell to increase surface area for **absorption of water** from the soil



tiny hairs on cells in the nose to **trap foreign bodies** and protect the lungs

UNICELLULAR vs MULTICELLULAR

Organisms are either **unicellular** or **multicellular**:

Unicellular organisms	Multicellular organisms
○ consist of a single cell ○ simple level of organisation ○ a single cell performs all the processes for life ○ **microscopic** organisms smaller in size ○ only visible under a microscope ○ e.g. bacteria and yeast fungus	○ consist of large numbers of cells ○ complex level of organisation ○ cells are organised into groups that are specialised to perform a particular process ○ **macroscopic** organisms larger in size ○ visible to the naked eye ○ e.g. humans, animals and plants
	

ORGANISATION OF CELLS

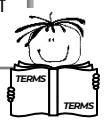
All living organisms have **levels of organisation** from atoms to molecules to organelles in cells. Cells are also specialised and organised into groups that perform specific functions.

○ A group of differentiated cells that perform a common function is known as a **tissue**, e.g. muscle tissue in animals or phloem in plants.

○ A group of different tissues, each with their own function, that performs a common function, is known as an **organ**, e.g. small intestine in animals/humans or a stem in plants.

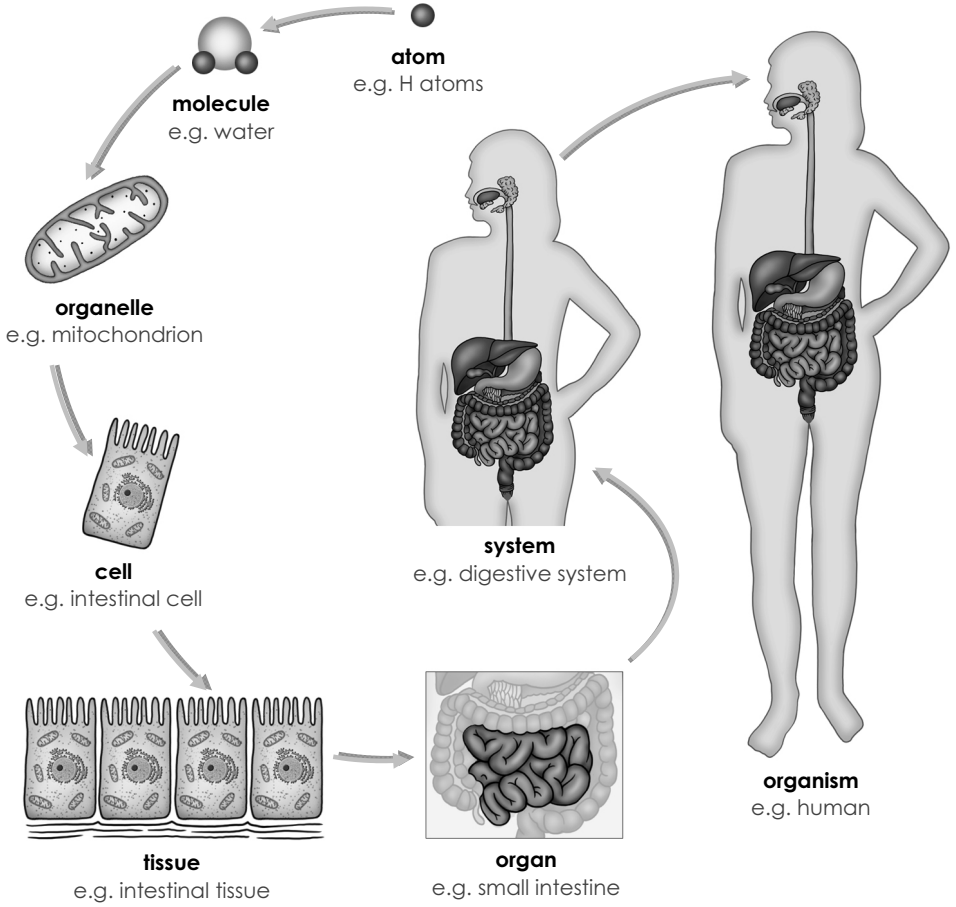
○ A group of different organs, each with their own function, that performs a common function, is known as a **system**, e.g. digestive system in animals/humans or vascular system in plants.

vascular system: system of tubes/ducts that transport fluids, e.g. blood vessels or xylem vessels in plants



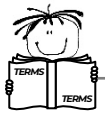
○ A group of different systems, each with their own function, that performs a common function, is known as an **organism**, e.g. a human, animal or tree.

Levels of Organisation – from atoms to organisms



MICROSCOPY

Microscopes are the instruments used to magnify objects in **microscopy**. There are various types of microscopes ranging from simple light microscopes that use light to view the specimen, to electron microscopes that use electrons to form an image of the specimen.



Microscopy: the use of a microscope to focus on objects that are invisible to the naked eye

History of Microscopy

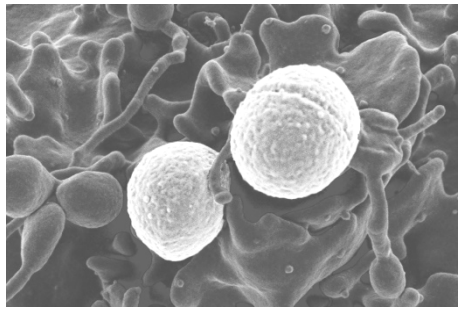
- 2000 BCE – Chinese scientists used a water-filled tube with a single lens to magnify objects.
- 100 – Glass was used to magnify objects and focus sun rays to make a fire.
- 1300s – Simple tubes with a lens on one end to magnify objects (10x) were in use.
- 1590 – Dutch spectacle makers, Zaccharias Jansen and his son Hans, experimented with various lenses in a tube. These lens tubes led to the development of the first microscope.
- 1609 – Italian physicist Galileo Galilei made an improved version with a focusing device.
- 1665 – English physicist Robert Hooke studied small strips of cork under the microscope and observed pores which were later identified as cells.
- 1674 – Dutch scientist Antonie van Leeuwenhoek used a magnifying glass to examine cloth in his business. He is regarded as the father of microscopy. He designed the first simple microscope with one lens to study blood, yeast, insects etc.
- 1830 – English businessman Joseph Lister discovered that using lenses together produces a better magnification.
- 1840 – German engineer Carl Zeiss revolutionised lens-making for microscopes.
- 1931 – German scientist Ernst Ruska and engineer Max Knoll invented the **Transmission Electron Microscope (TEM)**.

- Ongoing research produced different types of microscopes that are specialised for specific functions, e.g.:
  - Transmission Electron Microscope (TEM) – fires electrons **through** a specimen to magnify the specimen
  - Scanning Electron Microscope (SEM) – bounces electrons over the **surface** of the specimen to produce a magnified 3D image

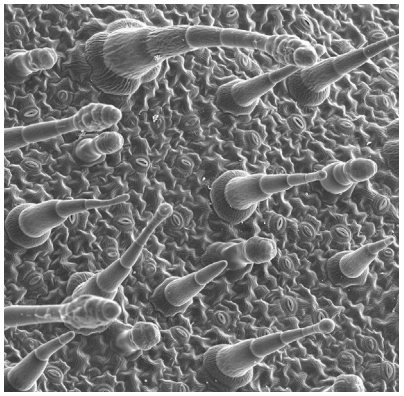
NOTE

Other modern microscopes include:

- *Scanning tunnelling microscope (STM) – uses a beam of electrons to show the atomic structure of the surface of the specimen.*
- *Atomic Force Microscope (AFM) – uses electrons to scan non-conducting surfaces like plastic.*



SEM (Scanning Electron Micrograph) of two bacteria outside a white blood cell

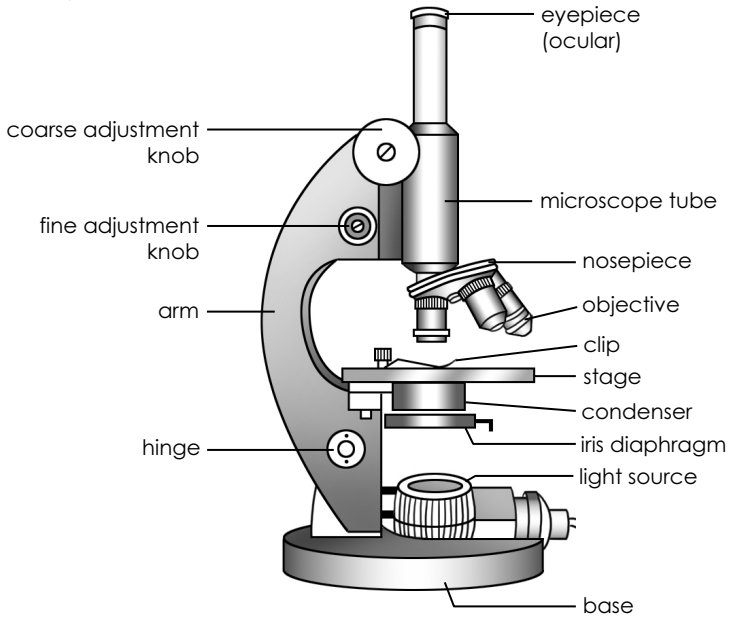


Electron micrograph of unicellular hairs on a leaf epidermis

*Modern **light microscopes** can magnify up to 2 000×.*
*Modern **electron microscopes** can magnify objects by 1 million×.*

The Light Microscope

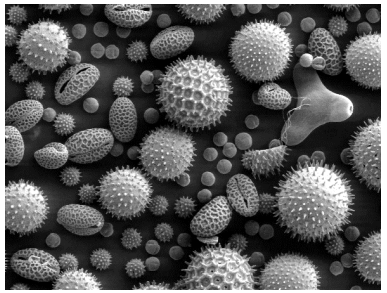
Parts of a light microscope



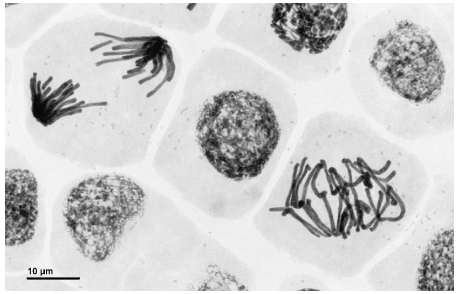
Representation of a light microscope

Functions of the parts of the light microscope

Microscope parts	Characteristic and function
Eyepiece (ocular)	Consists of the first set of lenses for magnification (e.g. 10×)
Coarse adjustment knob	Moves the microscope tube/stage up/ down quickly to bring the specimen into rough focus
Fine adjustment knob	Moves the microscope tube/stage up/ down very slowly for fine-tuning the focus
Arm	Used to carry the microscope and for attachment of the microscope tube, adjustment knobs and stage
Hinge	Enables the arm to move to different angles
Base	Provides stability for the microscope
Light source	Provides light to shine through the opening in the stage and illuminate the specimen
Iris diaphragm	Controlled by a lever to regulate the amount of light shining on the specimen
Condenser	Concentrates light rays from the light source onto the specimen
Stage	Flat platform on which the specimen slide is placed with an opening for light to pass through
Clips/clamps	Hold the specimen slide in position on the stage
Objectives	Sets of lenses with different magnifications attached to the nosepiece (e.g. 4×, 10× and 40×)
Nosepiece	Holds the objectives and rotates to bring different magnifications into position
Microscope tube	Holds the eyepiece in position and connects it to the objectives



Pollen grains



Chromosomes in cell division

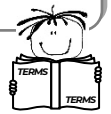
USING THE LIGHT MICROSCOPE

NOTE

Always use both hands to carry a microscope: one hand holding the arm, the other hand under the base.

- Place the microscope on a firm, flat surface with the **arm** facing you.
- Turn the rotating **nosepiece** so that the **shortest objective** with the **lowest magnification** is in position.
- Turn the **light source** on.
- Place the **slide** on the stage with the **specimen** positioned over the opening.
- Use the **clips** to clamp the slide in position.
- Look through the **eyepiece** and adjust the **iris diaphragm** and **condenser** lens until the specimen is well lit.
- Look at the stage **from the side** and turn the **coarse adjustment knob** until the objective **lens moves down** very close to the specimen slide, but does not touch it.
- Now look through the eyepiece and turn the **coarse adjustment knob** slowly in the **opposite direction** so that the objective **lens moves up** until the specimen is in focus.
- Use the **fine adjustment knob** to make finer adjustments until the specimen is clearly in **focus**.
- To **enlarge** the image, turn the nosepiece to position the **second objective lens** in place.
- You should only need slight adjustment of the **fine adjustment knob** when using the **second** and **third objective lenses**.

slide: a rectangular piece of glass on which an object is mounted for examination under a microscope



NOTE

***Only** use the **fine adjustment knob** to focus when using the longer lenses.*

- Adjust the light if necessary using the **iris diaphragm** and **condenser lens**.
- For a **higher magnification**, the **longest objective** can be clicked into position.

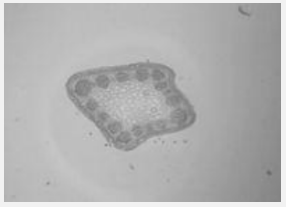
NOTE

*Make sure the lenses do **not** touch the cover slip.*

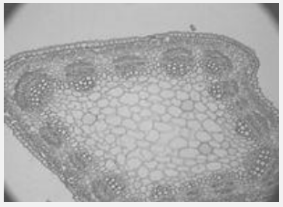
- After viewing, rotate the **shortest objective** into position before removing the slide.

MICROSCOPE IMAGES UNDER DIFFERENT MAGNIFICATIONS

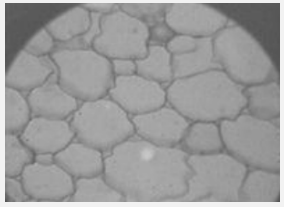
The photomicrographs below show a plant stem viewed through different objective lenses:



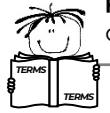
40× enlarged



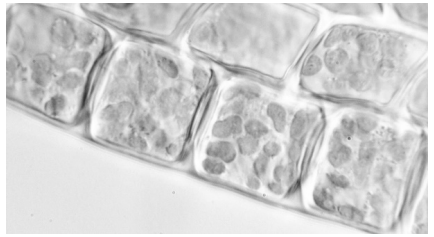
100× enlarged



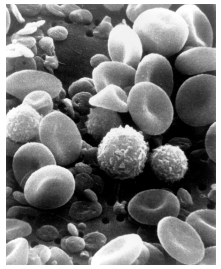
400× enlarged



photomicrograph: a digital image (photograph) of an object viewed through a microscope



Chloroplasts in moss cells



Blood cells

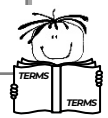
Preparing Slides of Plant and Animal Cells

PRACTICAL INVESTIGATION

Observing Plant Cells

Preparing a wet mount with epidermal cells from an onion leaf

wet mount: a microscope slide with a specimen placed in a drop of liquid



Requirements

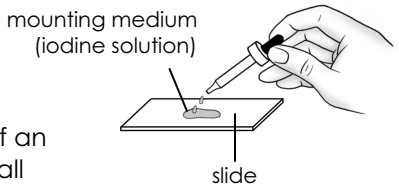
- slide
- cover slip
- dissecting needle
- onion leaf
- dissecting tweezers
- medicine dropper
- iodine solution
- scalpel/small knife

NOTE

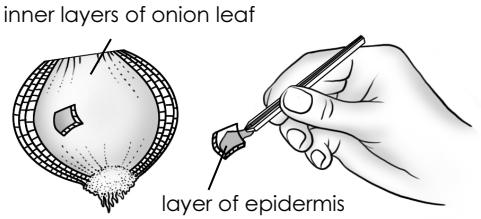
Iodine *solution is used as a mounting medium, to* ***stain*** *plant cells, instead of water.*

Method

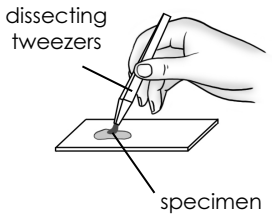
1. Use the medicine dropper to place a drop of iodine solution in the middle of the slide.



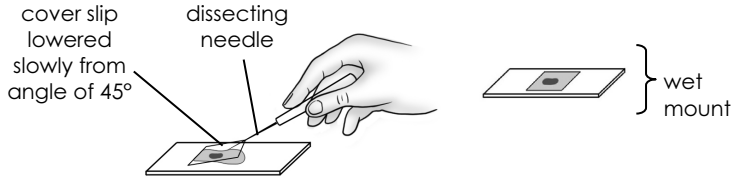
2. Take one of the innermost layers of an onion leaf and use the scalpel/small knife to cut a small piece out of it.
3. Use the dissecting tweezers to remove the thin membrane (epidermis) on the inside (concave side) of the piece of onion leaf.



4. Place the epidermis sample in the middle of the drop of iodine solution on the slide.



5. Place the cover slip on the mount as shown to avoid trapping air bubbles.



NOTE

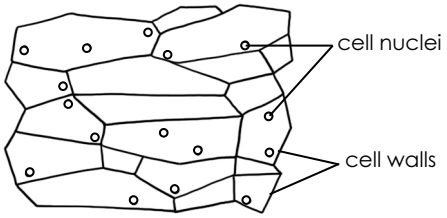
Use filter paper on the edge of the cover slip to remove excess solution.

NOTE

The ***cover slip*** *protects the lens and holds the specimen in place for viewing.*

6. Study the wet mount under low magnification and then under higher magnification.

Results



Onion epidermal cells

NOTE

Only draw a ***few cells*** *and provide* ***labels*** *for the structures that are* ***visible*** *in your slide.*

PRACTICAL INVESTIGATION

Observing Animal Cells

Preparing a wet mount with human cheek epithelial cells

Requirements

- slide
- cover slip
- toothpick
- medicine dropper
- two dissecting needles
- methylene blue

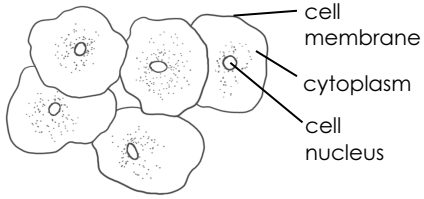
NOTE

Methylene blue *is used to* ***stain*** *animal cells.*

Method

1. Use the medicine dropper to place a drop of methylene blue stain in the middle of the slide.
2. Break the toothpick and use the blunt end to gently scrape the inside of your cheek.
3. Place the scraping in the drop of methylene blue on the specimen slide.
4. Use the two dissecting needles to spread out the scraping in the methylene blue solution.
5. Cover the mount with a cover slip as shown in the plant cell investigation (see p. 12).
6. Study the wet mount under a low magnification and then under a higher magnification.

Results



Human cheek epithelial cells

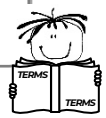
NOTE

Only draw a ***few cells*** *and provide* ***labels*** *for the structures that are* ***visible*** *in your slide.*

STEM CELLS

Stem cells are simple, **unspecialised** or **undifferentiated somatic cells** found in all organisms.

somatic cells: **all body cells** except reproductive cells (gametes or sex cells)



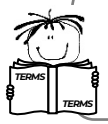
Characteristics of Stem Cells

- They do not have a specific function.
- They have the ability to divide and develop into many different types of cells.
- They can be stimulated to develop into any specialised cell, e.g. muscle cell, bone cell or blood cell.
- They can be used to replace damaged/diseased cells or entire organs.

Sources of Stem Cells

Stem cells may be sourced from embryos or adults:

Embryonic stem cells	Adult stem cells
○ human embryo/ foetus ○ umbilical cord of newborn baby	○ bone marrow ○ skin ○ placenta ○ blood ○ brain ○ teeth



embryo: an early stage in the development of a baby
foetus: a later stage of development when all the baby's tissues have been formed

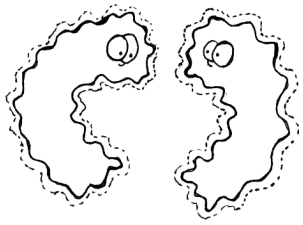
Stem Cell Research

There are exciting developments in the field of stem cell research. Scientists are making significant advances in the use of stem cells to give hope to people suffering from complex injuries or diseases.

- Scientists initially used stem cells from animals and then developed research into human stem cells.
- Human stem cells were first sourced from excess embryos at fertility clinics.
  - the stem cells could be stimulated to transform into any specialised cell
  - although embryonic stem cells are easier to culture, adult stem cells are less controversial
- A bone marrow transplant is very successful where healthy, transplanted stem cells replace damaged cells in cancer patients.
- Stem cells can be engineered to treat conditions like Parkinson's disease, spinal cord injuries, heart disease, diabetes, burns, etc.

Use of Stem Cells

Stem cells harvested from embryos or adults can be preserved and cloned (copied) to be used:

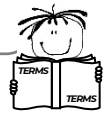


- for research in human development
- to replace damaged tissues and organs – this is called **therapeutic cloning**
- to treat diseases caused by damaged or absent tissues, e.g. develop insulin-producing cells in diabetics
- to form tissues as a future source of food, e.g. grow muscle cells to produce meat

Ethical Issues

Various ethical issues have been raised with regard to stem cell research. There are arguments that oppose and support this research.

ethical issues: problems that require a choice between right (ethical) or wrong (unethical) situations

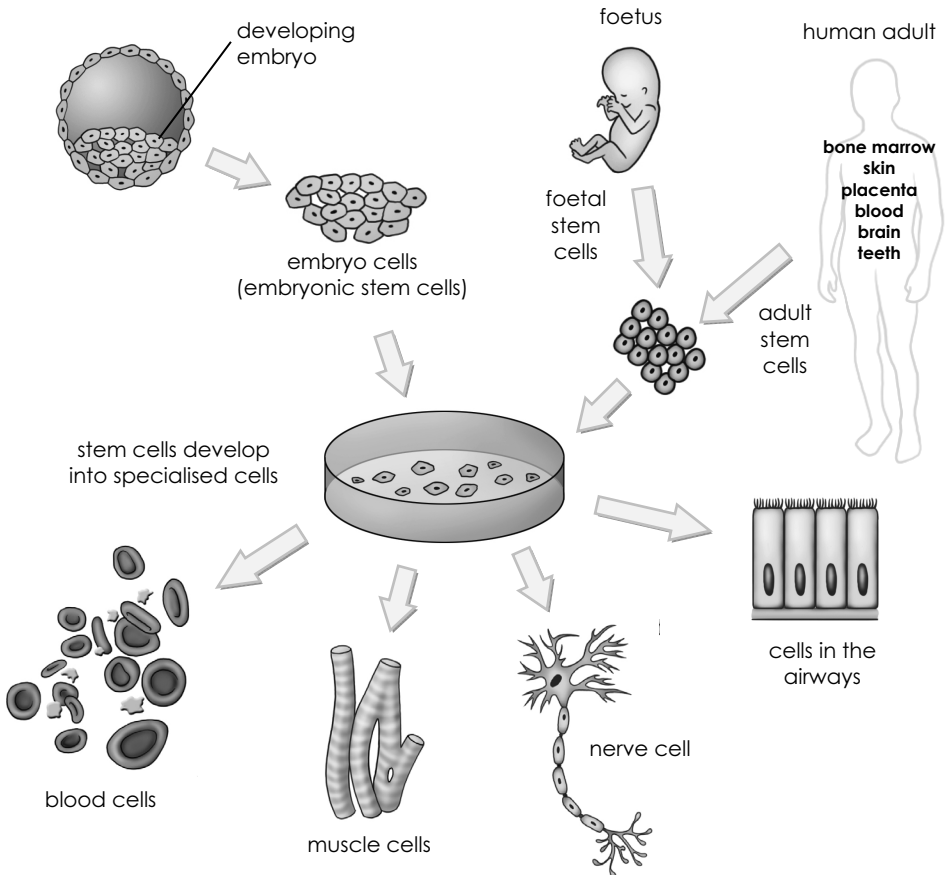


Arguments that oppose stem cell research

- Embryos are destroyed in the process.
- At which stage of the development of an embryo does it become a person?
- Embryos have the potential to develop into a living person with unique characteristics.
- We have a duty to respect the value of human life.
- Do we have the right to create/destroy life or play God?
- Who will regulate the development in research?
- The research involves experimenting on humans without doing proper clinical trials.
- Vulnerable patients may be exploited for experimental stem cell treatment.
- It may be difficult to control the movement and development of stem cells in the body.
- Women may have abortions to sell the embryos for research.

Arguments that support stem cell research

- Spare embryos in a fertility clinic would be destroyed eventually anyway.
- We have a duty to prevent suffering in fellow humans and develop cures.
- Embryos die in miscarriages naturally.
- Life-threatening diseases may be cured using stem cell therapy.
- Adult stem cells may also be harvested and do not result in the death of embryos.
- Stem cells may be harvested from the umbilical cord after the birth of a baby, frozen and stored for future use by the baby or its family.



Sources and specialisation of stem cells

TOPIC 2 SYSTEMS IN THE HUMAN BODY

US 7507: SO 1 – AC 1; SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Identify and describe the different organ systems
- Illustrate the significance of organ systems in the identification of diseases
- Define concepts and principles relating to organ systems
- Apply knowledge and skills to familiar and unfamiliar phenomena

UNIT 1 BODY SYSTEMS: OVERVIEW

You are already familiar with the organisation of life as discussed in Topic 1 Unit 3. *cells* ⇨ *tissues* ⇨ *organs* ⇨ *systems* ⇨ *organism*

The human organism is made up of various **systems** that are fully integrated to maintain a constant balance in the body. Although each system has a distinctly different function, they work together for effective functioning of the body. These systems are responsible to maintain the life processes mentioned in Topic 1 Unit 1.

MAIN BODY SYSTEMS

Digestive system
breaks down food for absorption

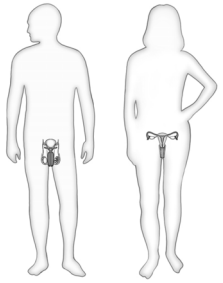
Circulatory system
transports gases, nutrients and waste

Respiratory system
supplies O_2
removes CO_2

Skeletal system **Muscular system**
Musculoskeletal system
support, protection and movement

Excretory system
removes waste and regulates water and salts

Nervous system
receives and responds to stimuli



Reproductive system
enables intercourse, provides sex cells and support for offspring

NOTE

*The muscular and skeletal systems will be studied together as the **musculoskeletal system**.*

NOTE

Other systems not included in this topic include:

***Endocrine system:** hormones*

***Integumentary system:** skin*

***Immune system:** resistance to disease*

In Units 2 - 8 of this Topic, we will look at an **overview** of each of these 7 systems with a focus on:

- the **main processes** – the functions of the organs
- the **main components** – the organs involved
- the **health issues** – the disorders/diseases associated with each system

NOTE

Three systems will be discussed in more detail:

Topic 3: Human Reproduction System

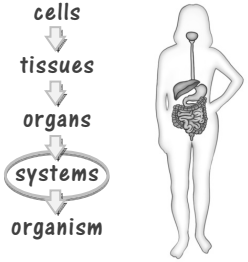
Topic 4: Circulatory and Respiratory Systems

Topic 5: Digestive System

UNIT 2

DIGESTIVE SYSTEM: OVERVIEW

The digestive system involves the intake of food that is broken down into nutrients that can be absorbed into the bloodstream and transported to cells to supply energy; undigested waste is also removed.



Digestive system
breaks down food for absorption

NOTE

*The **Digestive System** is discussed in more detail in **TOPIC 5** on p. 57.*

MAIN PROCESSES

There are four main **processes** that occur in the digestive system:

1. **Ingestion** – the intake of food into the mouth
2. **Digestion** – the breakdown of **large insoluble** molecules into **smaller soluble** molecules that can be absorbed into the bloodstream
   - digestion begins in the mouth with the teeth, tongue and saliva breaking down food
   - digestion also occurs in the stomach and intestines with muscle action and enzymes

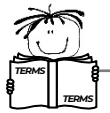
enzymes: special proteins that speed up chemical reactions and aid the breakdown/building up of molecules

large insoluble molecules are broken down in the mouth and gut

into smaller soluble molecules for absorption into the surrounding blood vessels

gut: alimentary canal, particularly stomach and intestines

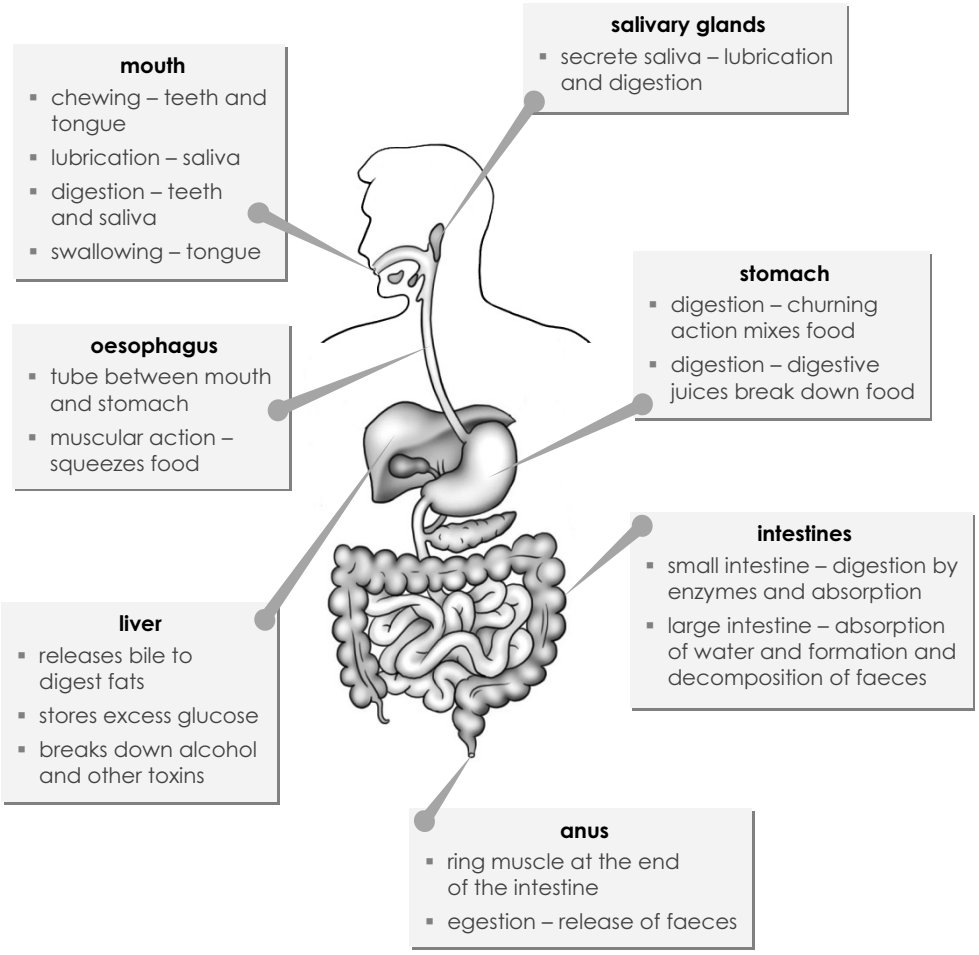
3. **Absorption** – soluble end-products of digestion are transferred from the gut, through the walls, into the surrounding blood vessels for transport to the cells in the rest of the body
4. **Egestion** – undigested food is removed from the body in the form of faeces (stools) via the anus



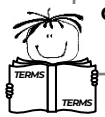
anus: ring-shaped muscle at the end of the gut that controls the removal of faeces from the body

MAIN COMPONENTS

The main **structures** involved in the digestive system are shown in the diagram below. A brief description is provided with each structure.



Main components of the digestive system



decomposition: breakdown or decay of matter

HEALTH ISSUES

Some common **disorders** associated with the digestive system are outlined in the table below:

Health issue	Causes	Symptoms
ulcers painful sores, damaged tissue in the lining of the gut	bacteria, but may be worsened by stress, smoking and drugs	pain and bleeding
anorexia nervosa eating disorder	psychological condition – fear of weight gain	loss of appetite, excess weight loss, obsessive exercising
diarrhoea watery stools (faeces)	viral/bacterial infection, food poisoning, polluted water	watery stools more than 3 times per day, dehydration
liver cirrhosis scarring/hardening of the liver	alcohol abuse, viral infection, liver diseases	yellow skin and tiredness

UNIT 3

CIRCULATORY SYSTEM: OVERVIEW

The circulatory system brings oxygen and nutrients to all body cells and removes waste products like carbon dioxide.

cells → tissues → organs → systems → organism

Circulatory system
transports gases, nutrients and waste

NOTE

*The **Circulatory System** is discussed in more detail in **TOPIC 4** on p. 45.*

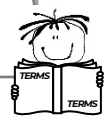
MAIN PROCESSES

The main **function** of the circulatory system is **transport**. It **circulates** blood between the heart, the lungs and all the cells of the body.

Blood is responsible for transporting the following around the body:

- **Oxygen** – absorbed into the blood at the lungs
- **Nutrients and minerals** – absorbed from the digestive system
- **Wastes** – released by the cells of the body during metabolism, e.g. CO_2

metabolism: the total of all chemical reactions in a cell



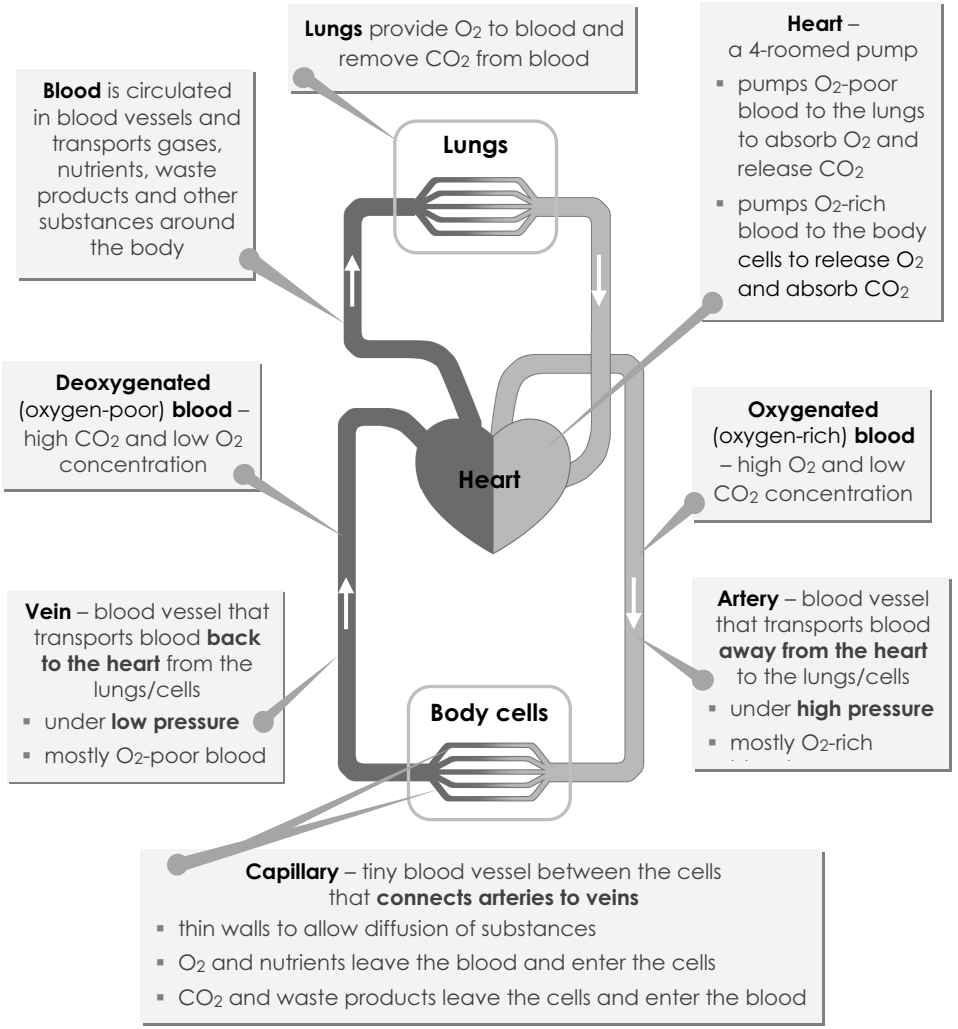
- **Blood cells** – white blood cells fighting infection
  – red blood cells transporting gases
- **Hormones** – secreted by glands and transported to target organs, e.g. insulin, adrenaline
- **Heat** – produced by respiration in the cells and distributed around the body

MAIN COMPONENTS

The main **structures** involved in the circulatory system:

- heart
- blood vessels (arteries, veins, capillaries)
- blood

Heart and Blood Vessels



Overview of the circulatory system

NOTE

*Refer to **TOPIC 4** on p. 45 for details on the structure and functioning of the heart and blood vessels.*

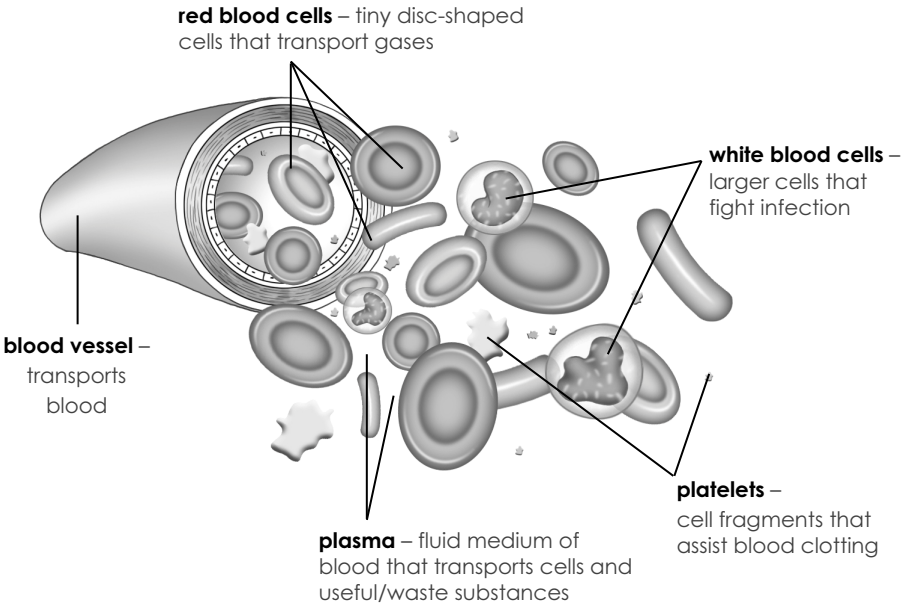
Blood

A fluid in blood vessels that is composed of:

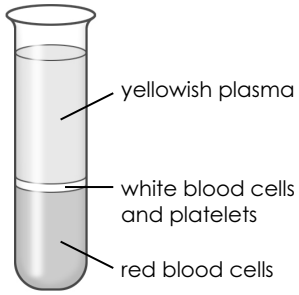
- **Red blood cells**
  - transport O_2 + CO_2
  - contain a red pigment called haemoglobin
- **White blood cells**
  - larger than red blood cells
  - fewer in number
    (1 white blood cell : 500 red blood cells)
  - protects the body by destroying pathogens (disease-causing organisms) or producing antibodies that stop the infection
- **Platelets**
  - cause **clotting of the blood** to stop bleeding
- **Plasma**
  - the **fluid** part of blood
  - the **medium** for the other components of blood
  - transports dissolved substances like salts, minerals, some gases, nutrients and waste products

NOTE

An adult will have about 5 litres of blood and each millilitre contains about 5 billion red cells.



Components of blood

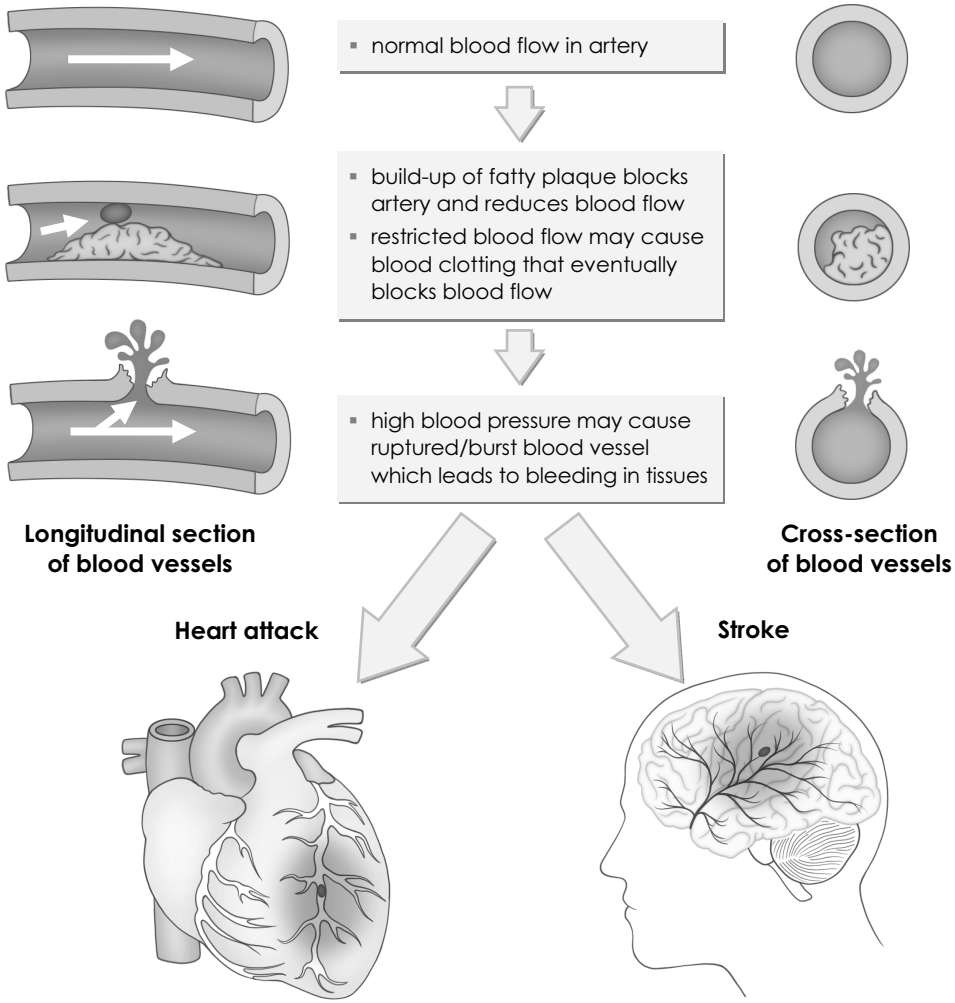


Blood separated to show layers of components

HEALTH ISSUES

The following common **diseases** are associated with the circulatory system:

Health issue	Causes	Symptoms
High blood pressure / hypertension	○ long-term (chronic) condition where the pressure of the blood against the walls of the arteries is abnormally high ○ this causes the heart to work harder and weakens the heart muscle ○ it is known as a 'silent killer' as there are often no symptoms ○ causes may be genetic, but **smoking**, **alcohol abuse**, **obesity** and excessive **salt** intake increase the risk of having high blood pressure	○ headaches, chest pain, shortness of breath, anger, irregular heartbeat, dizziness, blurred vision ○ may cause other conditions associated with the circulatory system such as **strokes** and **heart failure** ○ can lead to **kidney failure**, **vision loss**, **mood disorders/anxiety** and **dementia**
Heart attacks	○ occurs when the **heart muscle** does not receive enough oxygenated blood due to a blockage or a clot and the tissue is damaged	○ symptoms include **chest pain (angina)**, **shortness of breath**, **dizziness** and **tiredness** ○ may result in **cardiac arrest**, where the heart fails to pump blood effectively ○ this may lead to **death** within minutes if untreated
Strokes	○ caused when **blood flow** to a part of the brain is **reduced** leading to cell death and brain damage ○ may be caused by a **blockage** (clot) in the blood vessels or a **burst blood vessel** in the brain ○ high blood pressure is the main cause for strokes	○ symptoms include **paralysis** (often of only one half of the body), weakness, inability to speak or see, or even **death**

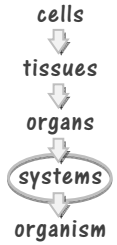


Development of a heart attack and a stroke

UNIT 4

RESPIRATORY SYSTEM: OVERVIEW

The respiratory system is responsible for supplying oxygen to the body cells and for removing carbon dioxide.



Respiratory system

supplies O_2
removes CO_2

NOTE

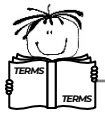
*The **Respiratory System** is discussed in more detail in **TOPIC 4** on p. 51.*

MAIN PROCESSES

NOTE

*It is important that you are able to distinguish between **breathing**, **gaseous exchange** and **respiration**.*

- **Breathing** – the **mechanical process** that moves air in and out of the lungs in the process of **inhalation** and **exhalation**.
- **Gaseous exchange** – the exchange of gases (oxygen and carbon dioxide) across a membrane in the lungs and the cells by **diffusion**.

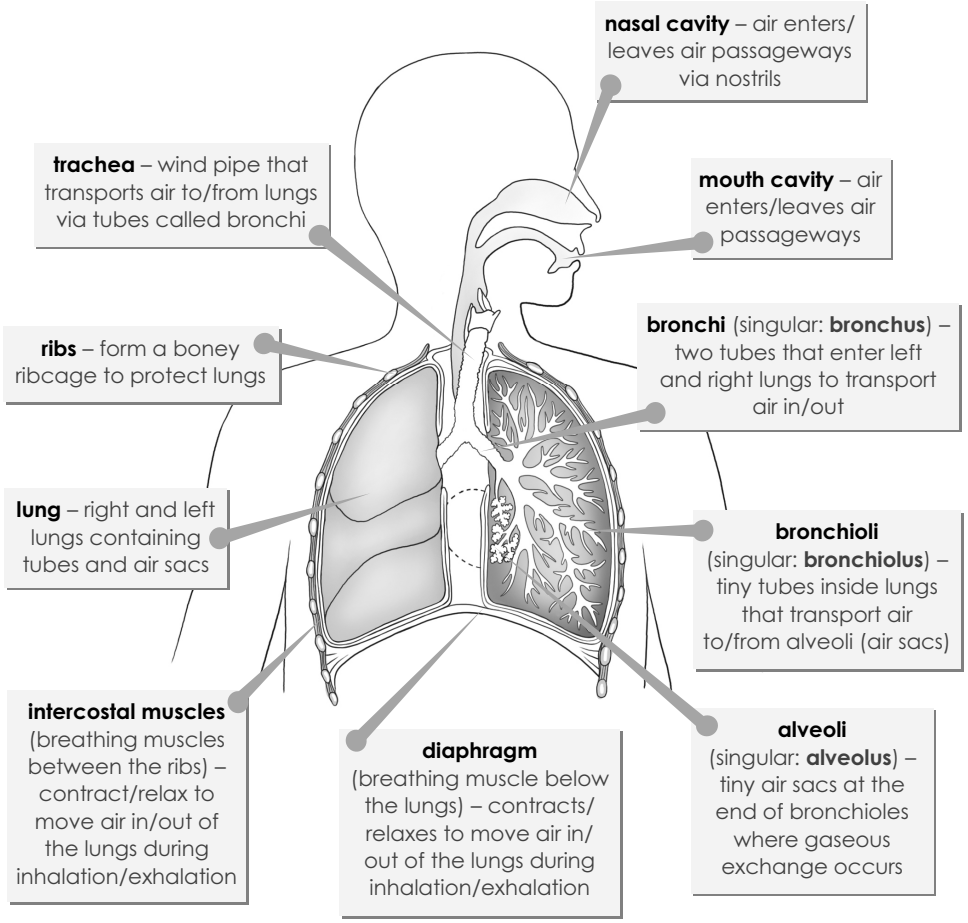


diffusion: the movement of particles from an area of high concentration to an area of low concentration

- **Respiration** – the release of energy, **carbon dioxide** and water from the breakdown of glucose in the presence of **oxygen** in the mitochondria.

MAIN COMPONENTS

The **structures** involved in the respiratory system include the nasal cavity, mouth, trachea and other air passageways, lungs and breathing muscles.



NOTE

*There are expanded notes on each of these structures in **TOPIC 4** on p.45.*

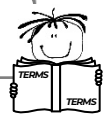
HEALTH ISSUES

The following **diseases** are associated with the respiratory system:

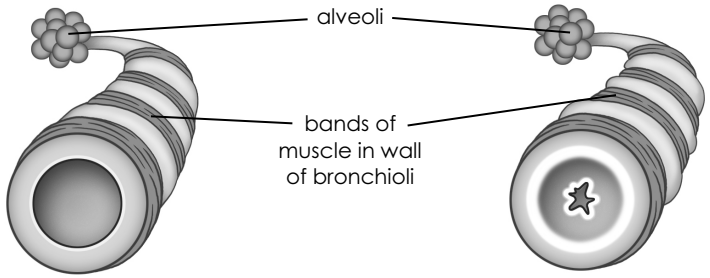
Asthma

- It is caused by the narrowing of the airways due to inflammation of the muscular walls which causes more mucus.
- Symptoms include wheezing, shortness of breath, chest tightness and coughing.
- It may be caused by both genetic and environmental factors.
- Exposure to pollution or allergens (e.g. pollen, animal fur, or dust mites) often trigger or worsen asthma attacks.

allergens: substances that cause an allergic reaction



- Asthma can be treated with inhalers that relax the muscle walls of the airways.



Normal open bronchiole
tube leading to alveolus with relaxed muscles and open airway

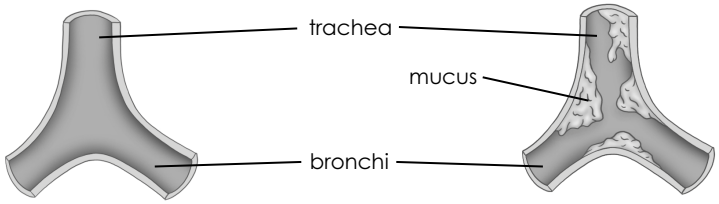
Asthmatic tightened bronchiole
tube leading to alveolus with contracted muscles, tightened, inflamed airways and excess mucus

Lung Cancer

- It is caused by the uncontrolled division of cells in the lungs which form cancerous tumours.
- Smoking is known to trigger the onset of cancers of the respiratory system.
- Symptoms include wheezing, weight loss, pain, shortness of breath and coughing.
- Treatment can include chemotherapy, radiation therapy or surgery to remove the tumours.

Bronchitis

- It is caused by the narrowing of the airways due to infection or long-term smoking.
- Air flow is restricted due to excess mucus and swelling from inflammation.
- Symptoms include a fever, tightness in the chest, shortness of breath and coughing up mucus.



Normal healthy bronchi tubes

Bronchi tubes with bronchitis

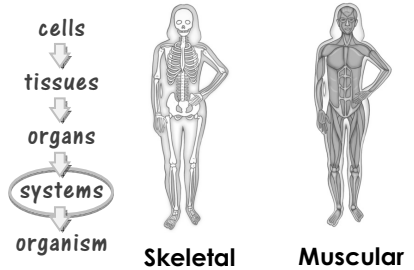
Asbestosis

- Asbestos was a common building material as fireproofing until the health hazards became known.
- People exposed to asbestos without safety masks may inhale the tiny fibres into the lungs.
- Asbestos fibres cause scarring in the lungs and shortness of breath which can result in respiratory failure.

UNIT 5

MUSCULOSKELETAL SYSTEM: OVERVIEW

The adult human skeleton consists of 206 bones. The skeleton protects and supports the body and enables movement through the action of muscles attached to the bones.



NOTE

*The muscular and skeletal systems will be studied together as the **musculoskeletal system**.*

MAIN PROCESSES

The **functions** of the musculoskeletal system include:

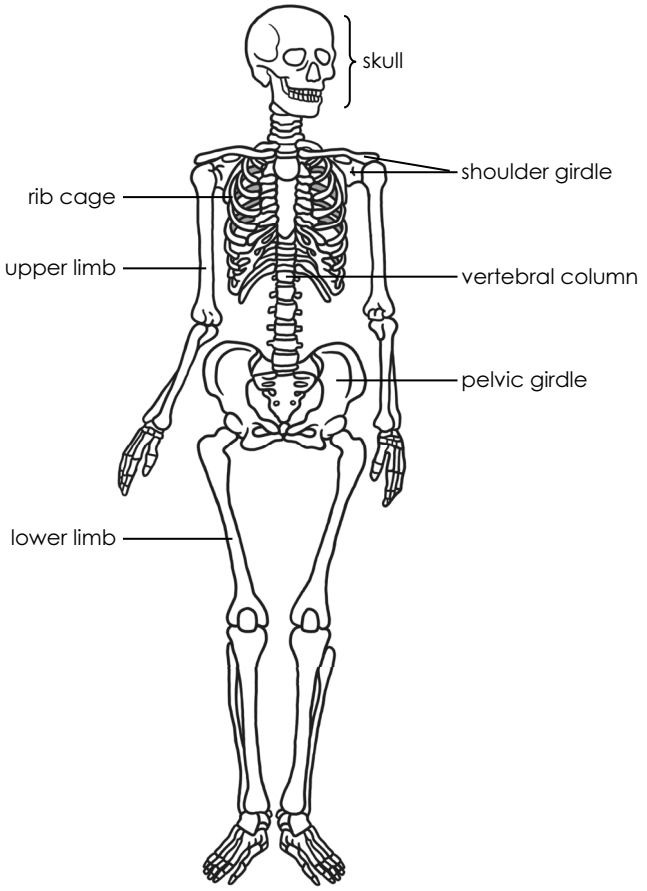
- **Contraction/relaxation of muscles**
  - muscle fibres contract (shorten) and relax (lengthen) to bring about movement
- **Movement and locomotion**
  - some muscles cause movement of the skeleton as they are attached to bones, enabling locomotion, e.g. walking
  - other muscles cause movement in inner organs, e.g. stomach, intestines, heart, or bladder to control movement of substances
- **Storage**
  - bones store minerals like calcium and phosphorus
- **Blood cell production**
  - red blood cells, most white blood cells and platelets are made in bone marrow
- **Protection and support**
  - parts of the skeleton protect organs, e.g.: skull (brain), ribcage (heart/lungs), vertebrae (spinal cord)

MAIN COMPONENTS

There are 5 **tissues** that compose the musculoskeletal system:

1. **Bone**

   Bone is a hard tissue containing many minerals like calcium and phosphorus.



Main components of the human skeleton

NOTE

The individual labels of the bones of the skeleton will be covered in detail in the Grade 10 Life Sciences curriculum.

2 Muscle

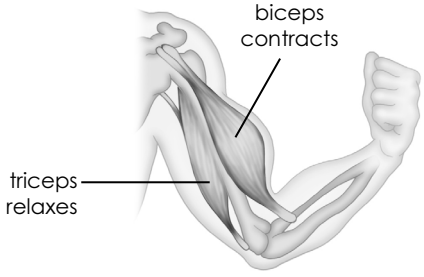
Muscle tissue consists of muscle fibres that are elastic and made predominantly of protein.

There are three types of muscle:

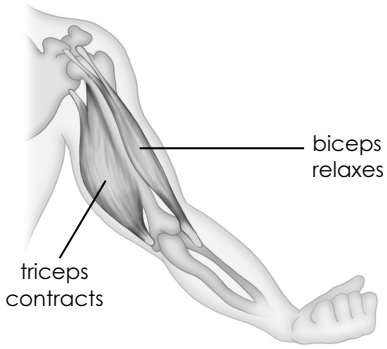
- **smooth muscles:** for involuntary movement of internal organs, such as peristalsis in the intestines
- **cardiac muscles:** for involuntary movement of the heart
- **skeletal muscle:** for voluntary movement of the skeleton

Skeletal muscles are paired and work **antagonistically**.

antagonistic muscles: muscles that work in opposition to each another; as one contracts, the other relaxes and vice versa



Antagonistic muscle action in **bending the arm**



Antagonistic muscle action in **extending the arm**

3 Cartilage

Cartilage is tough fibrous tissue that lines the ends of bones. Cartilage contains a protein called collagen that makes it strong and flexible. It reduces the friction between bones in a joint.

4 Tendons

Tendons are bands of tough, inelastic fibrous tissue that connects muscle to bone.

5 Ligaments

Ligaments are bands of tough, fibrous tissue that connect bone to bone. They have more elastic fibres to allow more flexibility in a joint.

joint: formed where bones meet and are joined by ligaments to allow for movement; the ends of the bones in a joint are covered in cartilage to prevent friction

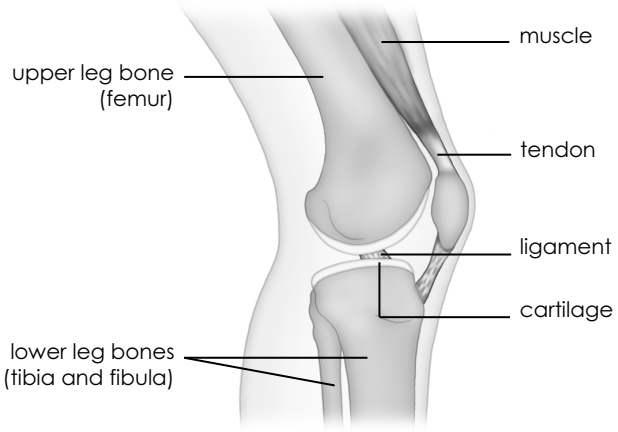


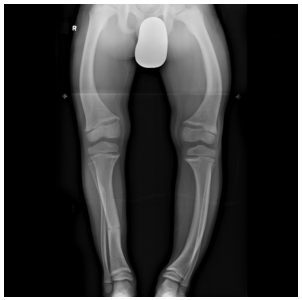
Diagram of a knee joint

HEALTH ISSUES

The following **diseases** are associated with the musculoskeletal system:

Rickets

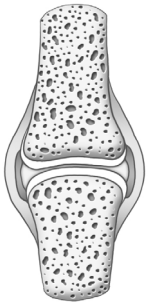
- It is a deficiency disease caused by a lack of calcium and vitamin D.
- It causes bones to soften and become weak.
- It affects the shape and development of legs, arms and pelvis of young children.



X-ray of bones affected by rickets

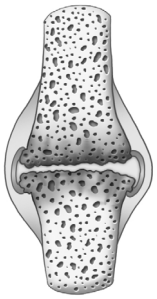
Arthritis

- Condition that occurs when the cartilage between two bones wears down and becomes thin.
- Friction between the two bones causes pain, swelling and inflammation.
- It causes deformity of joints and difficulty in movement.
- It affects mainly older people.



Normal joint

Normal hand

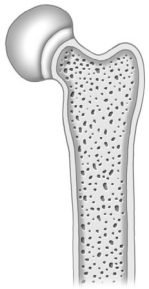


Arthritis joint

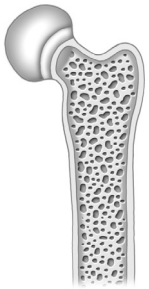
Arthritis hand

Osteoporosis

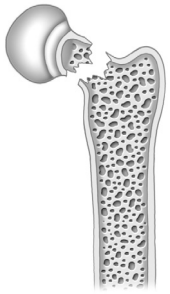
- This condition causes bones to become spongy and fragile, resulting in low bone density.
- These brittle bones increase the risk of fractures.
- It is caused by a lack of calcium and vitamin D in the diet.
- It occurs mainly in older people.



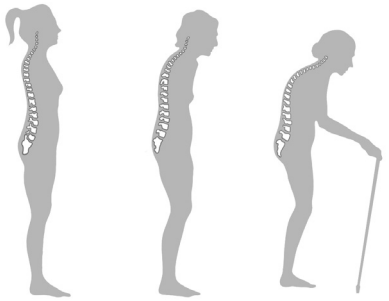
Normal bone



Osteoporosis bone



Broken osteoporosis bone

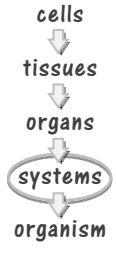


Posture changes due to osteoporosis and ageing

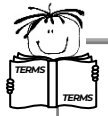
UNIT 6

EXCRETORY SYSTEM: OVERVIEW

- **Excretion** is a process that results in the removal of **metabolic waste** from an organism.



Excretory system
removes waste and regulates water and salts



metabolism: all the chemical reactions in a cell, e.g. respiration, protein synthesis, etc.

- **Metabolic waste** is substances produced by cells that are harmful to the organism if they accumulate.
- The main waste products are CO_2, excess water, salts and urea.
- CO_2 is removed by the lungs.
- Most of the other waste is excreted in urine via the kidneys.

NOTE

Faeces contain some metabolic waste, but is mostly undigested waste. The removal of faeces is known as egestion.

MAIN PROCESSES

There are three main processes involved in excretion:

- **filtration** of blood to form the filtrate
- **reabsorption** of useful substances back into the bloodstream
- **secretion** of additional waste in the blood into the filtrate

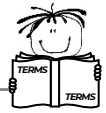
Filtration

- Waste products are carried by the blood into the kidneys.
- The kidneys filter the blood and waste products, salts, certain nutrients and water from the blood move into the kidney tubules to form a liquid called the **filtrate**.
- This filtrate will eventually form **urine** after useful substances are reabsorbed back into the blood.

Reabsorption

- Some of the substances filtered out of the blood into the kidney tubules are useful to the body.
- Useful substances, e.g. nutrients like glucose, vitamins and amino acids and also salts form part of the filtrate.
- Most useful substances (nutrients, necessary salts and water) are reabsorbed from the filtrate back into the blood by the process of **diffusion**.

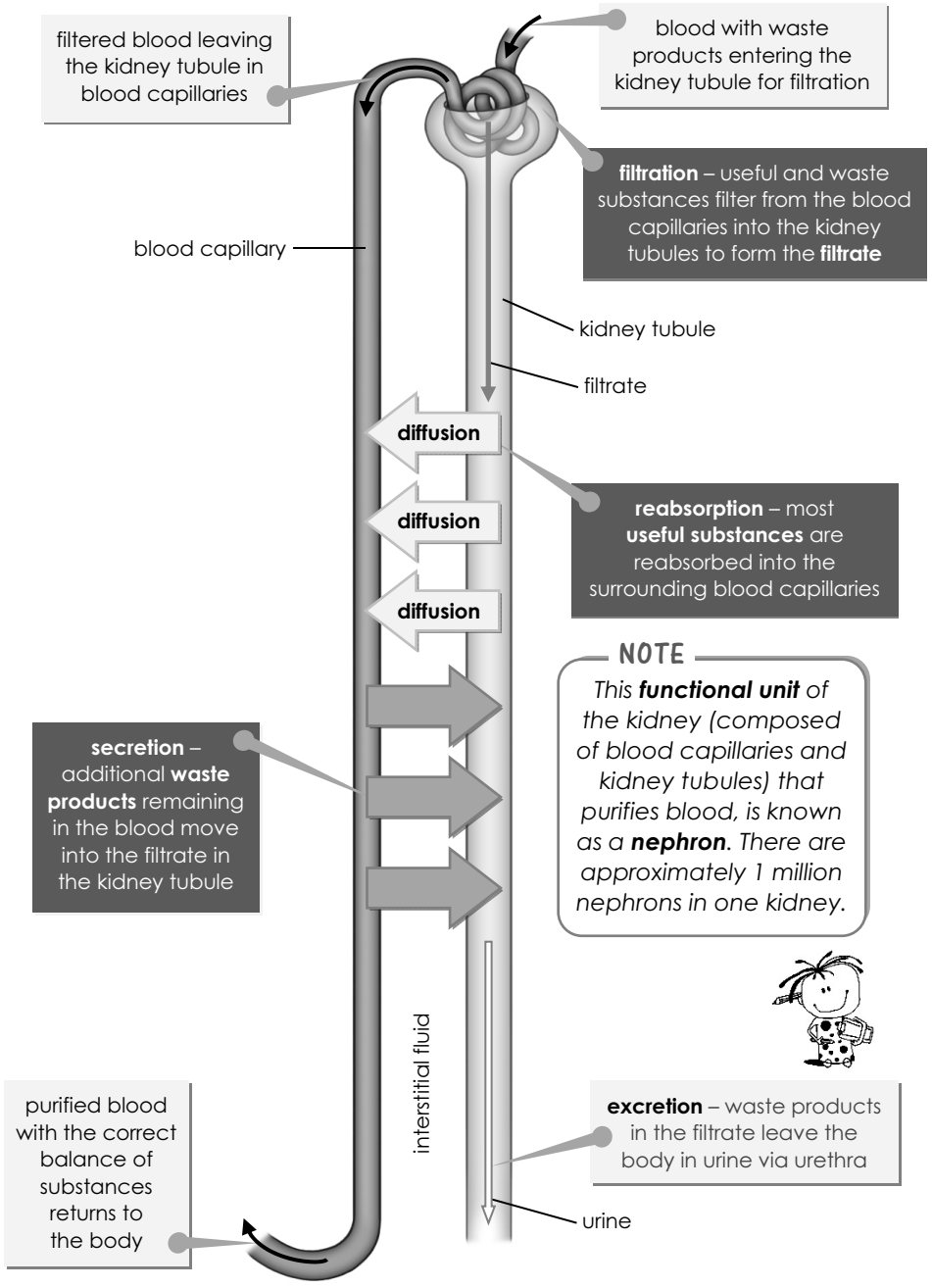
> **diffusion:** a process where particles move from an area of **high concentration** to an area of **low concentration** until they are evenly distributed; no energy is required



- Hormones control the amount of water reabsorbed back into the blood from the filtrate. This controls the water balance of our bodies and is known as **osmoregulation**.

Secretion

- Some waste products are still present in the blood after filtration.
- These waste products in the blood are added to the filtrate in the kidney tubules.



Simplified diagram to show processes of excretion in the kidney tubules

Excretion

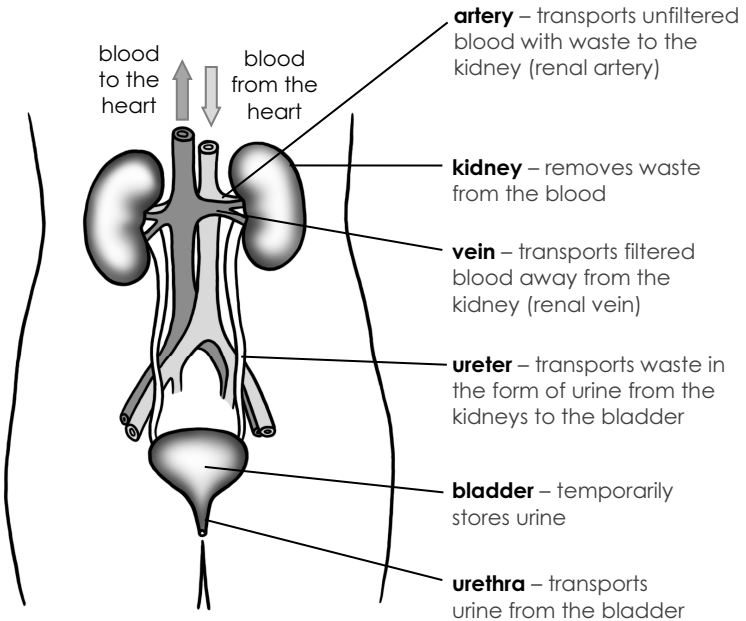
- The concentrated filtrate containing waste products eventually forms urine.
- Urine passes out of the kidney via the ureters to the bladder for storage.
- Once the urine reaches a certain level in the bladder, the increase in pressure triggers the urge to urinate.
- Metabolic waste leaves the body in urine via the urethra during urination. This is known as **excretion**.
- Urination is controlled by a ring muscle (sphincter) at the base of the bladder.

NOTE

The filtered blood that leaves the kidneys is purified and has balanced levels of useful substances.

MAIN COMPONENTS

The following **structures** play an important role in excretion: kidneys, ureters, bladder, urethra.



Excretory system in humans

HEALTH ISSUES

The following **diseases** are associated with the excretory system:

Kidney (Renal) Failure

- Renal failure is a state where the kidney is so damaged that it can no longer function.
- This can be due to an injury, complications after surgery, a drug overdose or the overuse of certain painkillers.
- Medical conditions like diabetes and high blood pressure can also cause kidney failure
- In renal failure, toxic waste products and excess water accumulate in the blood and may cause death.
- A person suffering from renal failure can be kept alive by dialysis or should otherwise undergo a kidney transplant.

***Dialysis** is a process whereby blood is artificially purified using a kidney machine.*

The patient's blood is filtered through a dialysis machine (artificial kidney) and purified blood is returned to the patient's body.

Treatment varies from a few hours per week to daily dialysis.

Bladder Infection (Cystitis)

- The urethra is open to the exterior, so it is easy for **bacteria** to enter and cause infection.
- The symptoms of bladder infections are lower abdominal pain, difficulty or burning urination, cloudy urine, and frequent urination.
- There may also be other symptoms of infection like **fever** and **nausea**.
- Bladder infections can be treated with **antibiotics**.
- Women are more likely to have bladder infections due to a shorter urethra which opens closer to the anus.

Kidney Stones

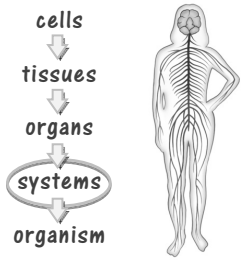
- Wastes and salts (calcium and uric acid) that form part of urine are dissolved in water.
- Solid crystals, known as kidney stones, form when these minerals do not dissolve properly due to insufficient water.
- Kidney stones occur more commonly in men and in people with obesity/high blood pressure/poor diet with low water intake.
- Large kidney stones can block the ureter, leading to severe pain in the side, lower abdomen and groin.
- Blood can occur in the urine due to damage to the urinary tubes.
- Other symptoms include: cloudy urine, difficulty urinating, nausea and vomiting.
- The kidney stones can be broken up by ultrasound waves and then excreted in the urine.
- Kidney stones that are too large are usually removed surgically.

UNIT 7

NERVOUS SYSTEM: OVERVIEW

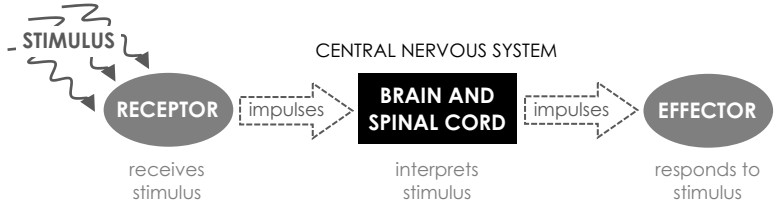
The nervous system enables survival by performing the following functions:

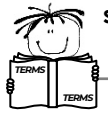
- **sensing** changes in our environment
- **interpreting** what these changes mean
- **responding** to the changes appropriately



Nervous system
receives and responds to stimuli

MAIN PROCESSES





stimulus: (plural: stimuli) a change in the environment that causes a response

Senses – receives stimuli and send impulses to the brain and spinal cord

The nervous system receives stimuli from the environment through our senses.

Sense	Organ	Stimulus
hearing	ear	sound
seeing	eye	light
touch	skin	mechanical
taste	taste bud	chemical
smell	olfactory organ in the nose	chemical

Although these are the main five senses, our nervous system senses many other stimuli, including balance and acceleration, temperature, pressure, pain and many chemical or physical changes that occur internally.

NOTE

Some animals have the ability to sense stimuli that humans cannot. Some fish and sharks can detect electric fields; many migratory birds can detect the Earth's magnetic field; certain snakes can detect an infra-red heat signature given off by nearby animals.

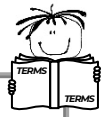
- Sense organs contain specialised cells to receive the stimuli called **receptors**.
- These receptors convert stimuli to **nerve impulses**.
- The nerve impulses are sent to the brain and/or spinal cord via **neurons** (nerve cells).

Interpretation – receives impulses from sense organs

- The brain makes sense of (interprets) the information received via impulses from the sense organs.
- It can associate meaning to the information received and provide understanding of the changes in the environment.

Response – sends impulses from the brain and spinal cord (central nervous system) to **effectors**

- The information received from the sense organs **(receptors)** via impulses may need a response.
- The brain or spinal cord sends impulses to the **effectors** (muscles or a gland).



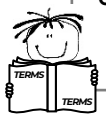
effectors: organs that respond to stimuli, e.g. muscles or glands

- Some responses are automatic and very rapid, these are known as **reflexes**.

EXAMPLE

THERMOREGULATION

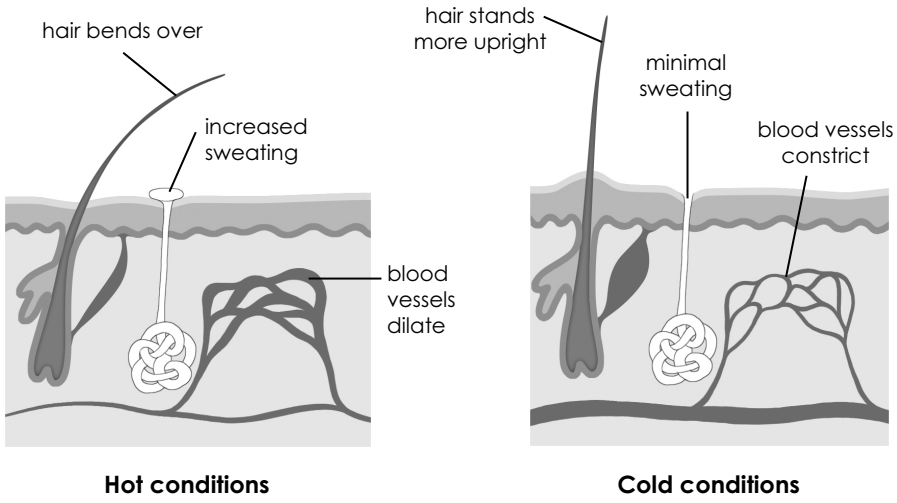
*The nervous system controls the internal body temperature of animals that keep their temperature constant – known as **endotherms**.*



endotherms: animals that are not affected by environmental temperature and maintain a constant body temperature, e.g. mammals

In hot conditions:

- *The brain detects the temperature increase in the skin.*
- *The blood vessels in the skin dilate (widen) – heat is lost through radiation as more blood flows nearer to the surface of the skin.*
- *The sweat glands are stimulated to produce sweat and the body cools due to evaporation.*
- *The body temperature decreases and returns to normal.*



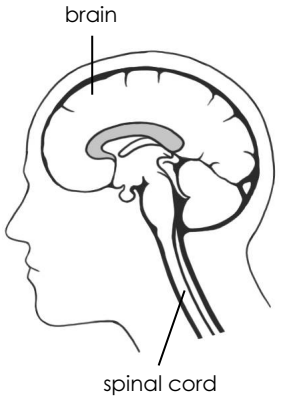
Hot conditions **Cold conditions**

In cold conditions, the opposite occurs and the body temperature increases and returns to normal.

MAIN COMPONENTS

All parts of the nervous system consist of specialised nerve cells called **neurons**.

The main **structures** in the nervous system:



Brain – part of the central nervous system

- processes and **interprets** information from the sense organs
- co-ordinates the appropriate **response**

Spinal Cord – part of the central nervous system

- responsible for triggering **reflexes**
- transmits impulses from the **receptors** to the brain
- transmits impulses from the brain to the **effectors** (muscles/glands)

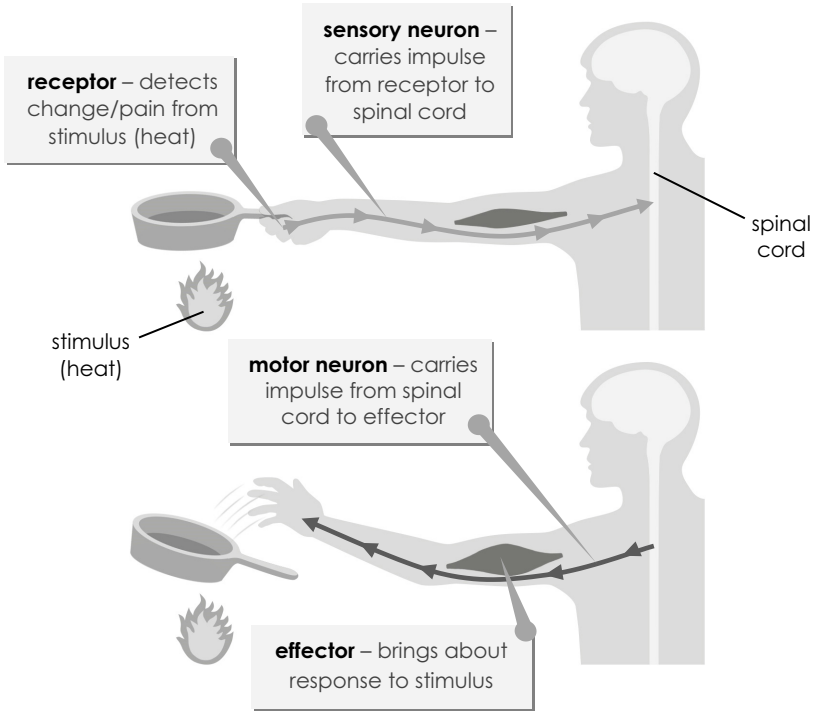
Nerve

- contains nerve cells/**neurons**
- transmits messages **via impulses** from the **receptors** in the sense organs to the spinal cord or brain
- transmits impulses from the spinal cord or brain to the appropriate **effectors** (muscles or glands)

Sense Organs (Receptors)

- ear – hearing
- eye – sight
- skin – touch and temperature, pressure and pain
- tongue – taste
- nose – smell

The nerve impulse pathway is summarised in the diagram below showing a reflex action.



Pathway of nerve impulses in a reflex action

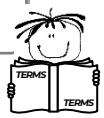
HEALTH ISSUES

There are many **conditions** that affect different components of the nervous system. Some of these include:

Deafness

- It includes partial or total loss of hearing.
- It is caused by damage or disease in the ear, brain or associated nerves.
- Treatment depends on the cause of deafness, but may include using hearing aids or cochlear implants.

cochlea: a part of the inner ear where sound is converted into a nerve impulse



Blindness

- It involves the loss of sight.
- It is caused by damage or disease in the eye, brain or associated nerves.
- Treatment depends on the cause of blindness, but it would usually involve surgery, such as a cornea or lens transplant.

Short-sightedness

- It is the inability to see distant objects clearly.
  - a person who is short sighted (has **myopia**) can only see nearby objects clearly
  - caused by an elongated eyeball or irregular shaped lens
- Treatment may include laser surgery, glasses or contact lenses.

NOTE

These conditions can also be genetic, i.e. passed from one generation to the next.

Effects of Drugs and Alcohol on the Brain

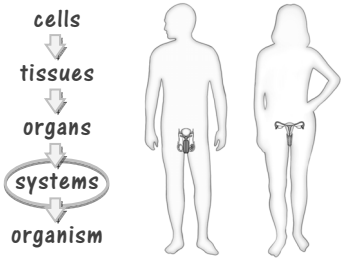
- Drugs and alcohol affect the transmission of impulses from neuron (nerve cell) to neuron within the brain.
- **Stimulants** ('uppers') cause impulses to travel faster and excite the central nervous system.
  - increased alertness, heart rate and feelings of joy (a 'high')
  - highly addictive substances
  - e.g. nicotine, caffeine, cocaine, ecstasy
- **Depressants** ('downers') cause impulses to slow down.
  - causes sedation, decreased heart rate, relaxation and anaesthesia (numbness to pain)
  - highly addictive substances
  - e.g. alcohol, heroin, sleeping tablets

Most drugs create a false sense of well-being, and gradually destroy fragile nerve tissue which can cause permanent damage, e.g. memory loss, personality disorders or ultimately death over time.

UNIT 8

REPRODUCTIVE SYSTEM: OVERVIEW

The reproductive system produces sex cells (**gametes**) for fertilisation and to ensure the continuation of the species.



Reproductive system
provides sex cells and support for offspring

NOTE

*Human Reproduction is discussed in more detail in **TOPIC 3** on p. 35.*

MAIN PROCESSES

The terms involved in the main processes of reproduction are:

- **growth** – increase in size and number of cells
- **cell division** – multiplication of cells for growth
- **maturation** – development of male and female individuals to sexual maturity
- **copulation** – sexual intercourse
- **ejaculation** – release of liquid semen (containing sperm/male gametes) from penis

semen: the fluid released by various glands in the male reproductive system that contains sperm

- **ovulation** – release of female gamete (ovum/egg cell) from ovary
- **menstruation** – shedding of the uterus lining every 28 days
- **fertilisation** – fusion of gametes (ovum and sperm) to form a zygote (fertilised ovum)
- **implantation** – ball of cells sinks into lining of uterus (womb) in pregnancy

These terms are discussed in more detail in TOPIC 3 on p.35, but are summarised in the flow diagram on the next page.

NOTE

Use the diagrams on p. 33 to understand the processes illustrated below. These processes will be discussed in more detail in TOPIC 3 on p. 35.

♂ = male ♀ = female

THE MAIN PROCESSES INVOLVED IN HUMAN REPRODUCTION

♂ *sperm production in testes*

Copulation

The male penis is inserted into the female vagina in sexual intercourse

stimulates

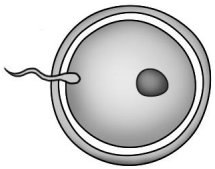
♂ **Ejaculation**

Semen containing sperm cells is released from the urethra of the penis into the vagina

sperm swims to Fallopian tube ♂

♂♀ **Fertilisation**

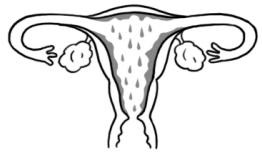
A male sperm fuses with a female ovum in the Fallopian tube to form a zygote



if fertilisation does not occur

♀ **Menstruation**

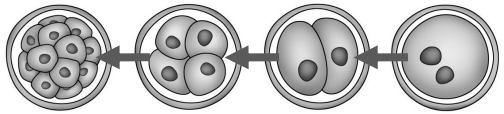
Part of the lining of the uterus (including the unfertilised ovum) is discharged via the vagina



ball of cells moves along Fallopian tube to the uterus

in ♀ **Cell division**

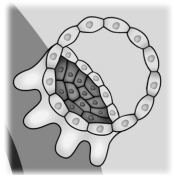
The fertilised ovum (zygote) divides repeatedly to form a ball of cells



pregnancy (gestation)

in ♀ **Implantation**

Ball of cells embeds into the wall of the uterus resulting in pregnancy



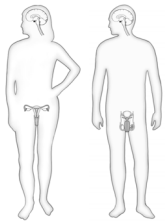
pregnancy (gestation)

in ♀ **Growth**

Cells continue to divide, and differentiate, causing an increase in size and complexity in the developing embryo

♂ OR ♀ **Maturation**

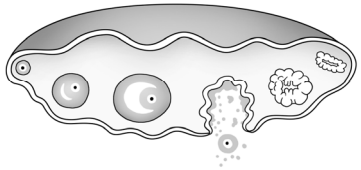
Birth occurs after 40 weeks. Growth continues for 15-20 years through puberty until individuals are sexually mature and able to reproduce



♀ *ovum production in ovaries*

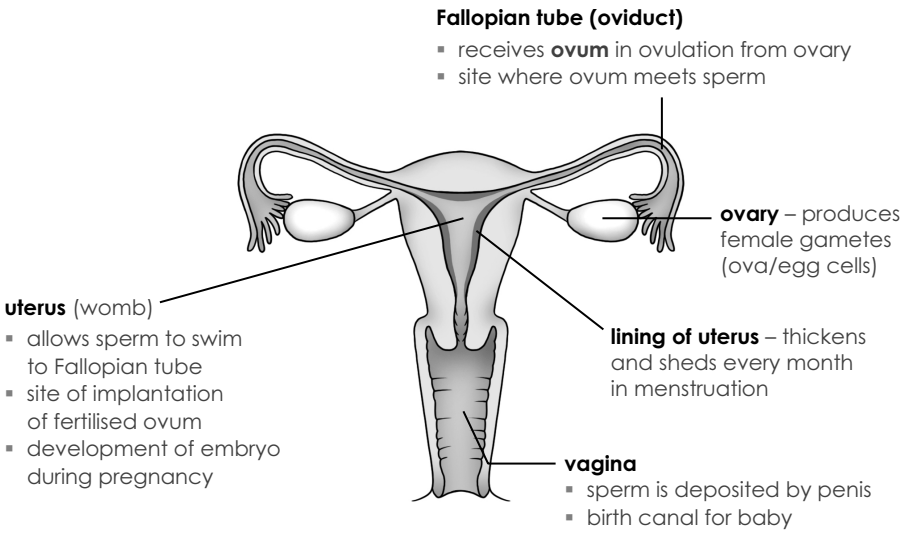
♀ **Ovulation**

An ovum is released once a month from an ovary into the Fallopian tube

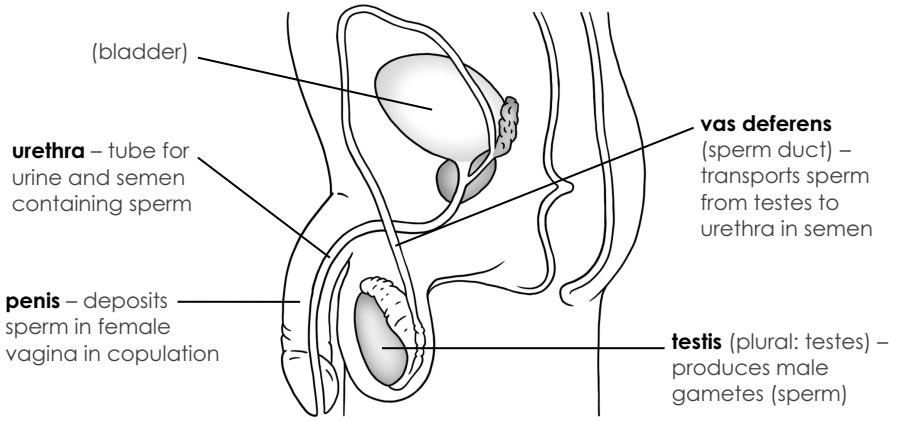


♀ *ovum released*

MAIN COMPONENTS



Front view of the female reproductive system



Side view of the male reproductive system

HEALTH ISSUES

Infertility

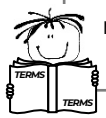
- It is the inability of a person to reproduce naturally.
- Infertility may be due to abnormalities in the male or in the female.

Male infertility

- Males may be infertile due to a low sperm count, where there are too few healthy sperm cells.
- Some of the factors that decrease sperm counts in males include:
  - increased age
  - smoking
  - stress
  - poor diet
  - excessive exposure of testes to heat (e.g. bathing, sauna, using a laptop on the lap)
  - damage to the testes (e.g. diseases like mumps and malaria or activities like cycling)

Female infertility

- Common causes of female infertility:
  - disruption to the menstrual cycle preventing ovulation or implantation
  - damage to the ovary, blocked Fallopian tubes or uterus (often caused by STDs)
  - hormonal imbalances during early pregnancy



STDs: sexually transmitted diseases that affect the reproductive system and other parts of the body

- Treatment may include hormone supplements, medication and lifestyle changes.

Foetal Alcohol Syndrome (FAS)

- Foetal alcohol syndrome is a condition that may occur in a baby when the mother drinks too much alcohol during pregnancy.
- Alcohol passes from the blood of the mother to the **foetus**, and affects development.
- Problems may include:
  - short stature
  - low birth weight
  - small head
  - poor coordination
  - low intelligence and learning disabilities
  - behavior problems
  - hearing or seeing difficulties

foetus: an embryo that has developed all the main tissues at about 8 weeks old

Sexually Transmitted Diseases (STDs)

NOTE

***STDs** are sometimes called **STIs** (sexually transmitted infections). An STI is a general term for all sexually transmitted infections that may or may not develop into a disease (STD).*

- Sexually transmitted diseases (STDs) can affect the sex partners, foetus, and newborn infant.
- STDs are transmitted via semen/sperm, vaginal fluid, saliva or blood.
- STDs can be grouped into three categories according to their symptoms:

Inflammatory diseases

STDs that produce inflammation of the **internal** parts of the sex organs.

- **Gonorrhoea** and **chlamydia** are the most common bacterial STDs that cause inflammation.

NOTE

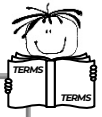
***Bacterial** infections are treated with **antibiotics**.*

***Viral** diseases may be treated with **antiviral drugs**.*

- These diseases can be treated and cured with antibiotics, but they may not show symptoms.
- Women with these infections are often infertile due to damage to the reproductive organs.

Skin lesion causing diseases

STDs that produce lesions (growths) on the **external** sex organs (genitals).



skin lesions: abnormal growths on the skin, e.g. warts, blisters or open wounds

- **Herpes** is the most common viral disease in this category.
  - symptoms can be treated with antiviral drugs
  - these infections cannot be cured
- **Syphilis** is a bacterial infection and can lead to death.
  - it is curable with **antibiotics**
- **HPV** (human papilloma virus) is incurable and causes warts on the genitals.

genitals: the external structures of the sex organs

  - it is the leading cause of cervical cancer in women

Diseases that affect other organ systems

Viral diseases that affect organ systems other than those of the reproductive system.

- e.g. Hepatitis and HIV.
- Both diseases can be spread by the exchange of sexual fluids or blood.
- HIV may lead to AIDS.

NOTE

*STDs are also discussed under **Contraception and Population Control** on p. 44.*

- ARVs (anti-retroviral drugs) slow the progress of the disease, but do not cure it.
- Infectious individuals may appear symptom-free for years and thus pass on the disease unknowingly.

TOPIC 3 HUMAN REPRODUCTION

US 7507: SO 5 – AC 1-2
US 7508: SO 1 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 3 – AC 1-3; SO 4 – AC 1-3
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Understand and illustrate the effect of harmful chemicals on the foetus
- Understand and illustrate the usefulness of contraceptive methods
- Formulate a scientific hypothesis
- Define concepts and principles relating to the reproductive system
- Implement a plan to investigate a phenomenon or problem
- Gather and interpret relevant data
- Explain and describe the impact of harmful chemicals and contraceptives on the quality of life

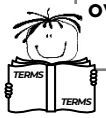
UNIT 1 PURPOSE OF REPRODUCTION AND PUBERTY

THE PURPOSE OF REPRODUCTION

- Reproduction is the biological process where new individuals (offspring) are made by existing individuals (parents).
- Reproduction ensures the continuation of a species to prevent extinction.
- Reproduction can produce new generations by:
  - asexual reproduction
  - sexual reproduction

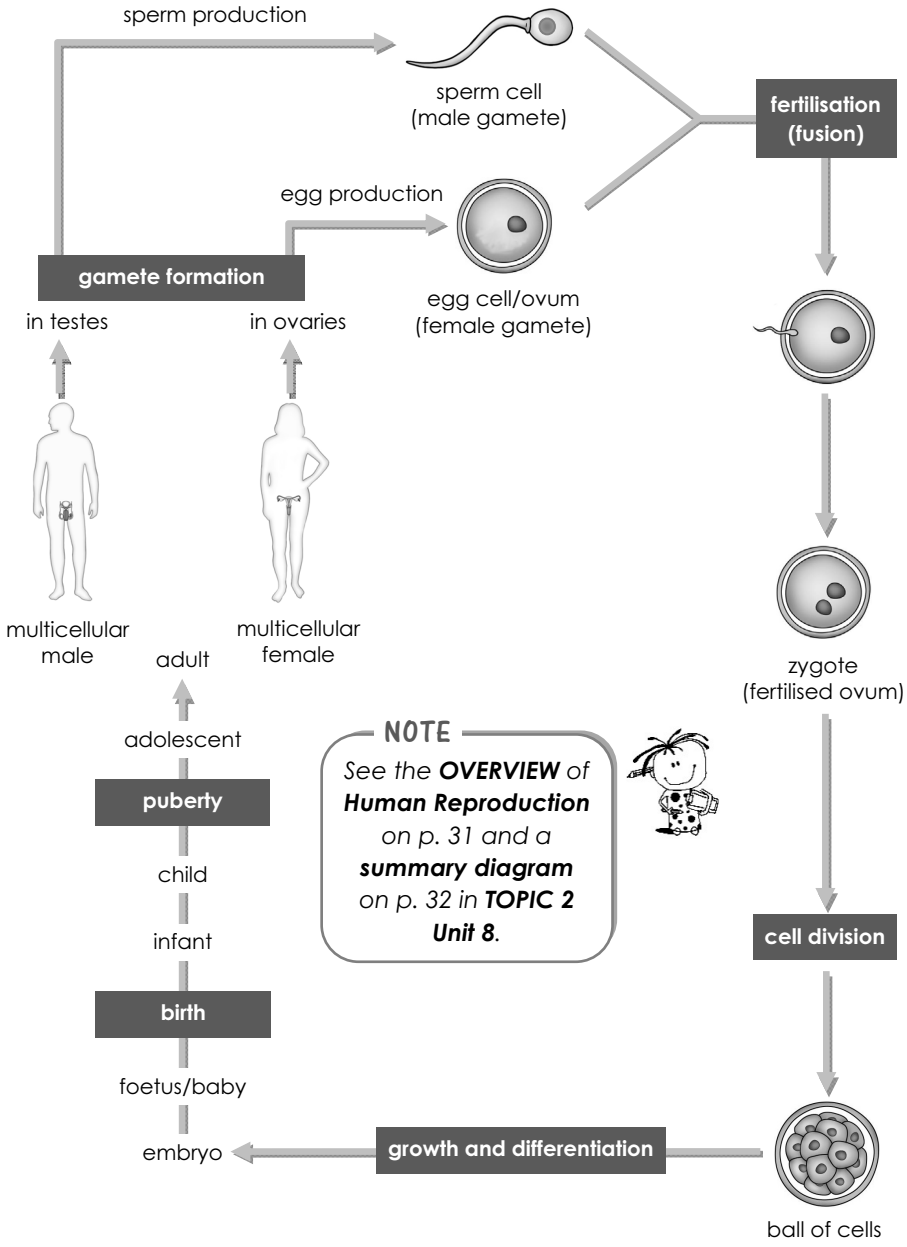
asexual reproduction: **one parent** makes an **identical copy** of itself to produce offspring (e.g. bacteria multiplying)

- **Sexual reproduction** occurs when offspring are produced due to the genetic contribution of two **different parents** (e.g. all animals).
- In sexual reproduction new individuals are produced by the **fusion of gametes** (sex cells).
- In humans, **sperm cells** are male gametes, **egg cells (ova)** are female gametes.



ovum = singular
ova = plural

- The main purpose of sexual reproduction is to create **variation** in the offspring due to the fusion of different gametes. Variation is essential for survival of a species in a changing environment.



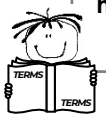
Summary of structures, stages and processes in human reproduction

NOTE

*See the **OVERVIEW** of **Human Reproduction** on p. 31 and a **summary diagram** on p. 32 in **TOPIC 2 Unit 8**.*

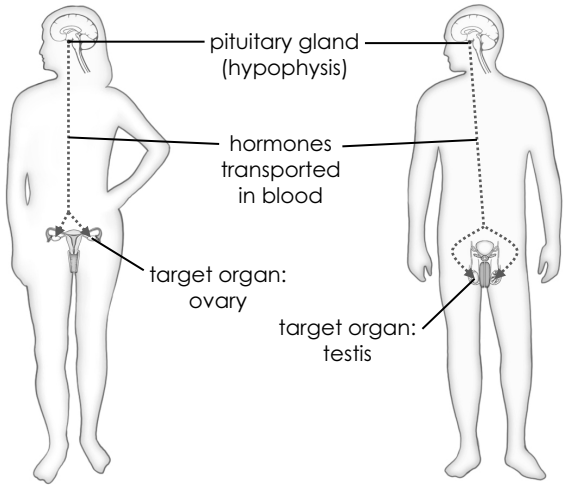
PUBERTY

- Puberty is the stage in the human life cycle when the sex organs mature for reproduction.
- It occurs at about 11 – 15 years in girls and 12 – 16 years in boys.
- It is a process controlled by different **hormones**.



hormones: chemical messengers produced by glands that trigger changes in cells, tissues or organs in other parts of the body

- The process of puberty is initiated when the **pituitary gland** (hypophysis) in the brain releases hormones into the bloodstream, stimulating the testes and ovaries to release sex hormones.
- Male testes produce **testosterone**.
- Female ovaries produce **oestrogen**.
- These hormones stimulate **target organs** and cause the development of **secondary sexual characteristics** during puberty.
- These characteristics further differentiate males and females and indicate sexual maturity.



Puberty in Boys

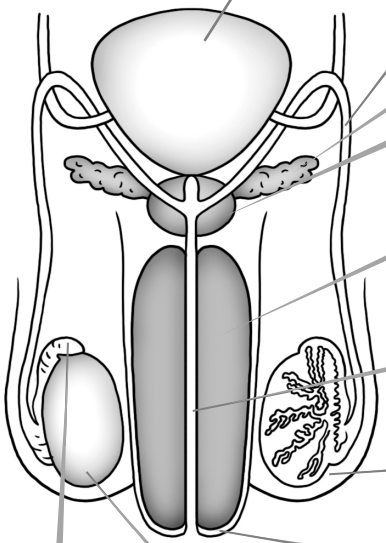
- **Testosterone** (from the **testes**) causes the development of the following secondary sexual characteristics:
  - growth spurt
  - increased muscle mass
  - a deeper voice
  - enlargement of the genitals (penis and testes)
  - production of sperm in the testes
  - sexual drive
  - increased production of sweat
  - increase in facial and body hair, e.g. moustache, beard, chest hair, underarm and pubic hair, longer leg hairs
  - wider shoulders
  - more oily skin (may develop acne)
  - behavioural changes, e.g. mood swings, emotional outbreaks and changed sleeping patterns

Puberty in Girls

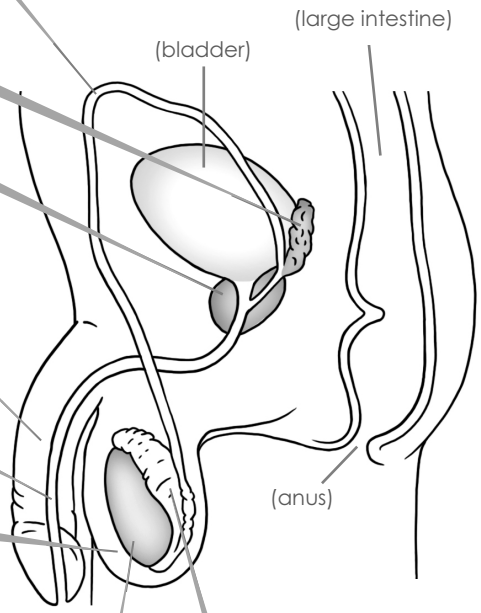
- **Oestrogen** (from the **ovaries**) cause the development of the following secondary sexual characteristics:
  - growth spurt
  - increase in fat deposited below the skin
  - widening of the hips
  - development of breast tissue
  - production of ova (egg cells) in the ovaries
  - ovulation (release of ova from the ovary)
  - start of menstruation
  - growth of body hair, e.g. underarm and pubic hair
  - more oily skin (may develop acne)
  - behavioural changes, e.g. mood swings, emotional outbreaks and changed sleeping patterns

REPRODUCTIVE ORGANS

Male reproductive organs (front view)



Male reproductive organs (side view)



vas deferens / sperm duct
- transports sperm cells from the epididymis of the testis to the urethra
- muscular walls contract to propel semen under pressure

seminal vesicle
prostate gland

glands that produce a milky semen with:
- nutrients to give sperm energy
- alkaline medium to protect sperm
- chemicals to stimulate movement of sperm

penis
- consists of specialised tissue that fills with blood so that the penis becomes firm and erect
- erect penis may be inserted into the female vagina to release semen which contains sperm

urethra
- transports semen from the vas deferens to the outside
- common pathway for semen and urine

scrotum
- a skin sac that suspends the testes outside the body
- keeps the testes at the optimum temperature for sperm development

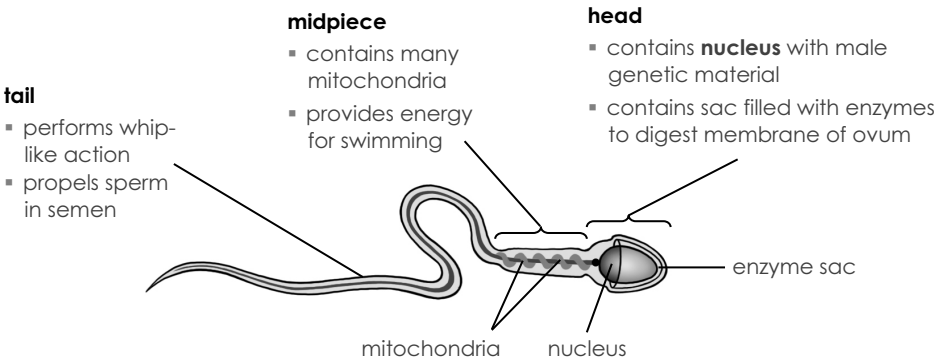
foreskin
- protective skin covering sensitive head of penis (glans penis)
- may be surgically removed in circumcision

testis
- produces sperm cells
- produces hormone called testosterone

epididymis
- stores sperm cells until they are mature

testis = singular
testes = plural

STRUCTURE OF SPERM CELL



Structure of male sperm cell

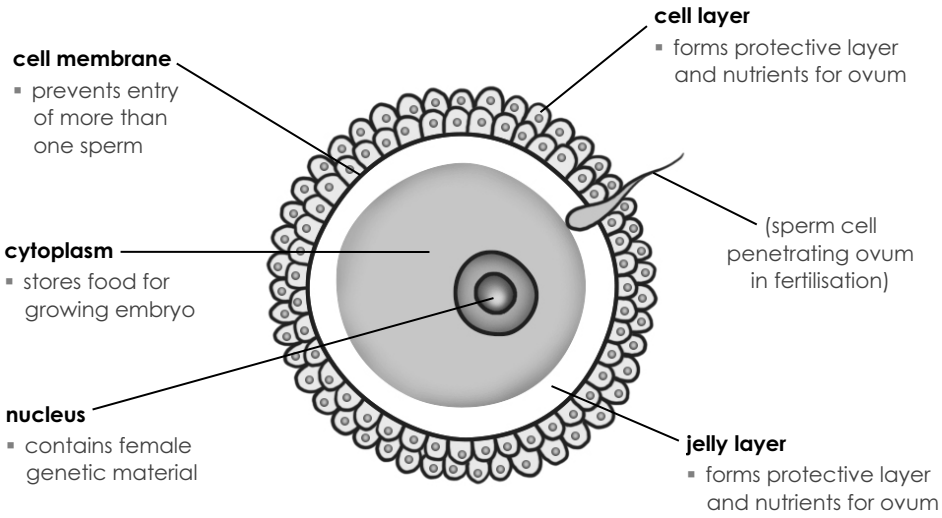
The male gamete is the **sperm cell**.

Sperm is:

- formed in the male testes
- constantly produced by cell division
- microscopic in size (0,05 mm)
- composed of 3 parts:
  - **head**
  - **midpiece**
  - **tail**
- stored in the epididymis on top of the testes until absorbed or released
- transported in semen
  - semen is a milky fluid
  - produced by glands (seminal vesicles and prostate)
  - released from the body in ejaculation

Millions of sperm are produced each day by the male testes from puberty to 70+ years old.

STRUCTURE OF OVUM (EGG CELL)



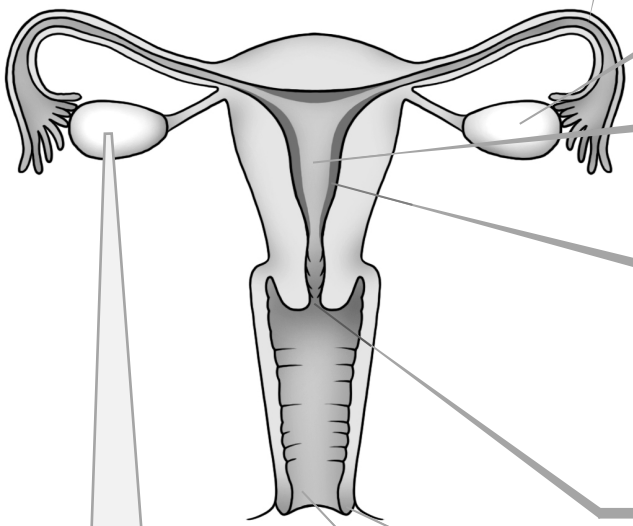
Structure of ovum (egg cell)

The female gamete is the **ovum** (egg cell).

An ovum is:

- formed in the female ovary
- produced by cell division every 28 days by alternate ovaries
- one of the largest human cells and visible to the human eye (0,1 mm)
- composed of basic cell structures and surrounded by:
  - a protective layer of jelly
  - layers of cells for nutrition
- released from the ovary in a process called **ovulation**
- drawn into the **Fallopian tube** and moved towards the **uterus** by little hairs (cilia)

Female reproductive organs (front view)



Fallopian tube (oviduct)
- transports the ovum from the ovary to the uterus
- site of fertilisation where the sperm cell fuses with the ovum

ovary
- produces and releases ova/egg cells
- produces the female sex hormones: oestrogen and progesterone

uterus
- site of development of embryo/ foetus until birth
- inner lining thickens every 28 days in preparation for possible implantation

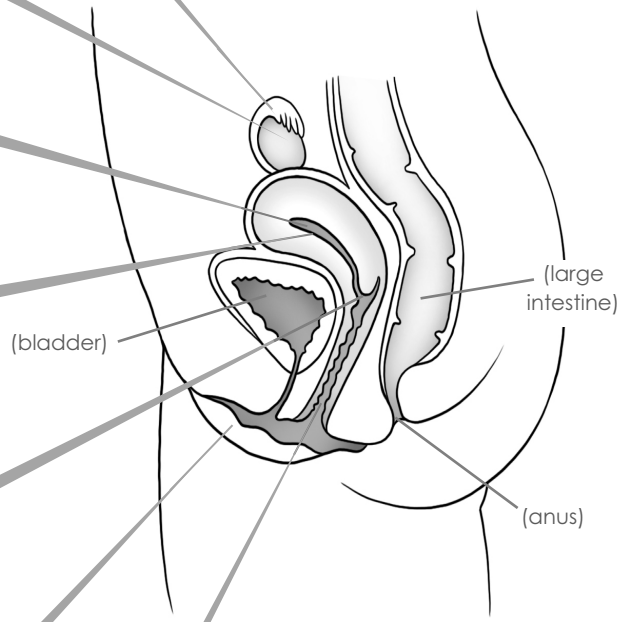
uterine lining (endometrium)
- thickens every month in preparation for implantation of a fertilised ovum
- thickened layer is shed in **menstruation** if implantation doesn't occur

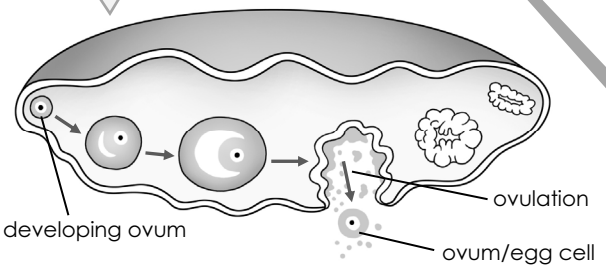
cervix
- the 'neck' of the uterus that leads to the vagina
- it secretes fluid to keep vagina moist
- it widens (dilates) during childbirth

vulva
- external female sex organs
- includes folds of tissue, glands and opening of vagina

vagina
- has muscular walls that can stretch and a protective mucous layer
- receives the penis during intercourse
- serves as the birth canal

Female reproductive organs (side view)





Section through ovary

UNIT 3

STAGES OF REPRODUCTION

NOTE

See p. 32 ***TOPIC 2 Unit 8*** *for an overview of the* ***main processes*** *involved in these stages.*

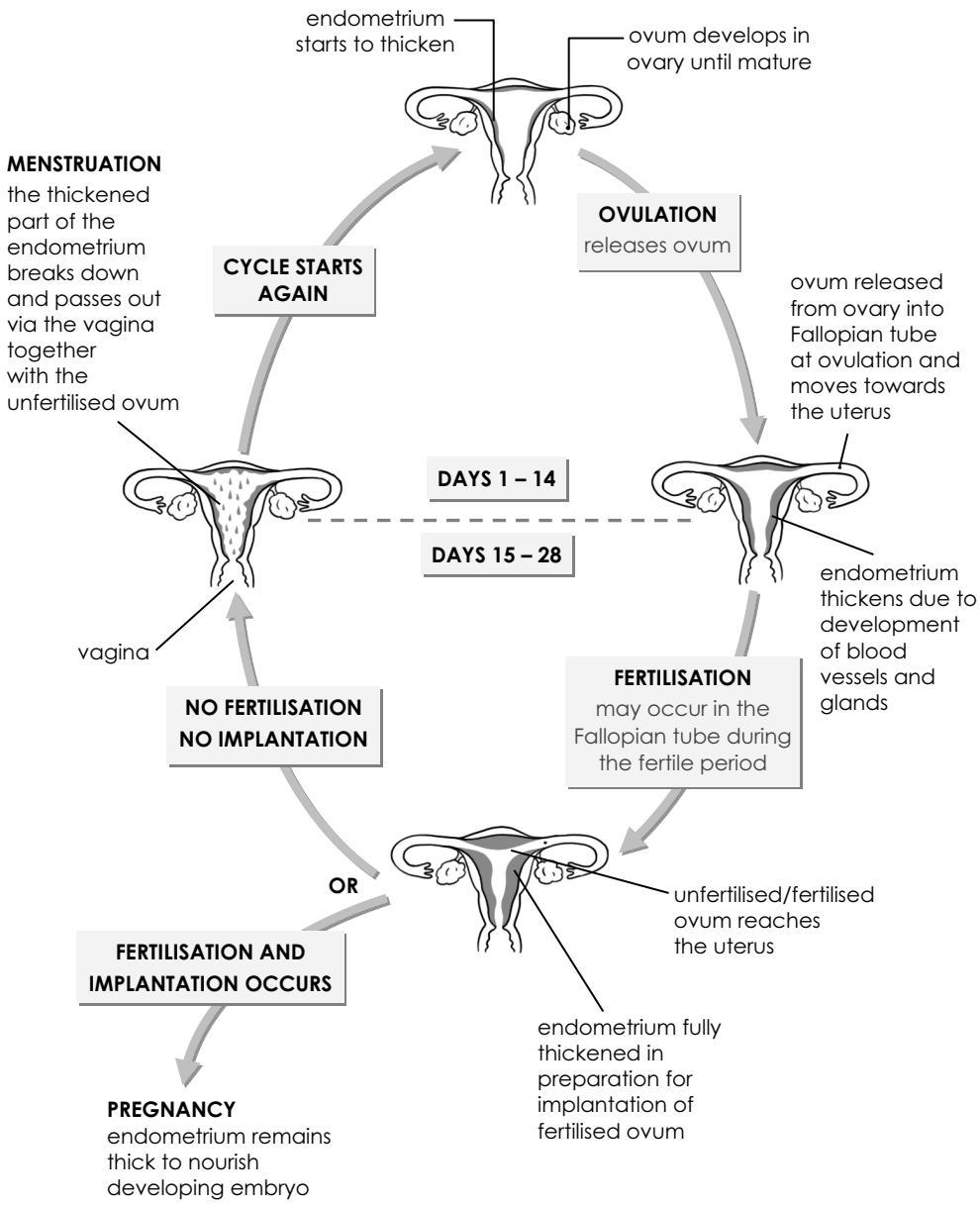
THE MENSTRUAL CYCLE

- During puberty, one of the ovaries releases a ripe (mature) ovum into the Fallopian tube in a process called **ovulation** every month.
- In preparation for the implantation of a fertilised ovum, the **endometrium** (inner lining of the uterus) thickens and becomes rich with blood vessels.
- If fertilisation does not take place, then **menstruation** occurs.
- Menstruation is the breakdown of the inner, thickened lining of the uterus, which is released via the vagina out of the body.
- This shedding of blood and endometrium tissue called menstruation (a period) usually lasts for 2 to 8 days.
- The **menstrual cycle** is the time period between menstruation events. It is usually a 28 day cycle.

NOTE

The length of a menstrual cycle may vary from 21 to 35 days. The length of menstruation also varies from 2 to 8 days.

- After ovulation, the ovum has 24 hours for fertilisation to occur before it degenerates (dies).
- Sperm cells are able to survive up to 5 days in the female reproductive system.
- This results in a window of about 6 days during the cycle where a female is fertile and pregnancy may occur. This period of 6 days around ovulation is known as the **fertile period** in the menstrual cycle.
- The menstrual cycle stops when pregnancy occurs as the endometrium remains thick to maintain the implanted, developing embryo.



Changes that occur during a menstruation cycle

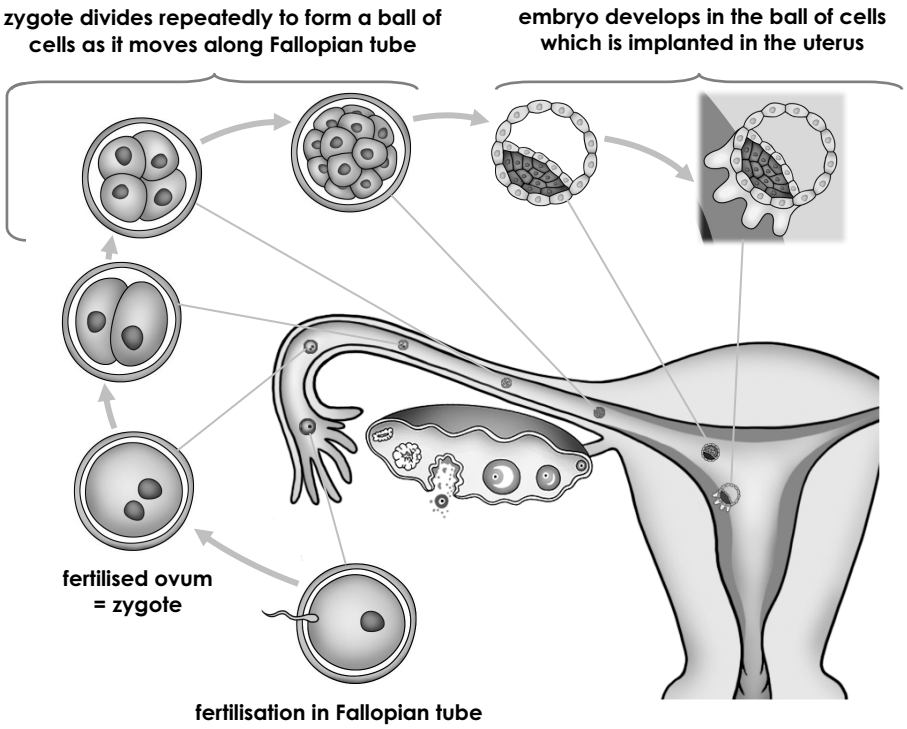
COPULATION

- Copulation is the process of **sexual intercourse**.
- When a man is sexually aroused, the tissue in the penis fills with blood, becomes firm and enlarged to create an **erection**.
- In **copulation** the erect penis is placed inside the female vagina and mechanical stimulation results in the release of semen.
- The release of semen from the male urethra is known as **ejaculation**.

During each ejaculation, approximately one teaspoon of semen is released, containing about 500 million sperm cells.

FERTILISATION

- The sperm are deposited at the cervix during copulation.
- Sperm enter the cervix and swim through the uterus to enter the Fallopian tubes.
- If ovulation occurs, the ovum is released into the Fallopian tube. A large number of sperm surround the ovum and attach to it.
- The sperm releases enzymes (from the sac on the head) that digest the outer jelly layer of the ovum.
- Once a sperm cell penetrates the ovum, the cell membrane of the ovum becomes impenetrable to other sperm.
- The nucleus of the sperm cell fuses with the nucleus of the ovum. This process is known as **fertilisation**.
- This fertilised ovum is now called a **zygote**. It contains the DNA of both male and female parents.

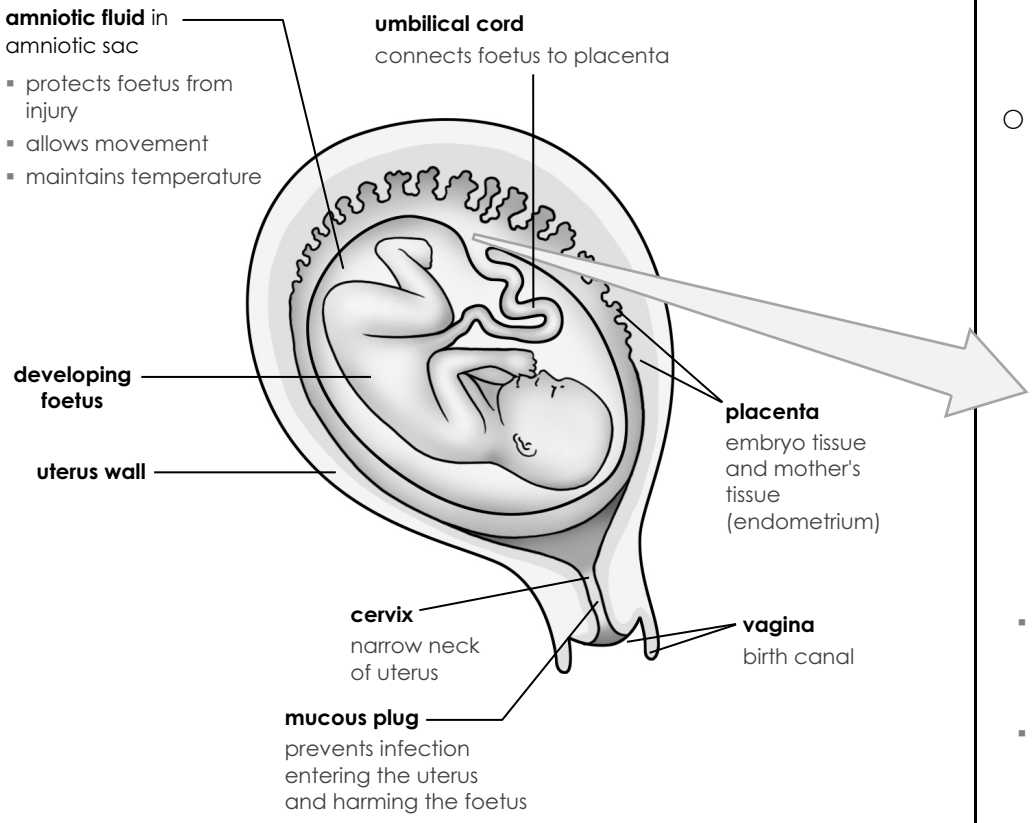


IMPLANTATION AND THE PLACENTA

- The fertilised ovum moves through the Fallopian tube into the uterus with the help of tiny hairs called cilia.
- It divides over and over again to produce a ball of cells which will eventually form the embryo.
- The developing embryo lands on the thickened endometrium, attaches and sinks into the lining. This is **implantation** and it results in **pregnancy**.
- The placenta forms between the embryo and the uterus. It is a combination of embryo tissue and the mother's tissue.
- The umbilical cord connects the embryo to the placenta.
- The placenta provides the embryo with nutrients (e.g. glucose) and oxygen and also acts like a filter to protect it from pathogens (harmful microorganisms).
- It also removes waste products (e.g. CO_2 and urea) from the embryo.

PREGNANCY (GESTATION)

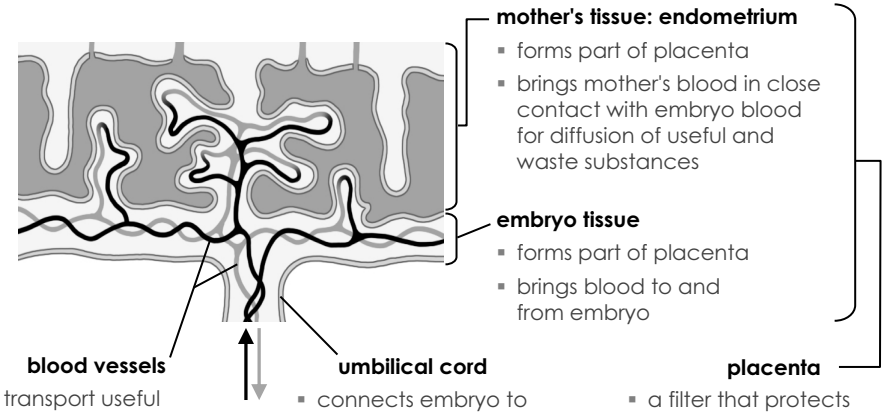
- Pregnancy in humans (gestation) is about 40 weeks.
- It is the time period from fertilisation until birth.
- The embryo grows and develops and after 8 weeks it is known as a **foetus** as all the specialised tissues have formed.
- The embryo is surrounded by the **amniotic sac** filled with **amniotic fluid** which protects the embryo from shocks, maintains constant temperature and allows free movement.
- Pregnancy ends when the uterus contracts to push the fully developed foetus out through the cervix and vagina in a process known as childbirth.



Section through uterus to show developing foetus

ROLE OF THE PLACENTA IN PROTECTING THE FOETUS

- The placenta plays an important role in providing the foetus with oxygen and nutrients and removing carbon dioxide and waste products.
- The placenta allows the transfer of antibodies to the developing baby
  - a pregnant woman has antibodies for most microorganisms to which she is exposed
  - these antibodies are transferred to her baby via the placenta to create a custom-made, protective immunity before birth
- If the mother is exposed to harmful substances (alcohol, tobacco, drugs) during pregnancy, they filter through the placenta and cause irreparable damage to the developing baby.
- HIV/AIDS virus is small enough to pass through the placenta to the foetus:
  - babies born to HIV-positive mothers may be infected with this virus
  - HIV-positive babies need to be treated with ARVs (antiretroviral drugs)
- German measles is caused by a virus that can bypass the placenta, infect the foetus and cause serious heart defects, blindness, deafness and other serious conditions.



Structure of placenta

EFFECTS OF ALCOHOL, SMOKING AND DRUG ABUSE ON THE FOETUS

- A pregnant woman may expose her baby to harmful toxins.
- The placenta acts as a filter to protect the foetus from pathogens or chemicals that may occur in the mother's blood.

NOTE

See p. 42 for more detail on the role of the placenta in protecting the foetus from harmful substances.

- The placenta ensures that the mother's blood never mixes with the foetal blood so there is no direct contact and the foetus is protected from most infections and toxins.

Alcohol

- A pregnant woman who drinks alcohol risks harming her baby.
- A baby exposed to alcohol during pregnancy may develop foetal alcohol syndrome (FAS).
- FAS characteristics are irreversible and include:
  - permanent brain damage
  - low birth weight
  - birth defects
  - learning problems
  - poor memory
  - behavioural problems

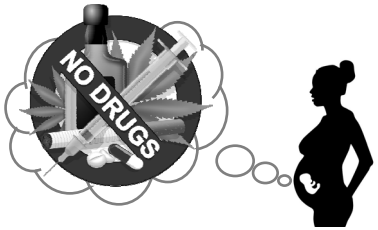
Sadly, South Africa has the highest incidence of FAS (foetal alcohol syndrome) in the world. It is particularly common in farming communities, but may affect any woman who consumes alcohol during pregnancy. The government is implementing education programs in schools to create awareness of the dangers of alcohol use during pregnancy. It is a preventable disease and statistics show that educated children make different choices as adults when they know the lifelong consequences of exposing a baby to alcohol before birth.

Smoking

- A pregnant woman who smokes exposes her baby to health risks that include:
  - lower oxygen supply to foetus which restricts normal development, particularly the nervous system
  - increased risk of premature birth
  - low birth weight
  - increased risk of birth defects and death of newborn baby
  - higher incidence of future obesity
  - higher risk of learning difficulties

Drug Abuse

- A pregnant woman who abuses drugs exposes her baby to harmful chemicals that affect normal growth and development.
- Tik (*crystal meth*), heroin and other drugs harm the developing foetus:
  - damage to the foetus is permanent
  - the nervous system i.e. brain development is particularly affected
  - a miscarriage (spontaneous abortion) may occur
- A baby born to a woman addicted to drugs may be born with the same addiction and require medical care to withdraw.
- A pregnant woman who abuses drugs may also increase the risk of passing on infectious diseases due to high risk behaviour, e.g. unprotected sex, using infected needles and multiple partners.



CONTRACEPTION AND POPULATION CONTROL

Conception is when a sperm fertilises an ovum so **contraception** means preventing conception/fertilisation.

NOTE

See p. 34 for more information on STDs.

NOTE

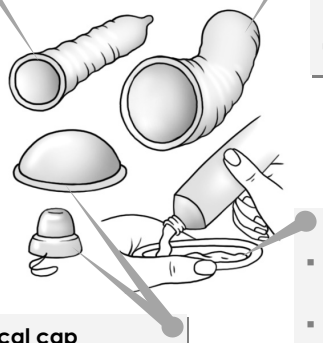
STDs (sexually transmitted diseases)

- *unprotected sexual contact can cause **sexually transmitted diseases** (STDs)*
- *some STDs may be treated with medical drugs, e.g. antibiotics*
- *other STDs cannot be cured, but may be kept under control with drugs, e.g. ARVs can help to control the effects of HIV/AIDS*
- *many STDs have few symptoms in the early stages and are easily transmitted to unsuspecting partners*
- *some barrier methods of contraception illustrated below can help prevent the transmission of STDs as they reduce direct contact and mixing of body fluids between partners*

Different Forms of Contraception

male condom
- acts as a **barrier**
- rubber sheath that fits over erect penis
- collects semen during ejaculation
- prevents sperm release in vagina
- prevents spread of STDs
- more effective when used with a spermicide

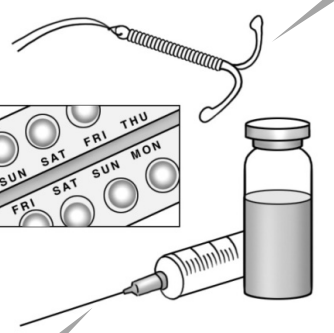
female condom
- acts as a **barrier**
- rubber sheath that lines the vagina
- protects from STDs



diaphragm and cervical cap
- act as **barriers**
- fit over the cervix
- prevent sperm entering uterus to reach ovum
- often used with spermicide

spermicide
- **chemical** gel/cream/foam that kills sperm
- most effective when used with diaphragm/cervical cap/condom

IUD (intra-uterine device)
- plastic/metal structure that is placed in the uterus by a health worker
- releases substances (copper/hormones) that:
  - prevent ovulation
  - thicken mucus in cervix to prevent entry of sperm
  - affect the lining of the uterus to prevent implantation or development of embryo



contraceptive pill
- daily tablets that contain female **hormones**
- prevents ovulation
- thickens mucus in cervix to prevent entry of sperm
- affects the lining of the uterus to prevent implantation or development of embryo

contraceptive injection
- female **hormones** injected into muscle every 3 months
- prevents ovulation
- thickens mucus in cervix to prevent entry of sperm
- affects the lining of the uterus to prevent implantation or development of embryo

ADDITIONAL METHODS

- ***Rhythm method** is a form of contraception where sexual intercourse is avoided during the fertile period of the menstrual cycle. The most fertile days are the 6 days around ovulation. Although it is not very reliable, some people prefer it to the other methods listed above for religious, cultural or health reasons.*
- ***Surgical methods** of contraception involve a **vasectomy** (cutting and tying the vas deferens/sperm ducts) in males and/or **tubal ligation** (cutting and tying the Fallopian tubes) in females. These are **permanent** forms of contraception normally recommended for people who already have children.*

Population control involves governments/authorities that manage the growth of a population. This may be achieved by:

- limiting the number of children allowed per family
- providing free contraceptives and education on birth control
- offering tax incentives to have fewer children – in countries with a high birth rate

Some countries with a low birth rate offer incentives to encourage couples to have more children to keep the population stable.

ABORTION, INFERTILITY AND SURROGACY

Abortion involves deliberately terminating a pregnancy before the birth date. There are different views on abortion that support/oppose the removal of a foetus during pregnancy. Alternatives to abortion include:

- giving the baby to another family for adoption
- leaving the baby in the care of an organisation that provides homes for unwanted babies
- keeping the baby with the support of partner and/or family

Infertility is the inability to have children after regular sexual intercourse. Infertile couples have various options including:

- **adoption** of a baby
- **fertility treatment** using hormones to stimulate ovulation
- **in vitro fertilisation** where fertilisation occurs artificially outside the body and the fertilised ovum is implanted directly into the uterus
- using another woman's eggs and/or uterus to achieve fertilisation and pregnancy

Surrogacy is when a woman carries a pregnancy for another woman who is unable to fall pregnant or maintain a pregnancy.

- a fertilised ovum is placed into the surrogate mother's uterus
- the new parents take over the care of the baby after birth
- the surrogate mother may be paid for her services in bearing the child

TOPIC 4 CIRCULATORY AND RESPIRATORY SYSTEMS

US 7507: SO 5 – AC 1-2
US 7508: SO 2 – AC 1; SO 4 – AC 3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Understand the causes of health issues associated with circulation and respiration
- Conduct a heart dissection
- Understand ways of representing data
- Define concepts and principles relating to circulation and respiration
- Demonstrate the effect of exercise on the heart rate
- Apply knowledge and skills to familiar and unfamiliar phenomena

The circulatory and respiratory systems are closely linked, as their combined function is to get oxygen to each cell in the body. The circulatory system includes the heart, blood vessels and blood. The respiratory system consists of the lungs and air passageways.

UNIT 1 CIRCULATORY SYSTEM

The circulatory system consists of the heart, blood vessels (arteries, veins and capillaries) and blood (liquid medium).

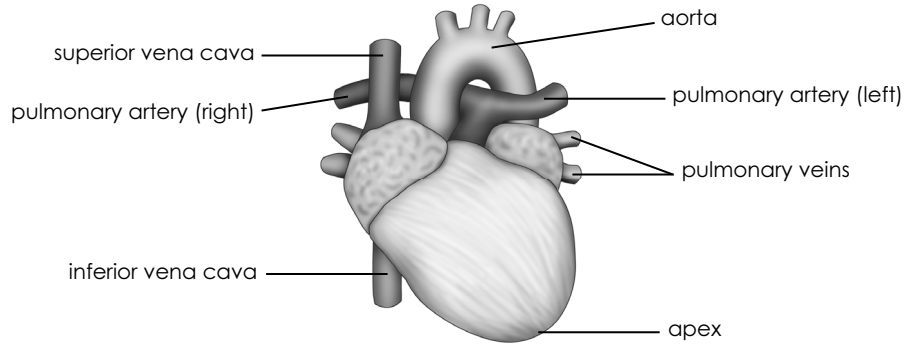
THE HEART

External Structure

NOTE

*See the **OVERVIEW** of the **Circulatory System** and a **summary diagram** on p. 18 in **TOPIC 2 Unit 3**.*

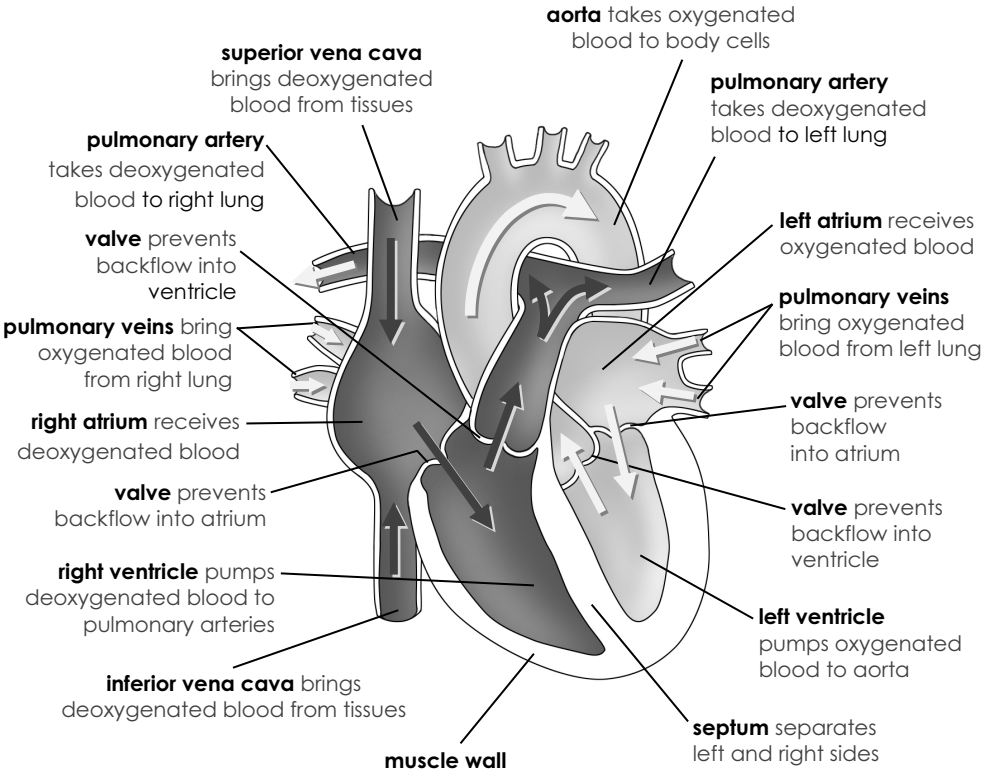
- The human heart is a hollow, pear-shaped muscular organ and is approximately the size of a closed fist.
- The walls of the heart consist of **cardiac muscle** tissue, which contracts and relaxes automatically.
- It is positioned in the centre of the chest cavity, above the diaphragm and between the lungs.
- It is protected by the ribs and breastbone.
- The upper end of the heart is slightly wider and it tapers downwards and to the left to form the **apex**.



External structure of the heart

Internal Structure

- The heart consists of four chambers, two smaller, upper chambers and two larger, lower chambers.
- Each side has an upper chamber and a lower chamber.
- The upper chambers are known as **atria** (atrium = singular) and the lower chambers are the **ventricles**.
- The **septum** is a wall that separates the left and right sides, preventing the mixing of oxygenated with deoxygenated blood.
- The left side only pumps **oxygenated blood**, while the right side only pumps **deoxygenated blood**.
- The **atria** have thin walls and receive the blood into the heart under **low pressure**.
- The **ventricle/s** have thick muscular walls that pump blood to all parts of the body under **high pressure**.
- One-way valves stop backflow of blood in the heart.
- The opening and closing of the valves cause the 'LUB-DUP' sound that can be heard when listening to the heart through a stethoscope.



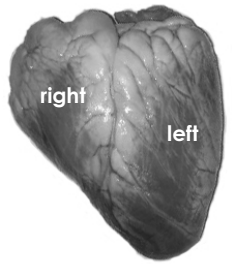
Internal structure of the heart

PRACTICAL INVESTIGATION

Investigating the Structure of the Heart by Dissection

Materials

- dissecting tray
- dissecting scissors
- scalpel
- forceps/tweezers
- sheep/pig heart



Observations

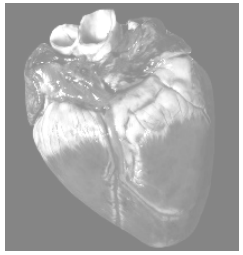
Observations Before Dissecting

NOTE

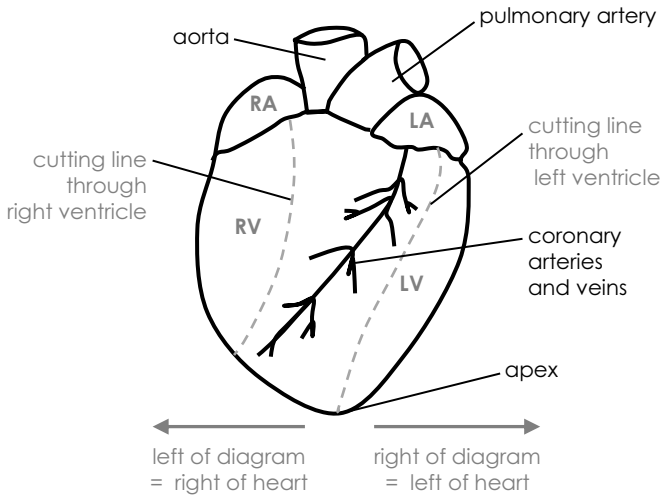
RA = right atrium *LA = left atrium*
RV = right ventricle *LV = left ventricle*

1. Determine which side of the heart is the front/ventral side.

2. Place the heart on the dissecting tray as shown in the photograph:
   - the wider, larger part at the top with larger blood vessels (aorta and pulmonary artery) at the front
   - apex (tip) pointing towards bottom right (LV)
   - a groove with blood vessels going from top right (LA) towards bottom left (RV)



3. Examine the heart and refer to the diagram on the next page to note the following:
   - apex points to your right = left side of heart (LV)
   - smaller, thin-walled upper chambers (dark flaps) = atria (LA & RA)
   - larger, thick-walled lower chambers = ventricles (LV & RV)
   - left side of the heart with thicker walls feels firmer
   - smooth, tough membrane surrounds heart
   - light coloured fatty tissue insulates the heart
   - coronary arteries and veins branch across heart in grooves towards apex
   - largest blood vessel with thickest wall opens near RA = aorta
   - 2nd largest blood vessel = pulmonary artery opens near LA
   - smaller blood vessels at back/dorsal side of heart entering RA = venae cavae
   - smaller blood vessels at back/dorsal side of heart entering LA = pulmonary veins



4. Use a thin rubber/glass tube to carefully pour water into the:
   - aorta/pulmonary artery → water will fill the valves and close the blood vessel
   - left atrium (LA) or pulmonary veins (if present) and gently squeeze the left ventricle (LV) → water will leave the heart via the aorta
   - right atrium (RA) or venae cavae (if present) and gently squeeze the right ventricle (RV) → water will leave the heart via the pulmonary artery

Dissecting Procedure

1. Remove the **outer membrane** to expose the cardiac muscle.

2. Use the scalpel to make an incision in the wall of the **right atrium**.

NOTE

Note the thin walls.

3. Put your finger into the atrium and gently push it into the **right ventricle**.

NOTE

Your finger is surrounded by the valve that prevents backflow from the ventricle to the atrium.

4

4 Use the scissors to continue cutting from the atrium into the ventricle (see the diagram alongside for rough cutting guidelines down towards the apex).

NOTE
The thicker walls of the ventricle and the strings attached to the walls to hold the valve in place.

5 Use a small finger to examine the top of the right ventricle and find the opening to the **pulmonary artery**. Push your finger upwards until it appears at the cut end of the pulmonary artery.

6 Use the scissors to cut down the length of the pulmonary artery wall into the right ventricle.

NOTE
The flaps of the valve at the base of the pulmonary artery prevent backflow of blood into the right ventricle.

7 Repeat steps 2, 3 and 4 to dissect the **left atrium** and **left ventricle**.

NOTE
The left ventricle walls are much thicker as it pumps blood throughout the body.
The septum (wall) separates the left and right sides of the heart.

8 Use the scissors to cut through the **aorta** wall and down into the left ventricle.

NOTE
The flaps of the valve at the base of the aorta prevent backflow of blood into the left ventricle.

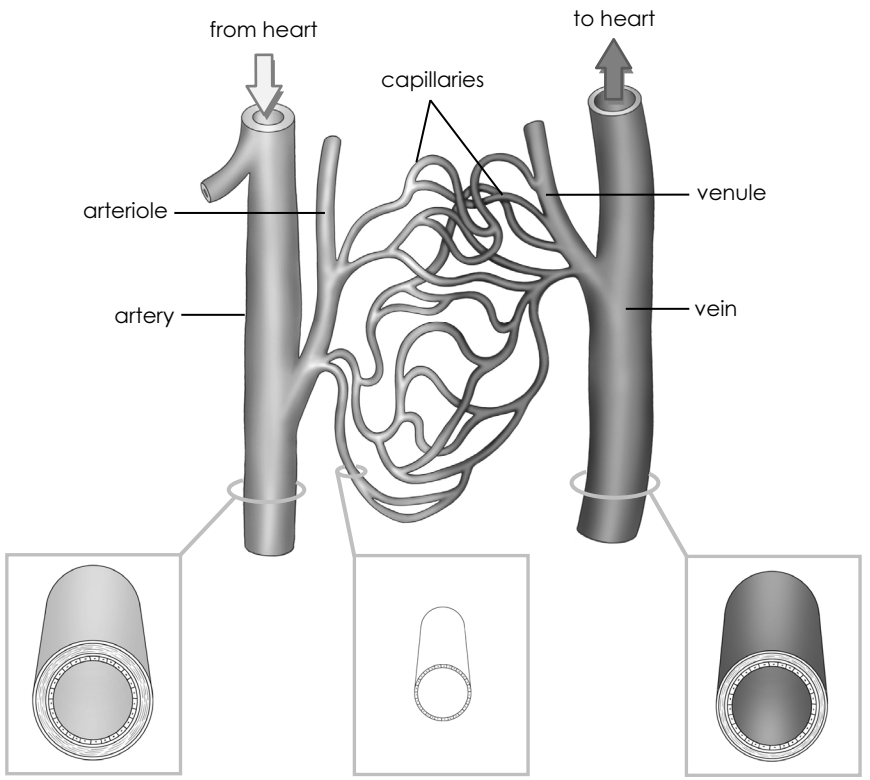
BLOOD VESSELS

- Humans have a **closed circulatory system**, which means that the blood remains within the blood vessels.
- There are 3 different types of blood vessels: arteries, veins and capillaries.

Table to show differences between arteries, capillaries and veins

Arteries	Capillaries	Veins
○ transports blood away from heart to tissues	○ transports blood between arteries and veins	○ transports blood to heart from tissues
○ oxygenated blood (except pulmonary arteries to lungs transport deoxygenated blood)	○ oxygenated and deoxygenated blood	○ deoxygenated blood (except pulmonary veins from lungs transport oxygenated blood)
○ branch into smaller arterioles	○ form branches between arterioles and venules	○ branch into smaller venules
○ thick muscular walls	○ no muscle layer (very thin walls)	○ thin muscular walls
○ many elastic fibres	○ no elastic fibres	○ fewer elastic fibres
○ pulse from heart beat	○ no pulse	○ no pulse
○ blood at high pressure	○ blood at lower pressure	○ blood at low pressure
○ blood flow is fast and in spurts	○ blood flow is slower – to allow diffusion	○ blood flow is slow and smooth
○ walls not permeable	○ walls permeable to allow diffusion	○ walls not permeable
○ narrow lumen	○ very narrow lumen – wide enough for one red blood cell	○ wider lumen
○ no valves	○ no valves	○ valves to prevent backflow due to low pressure

Different types of blood vessels



Cross-section of **artery**
thick muscular wall
narrow lumen

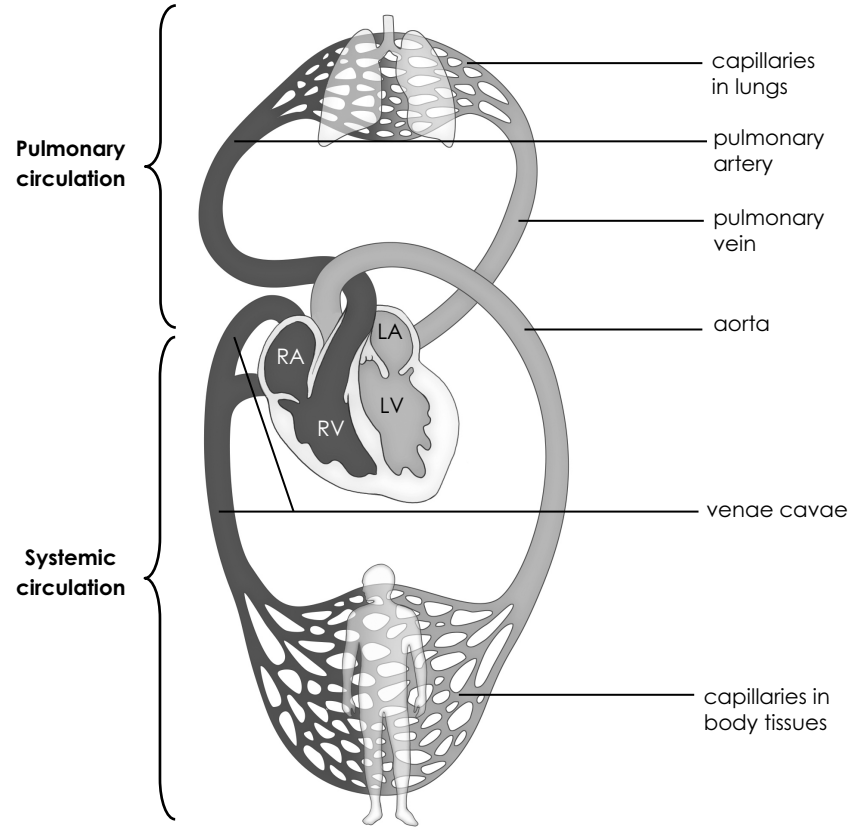
Cross-section of **capillary**
no muscular wall
very narrow lumen

Cross-section of **vein**
thin muscular wall
wider lumen

CIRCULATION

- Blood travels around the body in blood vessels:
  - it goes away from the heart in arteries and
  - returns to the heart in veins
- Humans have a **double circulation**, which means that the blood will pass through the heart **twice** in one complete circuit of the body.
- One full circuit is made up of two smaller circuits, the **PULMONARY** circulation and the **SYSTEMIC** circulation.

- **PULMONARY CIRCULATION**
  - **deoxygenated blood** leaves the right ventricle through the **pulmonary artery**
  - it passes to the lungs where the blood is oxygenated
  - **oxygenated blood** returns to the left atrium through the **pulmonary veins**
- **SYSTEMIC CIRCULATION**
  - **oxygenated blood** leaves the left ventricle through the **aorta**
  - it is pumped to all parts of the body, and becomes deoxygenated in the tissues
  - **deoxygenated blood** returns to the right atrium through the two **venae cavae** (superior and inferior)



Double circulatory system

*If we could follow the path of a single red blood cell in one full circuit of the body, it would not travel to **every** system.*

Each red blood cell is pumped from the heart to the lungs to be oxygenated, returns to the heart to be pumped to a specific tissue where it delivers oxygen and picks up carbon dioxide, before returning to the heart again.

THE EFFECT OF EXERCISE ON HEART RATE

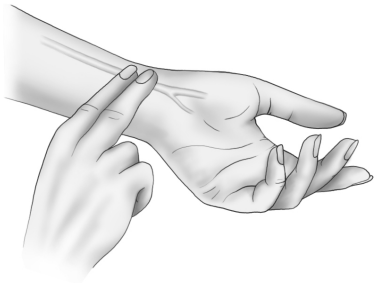
- **Heart rate** is the number of times the heart beats in ONE minute.
- It is measured in **beats per minute** or **bpm**.
- The average adult heart rate is 70 bpm.
- Heart rates can be measured using heart rate monitors.

Heart rate monitors are common on modern wearable technology devices like smart watches and activity trackers.

- Heart rate can be measured manually by finding your pulse and counting the number of beats in a minute.
- The **pulse** is caused by pressure waves in the arterial walls generated by the heartbeat. It can be felt in points of the body where the arteries are near the surface (e.g. in the wrist or neck).
- When feeling for the pulse, one should always use two fingers (not the thumb) to apply pressure on the pulse point.

NOTE

A fit person has a lower pulse rate (40 – 60 bpm) at rest and returns to a normal pulse rapidly after exercise.



- Exercise has a marked effect on the heart rate.
- While exercising, your muscles respire more to release more energy.
- This produces more CO_2 which enters the bloodstream.
- Sensors in the blood vessels detect the increase of CO_2 and the brain sends an impulse to the heart to beat faster and to the respiratory muscles (intercostal muscles and diaphragm) to increase the breathing rate.

NOTE

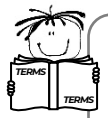
Respiration occurs in the mitochondria of each cell to release energy and CO_2.

- These two responses increase the rate at which CO_2 is removed from the blood, but simultaneously increases the uptake of O_2 into the blood. The additional oxygen is needed for the increased respiration occurring in the muscle cells.

NOTE

Stress, anxiety and fear also increases heart rate to provide more oxygen to cells in emergencies.

BENEFITS OF EXERCISE FOR THE CARDIOVASCULAR SYSTEM



'cardio' = heart
'vascular' = vessels
cardiovascular = heart and blood vessels

- Exercise keeps the body fit and healthy:
  - muscles enlarge and absorb oxygen more efficiently
  - weight loss (more fat is used for energy to exercise) reduces strain on the heart
  - heart muscle strengthens and pumps blood more efficiently
  - promotes breathing rate which increases the volume of air inhaled
  - increased blood supply to cells provides more oxygen for respiration which increases energy output
  - increased blood pressure improves oxygen supply and removal of waste
  - increased heart rate decreases the risk of blood clotting which may cause heart attacks and strokes

UNIT 2

BREATHING, GASEOUS EXCHANGE AND RESPIRATION

THE RESPIRATORY SYSTEM

NOTE

*See the **OVERVIEW** of the **Respiratory System** and a **summary diagram** on p. 21 in **TOPIC 2 Unit 4**.*

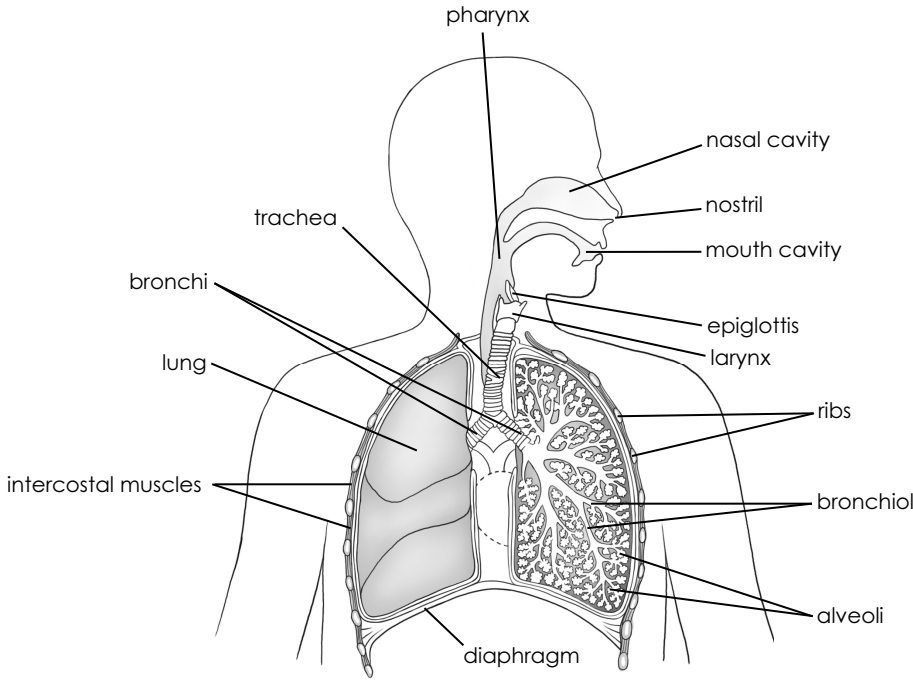


Diagram of the human respiratory system

Air Passageways

The air passageways transport air to and from the lungs and include the **nasal cavities**, **pharynx** (throat), **trachea** (windpipe), **bronchi** and **bronchioli**.

Nasal cavities

- Two nostrils lead to the nasal cavities.
- Hairs filter larger particles from the inhaled air.
- A rich supply of **blood capillaries** warm the incoming air.
- The nasal cavities also secrete mucus that:
  - **traps dust and germs**
  - **kills** inhaled germs (antiseptic)
  - **moistens** the incoming air

Pharynx (throat)

- The nasal cavities open into the pharynx.
- The pharynx leads to two openings:
  - the **trachea** (windpipe – for air)
  - the **oesophagus** (gullet – for food)

Trachea (windpipe)

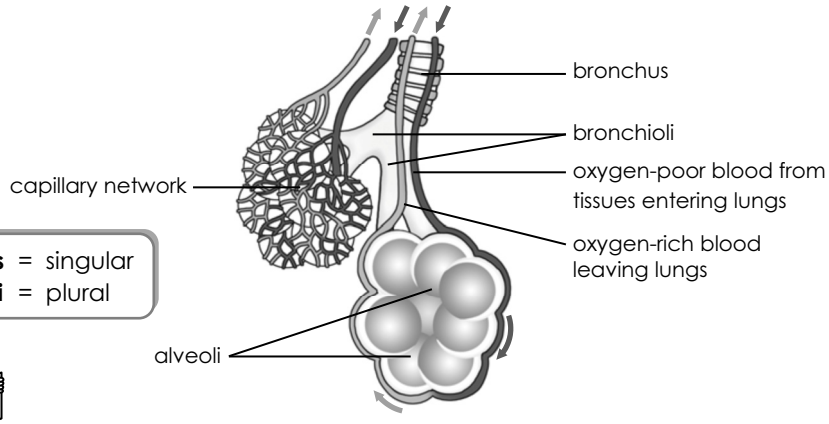
- The trachea is a long tube, located at the front of the oesophagus.
- The **larynx** (voice box), which houses the vocal cords, is located at the top of the trachea.
- The **epiglottis** is a flap of cartilage at the top of the larynx that closes the opening to the trachea during swallowing. This prevents food entering the trachea.
- The walls of the trachea are reinforced and kept open by cartilage rings.

Bronchi and bronchioli

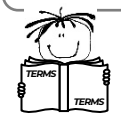
- The trachea divides into a right and left **bronchus** that enter the right and left lung respectively.
- The **bronchi** are held open by cartilage rings.

bronchus = singular
bronchi = plural
bronchiole = singular
bronchioli/ bronchioles = plural

- Inside the lungs, the bronchi divide into smaller branches to form the **bronchioli** (or **bronchioles**).
- Bronchioli do not have cartilage rings.
- Each bronchiolus ends in a bundle of air sacs known as **alveoli**.
- The alveoli are surrounded by a network of **capillaries**.



alveolus = singular
alveoli = plural



Structure of the alveoli and associated air passageways

It is important to distinguish between **breathing**, **gaseous exchange** (see p. 53) and **respiration** (see p. 55).

BREATHING

- Breathing is the mechanical process where air is drawn into the lungs during **inhalation** and then forced out of the lungs during **exhalation**.

NOTE
The lungs are not muscular so they cannot expand and contract independently.

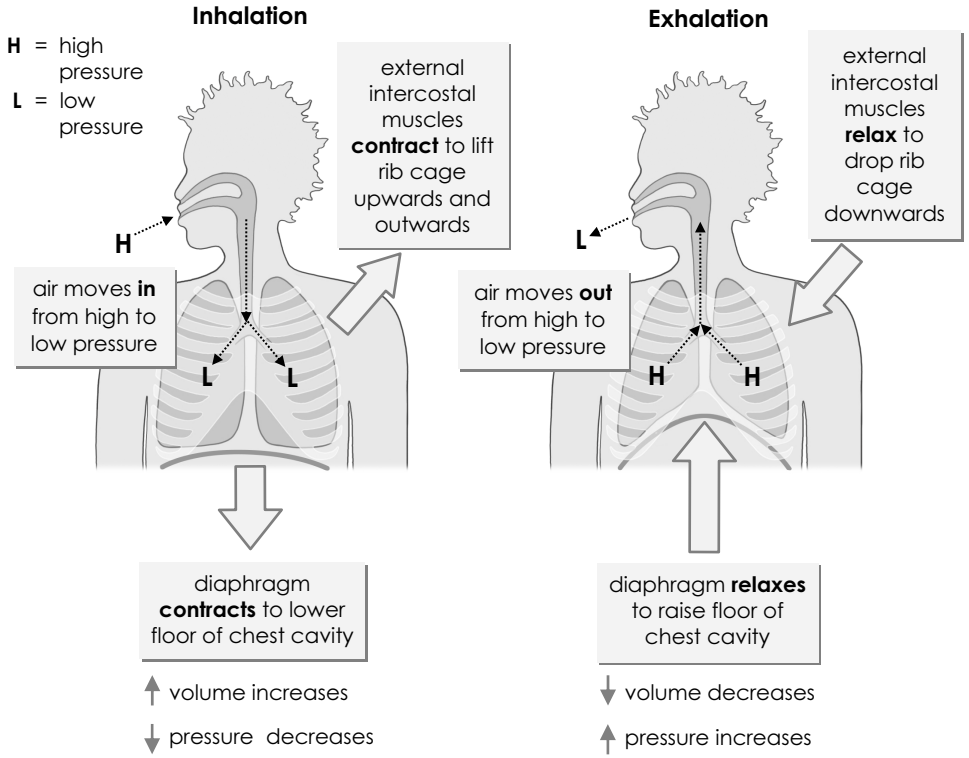
- The mechanism of breathing is achieved by the muscles around the lungs, namely the **diaphragm** and the **intercostal muscles**.
- The diaphragm is a sheet of muscle that is dome-shaped when relaxed and flat when contracted. It stretches across the ribcage below the lungs.
- The intercostal muscles are found between the ribs.

NOTE
We do not breathe in oxygen and breathe out carbon dioxide!
Air is inhaled and air is exhaled. The difference is that exhaled air has less oxygen and more carbon dioxide than inhaled air.

Inhalation	Exhalation
○ diaphragm contracts and flattens in shape – lowering the floor of the chest cavity ○ the external intercostal muscles contract – lifting the rib cage upward and outwards ○ thus, the volume of the chest cavity increases ○ the pressure in the chest cavity decreases ○ air from the atmosphere is drawn into the lungs to equalize the pressure	○ diaphragm relaxes and returns to its domed shape – raising the floor of the chest cavity ○ the external intercostal muscles relax – dropping the rib cage downward and inwards ○ thus, the volume of the chest cavity decreases ○ the pressure in the chest cavity increases ○ air in the lungs is forced out due to the high pressure

NOTE

Air always moves from a high pressure to a low pressure.



GASEOUS EXCHANGE

Gaseous exchange is the movement of gases from a high concentration to a low concentration by **diffusion**. It occurs in the **lungs** (between the alveoli and the blood) and in the **body tissues** (between the blood and the cells).

Gaseous Exchange in the Lungs

○ Once air is inhaled, oxygen is absorbed from the lungs into the blood.

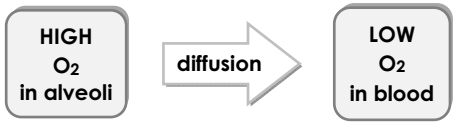
○ Carbon dioxide is released from the blood into the lungs to be exhaled.

○ This process occurs in the alveoli by **diffusion**.

Exchange of O_2

○ The air in the alveoli has a higher O_2 concentration (due to inhalation) than the blood in the surrounding blood capillaries (due to respiration).

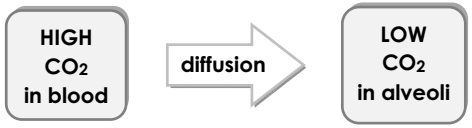
○ The O_2 dissolves in a thin layer of moisture that lines the alveoli and diffuses through the thin walls of the alveoli and thin walls of the capillaries into the blood.

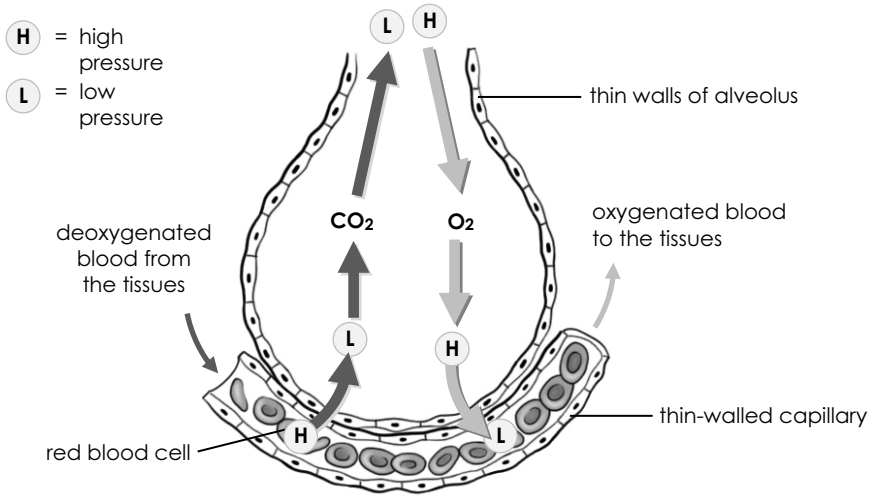


Exchange of CO_2

○ The blood that reaches the alveoli from the tissues has a higher CO_2 concentration (due to respiration) than the air in the alveoli (due to exhalation).

○ CO_2 diffuses from the blood in the capillaries through the thin walls of the capillaries and thin walls of alveoli into the air in the alveoli.





Gaseous exchange in the alveolus

- Blood that is rich in oxygen and lacks carbon dioxide is known as **oxygenated** blood.
- Blood that is rich in carbon dioxide and lacks oxygen is known as **deoxygenated** blood.
- The alveoli are structurally suited for the process of gaseous exchange as:
  - there are many air sacs, thus creating a **large surface area** for diffusion
  - they have **thin walls** (only one cell layer thick), so gases have a short distance to diffuse
  - they are constantly **ventilated** by inhalation and exhalation which keeps the concentration of O_2 high and CO_2 low
  - they have a **rich network of blood capillaries** to maximise diffusion and increase the amount of blood moving past the alveoli. This keeps the concentration of O_2 low and CO_2 high in the blood for diffusion.

There are about 400 million alveoli in both lungs. If all the alveoli could be laid out flat, they would occupy an area of around 70 – 100 m² which is about the size of half of a tennis court.

Gaseous Exchange in the Body Tissues

Exchange of O_2

- Oxygenated blood from the lungs reaches the tissues via the heart.
- The blood in the capillaries has a higher O_2 concentration (due to gaseous exchange in the lungs) than the cells of the tissues (low concentration due to respiration).
- A diffusion gradient is therefore created between the blood (high concentration) in the capillaries and the cells (low concentration).
- O_2 diffuses through the walls of the capillaries into the fluid between the cells and into the cells.

HIGH O_2 in blood → diffusion → **LOW O_2 in tissues**

NOTE

O_2 is constantly used for respiration which occurs in the mitochondria of every cell.

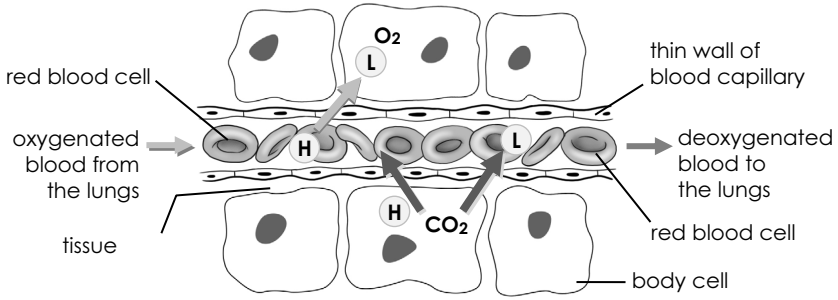
Exchange of CO_2

- The cells have a higher CO_2 concentration (due to respiration) than the blood in the capillaries (low concentration due to gaseous exchange in the lungs).
- The CO_2 diffuses from the cells into the surrounding tissue fluid and then diffuses into the blood in the capillaries.

NOTE

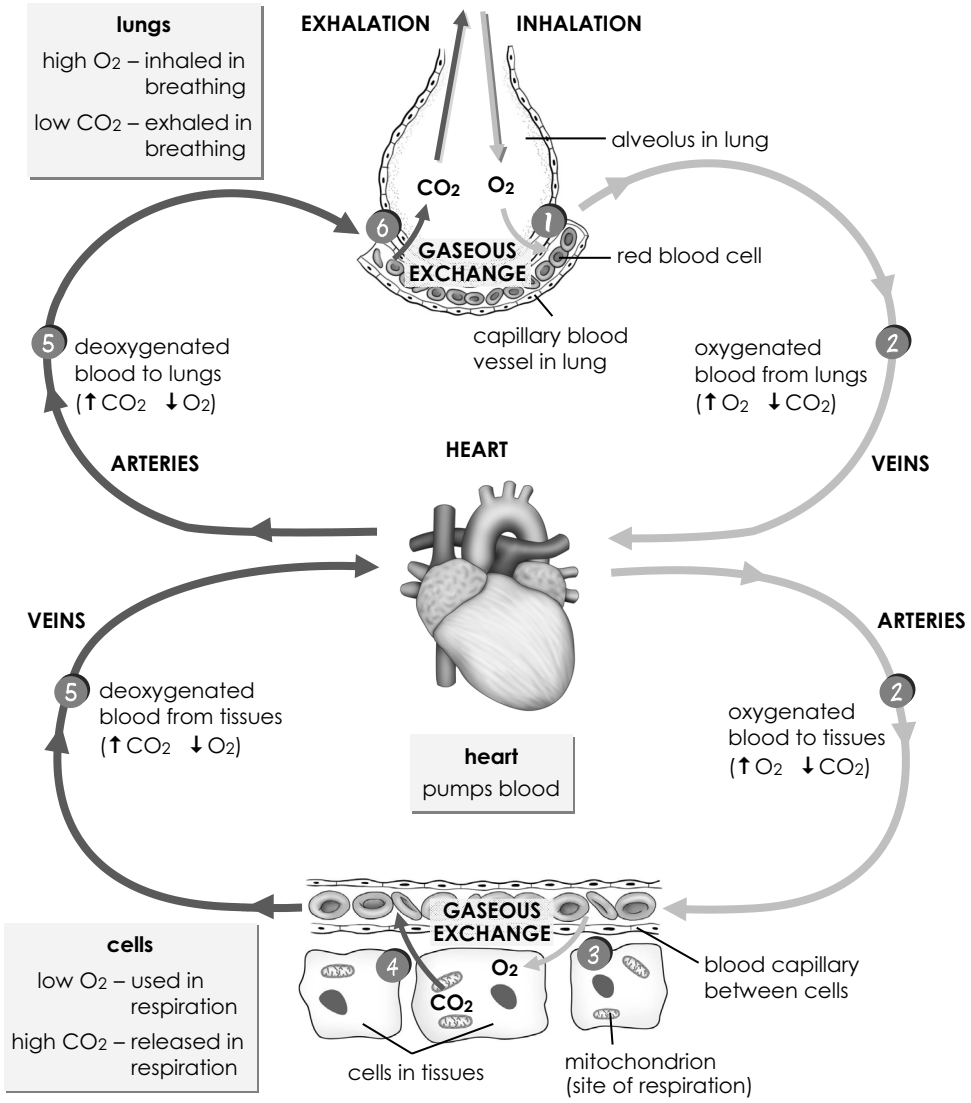
CO_2 is released during respiration in the cells.

HIGH CO_2 in cells → diffusion → **LOW CO_2 in blood**



Gaseous exchange in the body tissues

Representation of gaseous exchange at lung and tissue level



Key:

1. – exchange of O_2 at alveoli
2. – transport of O_2 to heart and tissues
3. – exchange of O_2 at tissues
4. – exchange of CO_2 at tissues
5. – transport of CO_2 to heart and lungs
6. – exchange of CO_2 at alveoli

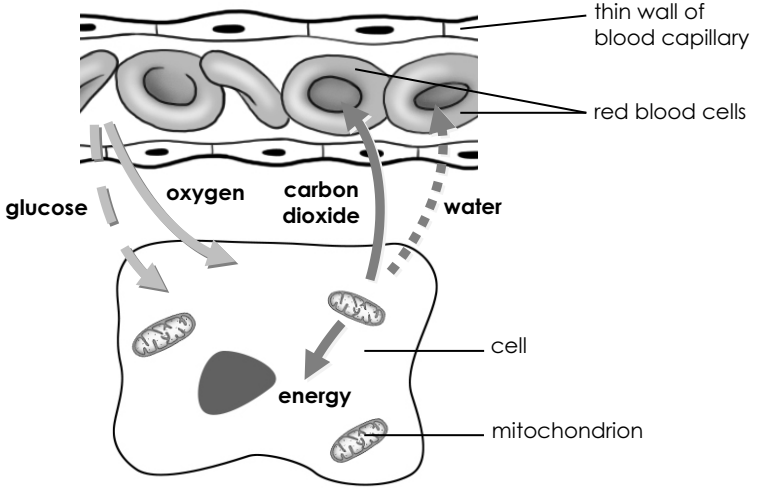
RESPIRATION

Respiration is a process that occurs in the mitochondria of all living cells. It breaks down **glucose** using **oxygen** to release **energy**.

Carbon dioxide and **water** are released as waste products. The energy is stored for cellular activities.

glucose + oxygen → **RESPIRATION** → **carbon dioxide + water + energy**

Blood transports the glucose and oxygen to the cells and removes carbon dioxide and water from the cells.

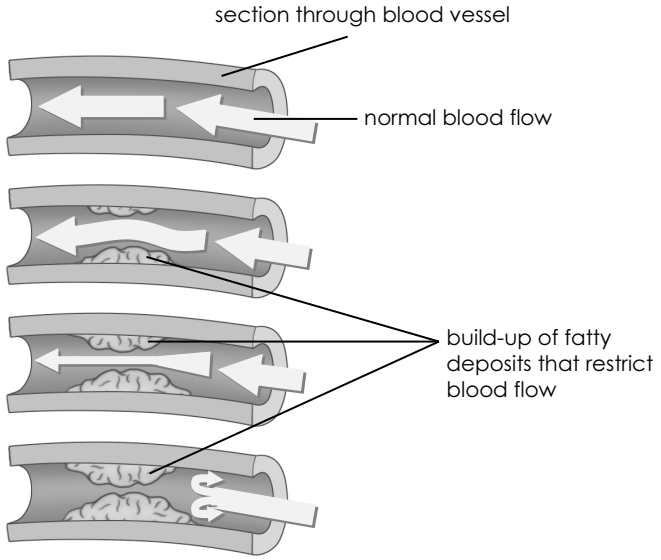


Cell with blood capillary showing process of respiration

CAUSES OF HEALTH ISSUES ASSOCIATED WITH THE CIRCULATORY AND RESPIRATORY SYSTEMS

- There are three unhealthy lifestyle practices that have harmful effects on the circulatory and respiratory systems:
  - smoking
  - alcohol abuse
  - high cholesterol diet

	Circulatory system	Respiratory system
Smoking	○ raises blood pressure and heart rate ○ decreases amount of oxygen carried by the blood ○ causes build-up of fatty deposits on the artery walls ○ increases risk of stroke and heart attack due to blockages of the blood supply	○ cigarette smoke contains carbon monoxide that blocks the transport of O_2 ○ tar in cigarette smoke accumulates in the lungs and blocks uptake of O_2 ○ excess mucus released by damaged tissues causes 'smokers cough' ○ smoke damages alveolar walls which reduces the area for gaseous exchange and causes constant breathlessness ○ toxic chemicals in smoke are known to promote diseases like emphysema, bronchitis, pneumonia and lung cancer
Alcohol abuse	○ increases heart rate which puts unnecessary strain on the heart muscle; this may lead to heart attacks or high blood pressure ○ affects ability of heart muscle to contract	○ increases risk of lung infections, e.g. pneumonia
High cholesterol diet	○ causes fatty deposits which narrow the arteries and increase the risks of blood clotting and consequently, heart attacks and strokes ○ increases the force required by the heart to pump blood around the body which puts more strain on the heart and increases blood pressure	



Changes in blood flow due to formation of fatty deposits in blood vessels

TOPIC 5 DIGESTIVE SYSTEM

US 7507: SO 3 – AC 1; SO 5 – AC 2
US 7508: SO 2 – AC 1; SO 3 – AC 1,3; SO 4 – AC 3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Explain and understand the requirements of different diets
- Illustrate the significance of understanding nutritional value of food in life
- Investigate food samples for the presence of nutrients
- Understand ways of representing data
- Define concepts and principles relating to digestion
- Interpret scientific evidence and apply knowledge and skills

NOTE

*See the **OVERVIEW** of the **Digestive System** on p. 16 in **TOPIC 2 Unit 2**.*

UNIT 1 HEALTHY DIET

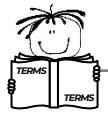
In order for someone to be healthy, they need to follow a **balanced** diet.

NOTE

***Diet** is the eating plan or the total amount of food eaten each day.*

A balanced diet requires consumption of the correct amounts and ratios of different components: proteins, carbohydrates, fats and oils, vitamins and minerals, fibre and water. A balanced diet provides food that can be used for:

- energy – fuel for respiration
- growth – increase in size and number of cells
- repair and replacing cells
- protection against infection

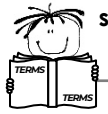


healthy diet: balanced proportions of different food groups with as much natural, raw, unrefined/unprocessed foods as possible

COMPONENTS OF A HEALTHY DIET

Water is not a food and it does not provide the body with any nutrients, but it is an essential component of a balanced diet, as it:

- makes up approximately 60% of the human body
- is the medium for all chemical reactions
- acts as a solvent for various substances (useful as well as waste)



solvent: a liquid that dissolves nutrients, waste or gases

- transports nutrients and waste around the body
- aids in digestion
- softens food for easier egestion

Fibre or roughage forms part of many foods from different food groups. It is composed of cellulose from plant cell walls and plays an important role in the digestive system. Fibre is found in vegetables, fruit, cereals and seeds. It is essential for a healthy diet as it:

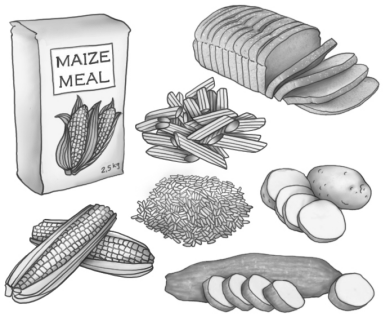
- adds bulk to the chyme and stimulates peristalsis
- absorbs toxins from the gut
- softens faeces which prevents constipation
- speeds up movement of food through gut

Building foods

Proteins are used for growth and repair of cells.

e.g. dairy (milk, cheese, yoghurt), meat, eggs, beans and nuts

Energy foods



Carbohydrates (starches and sugars) provide the body with energy.

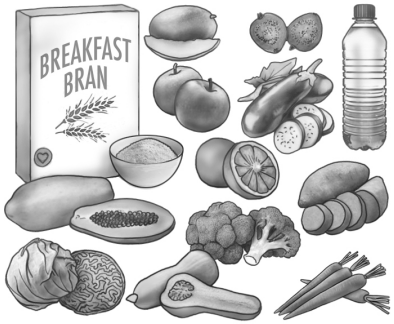
e.g. grains: bread and cereals

Energy and insulation foods

Fats and oils form part of cell membranes, act as an energy reserve and provide insulation.

e.g. oils, butter, nuts and seeds

Protection and regulation foods



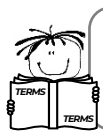
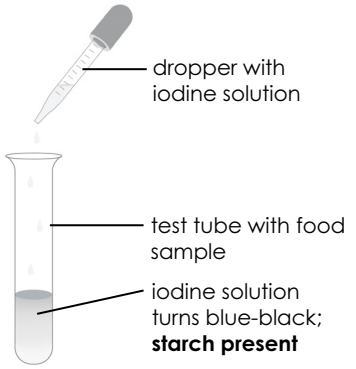
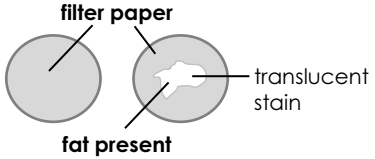
Vitamins are organic substances required in small quantities to regulate body processes. Vitamins occur in unrefined foods like raw fruit and vegetables.

Minerals are inorganic salts required in tiny quantities.
e.g. calcium, iron, iodine, sodium, potassium

Vitamins and minerals are vital for normal cell function, growth and development.

PRACTICAL INVESTIGATION

Testing Food Samples for the Presence of …

Starch	Fats and oils
Aim To test for the presence of starch in a food sample.	**Aim** To test for the presence of a fat/oil in a food sample.
Materials ▪ test tube ▪ iodine solution ▪ food sample ▪ dropper	**Materials** ▪ food sample ▪ dropper ▪ ethanol/ether ▪ filter paper
Method ▪ Place 1 cm^3 of the food sample into a test tube. ▪ Using the dropper, add a few drops of yellow-brown iodine solution to the test tube.	**Method** ▪ Ground the food sample into a fine powder. ▪ Dissolve the powder in 1 cm^3 of ethanol/ether.  If your food sample is already liquid, simply drop onto filter paper. ▪ Drop some of the liquid onto the filter paper and wait a few minutes.
Results If the food sample stays yellow-brown, the test is negative for starch. If the food sample turns **blue-black**, the test is **positive** for starch.  dropper with iodine solution test tube with food sample iodine solution turns blue-black; **starch present**	**Results** If there is no mark on the filter paper, the test is negative for fats/oils. If there is a **translucent stain** (semi-transparent mark) on the filter paper, the test is **positive** for fats/oils.  filter paper translucent stain fat present

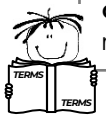
MALNUTRITION

It is important to eat a variety of foods in the correct quantities. Eating too much or too little of certain food groups can lead to malnutrition. 'Mal' means 'bad', so malnutrition is bad nutrition, not just under-eating.

Overnutrition

When you are overnourished, it means you are eating more than your body needs. The excess food (especially carbohydrates) is stored as fat and you can become **obese**.

This excess fat in the tissues can block the blood vessels and lead to complications such as diabetes, heart disease, high blood pressure and strokes.



diabetes: a condition where the body cannot regulate the sugar/glucose levels in the blood

Undernutrition

A person is undernourished because they eat too little of a particular food group. This can lead to a deficiency disease/disorder. The table below provides a few examples.

Disease/disorder	Deficiency
○ constipation	○ fibre (roughage)
○ kwashiokor	○ protein
○ scurvy	○ vitamin C
○ anaemia	○ iron

NOTE

*In **TOPIC 2** on p. 24 we covered other deficiency disorders such as **rickets** (Vitamin D).*

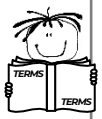
Some diets may lead to **eating disorders** as they either exclude vital food groups or provide insufficient amounts of food. Eating disorders require intervention to prevent long-term damage to tissues and normal development.

Additives

There are various **additives** (a chemical added to food) that manufacturers put in food that may also cause health problems like allergies or concentration problems if eaten in large amounts.

These include:

- **preservatives** – prolong the shelf life of food to keep it fresh for longer
- **flavourants** – improve the taste of food
- **colourants** – improve the appearance of food



Fast foods and **processed foods** are mostly refined foods, i.e. they have been changed in some way from their natural raw state. They may contain additives including extra salt and sugar which lower the nutritional value. These foods lead to various health issues and less efficient cell functioning.

DIETS FROM DIFFERENT CULTURES

There are various diet preferences in different parts of the world. It may be due to personal taste, health reasons, special customs or religious reasons.

KOSHER – Jewish people follow a kosher diet. 'Kosher' refers to the foods that are permitted. Pork, shellfish and rabbit are not kosher. Meat and dairy may not be eaten in the same meal nor prepared in the same space or with the same utensils or cooking apparatus.

HALAAL – This refers to what is allowed under traditional Islamic law regarding meat preparation and drinks. There are rules that must be followed to slaughter an animal. Pork, shellfish, insects and alcohol are not permitted.

VEGETARIAN – People who prefer to avoid some or all animal products and eat plant material only. This diet may be due to health, religious, moral reasons or, simply personal preference.

UNIT 2

ALIMENTARY CANAL AND DIGESTION

NOTE

*See p. 16 for an **OVERVIEW** of the **Digestive System** and a **summary diagram** on p. 17.*

The alimentary canal (gut) is a long, twisted tube that runs through the body from the mouth opening at the top to the anus at the end.

The role of the alimentary canal is to **digest** food into smaller soluble nutrients that can be **absorbed** by the blood stream and taken to cells for energy, growth and repair of damaged tissues and several other body processes.

The digestive system consists of different organs, each structurally suited for its specific function and contributing to the overall function of the system.

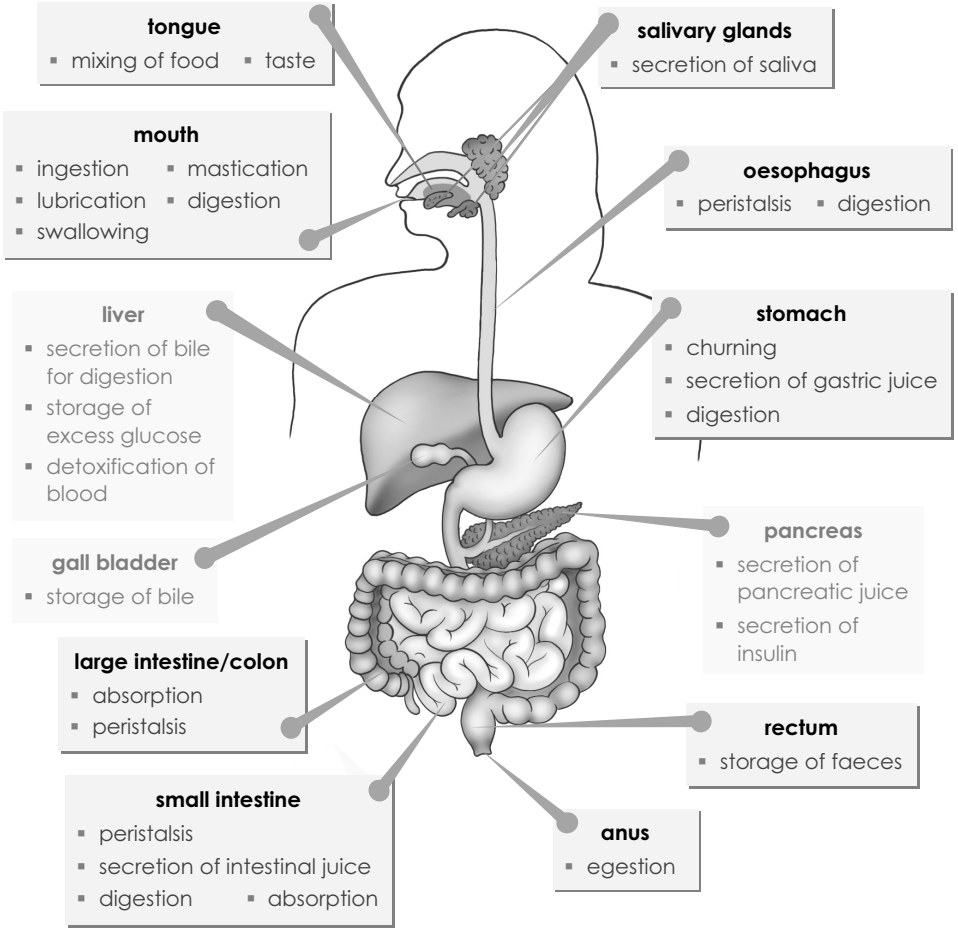
There are 5 main processes that occur in the alimentary canal:

- **ingestion** – food enters the mouth
- **digestion** – food is broken down
- **absorption** – nutrients (end-products of digestion) are taken into the blood
- **assimilation** – nutrients become part of cells
- **egestion** – undigested waste is removed via the anus

The diagram alongside illustrates the structures of the digestive system as well as the main processes/functions associated with each. Each structure is discussed in more detail in the notes that follow in this unit.

NOTE

*The **accessory organs** (liver, gall bladder and pancreas) are in grey font. They do not form part of the alimentary canal (no food passes through these organs), but they assist the alimentary canal in its functioning.*



The human digestive system

STRUCTURE AND FUNCTIONS OF THE DIGESTIVE ORGANS

Mouth and Mouth Cavity

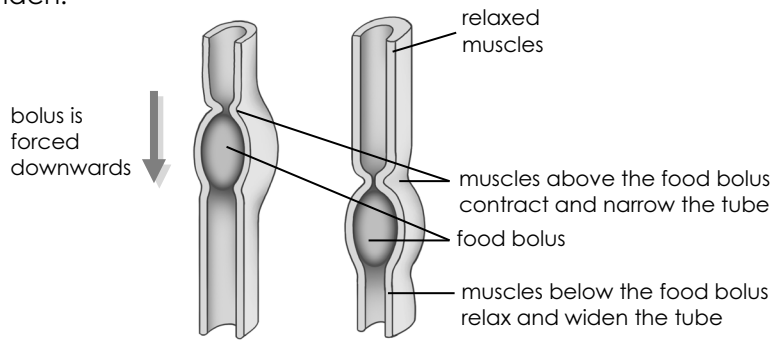
- The mouth is the opening where food enters the body by **ingestion**.
- The **teeth** bite and chew food (**mastication**), breaking it into smaller pieces.
- Food is mixed with saliva which lubricates and softens the food, and contains enzymes that break down starch.

NOTE

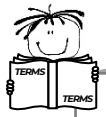
Adaptations *always refer to* ***structure*** *and* ***function****, i.e. how the structure is adapted for the function.*

Oesophagus

- The oesophagus is a hollow tube made of involuntary muscle tissue.
- It connects the back of the mouth cavity to the stomach.
- Muscles in the wall of the oesophagus perform a series of rhythmical contractions to push the food bolus forward. This movement is called **peristalsis**.
- Digestion of starch by salivary enzymes continues until the food reaches the stomach.



Peristalsis in the oesophagus



food bolus: a round ball of chewed food that is mixed with saliva in the mouth cavity and pushed in the direction of the oesophagus during swallowing

Stomach

- The stomach is a muscular bag that receives food from the oesophagus.
- The thick muscular walls squeeze and grind the food in the process of **churning**.
- Churning breaks up the food so that it mixes more effectively with **gastric juices** which contain enzymes to speed up digestion.
- Enzymes in the gastric juice speed up the digestion of protein.
- HCℓ (hydrochloric acid) provides acid medium for enzyme action.
- Food leaves the stomach in a semi-solid, acid state called **chyme**.

NOTE

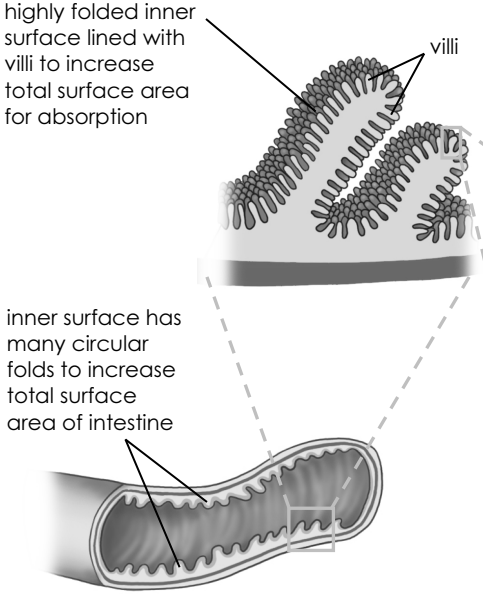
Gastric juice *consists of* ***hydrochloric acid*** *produced by the walls of the stomach and* ***enzymes****, which are special proteins that speed up chemical reactions.*

Small Intestine

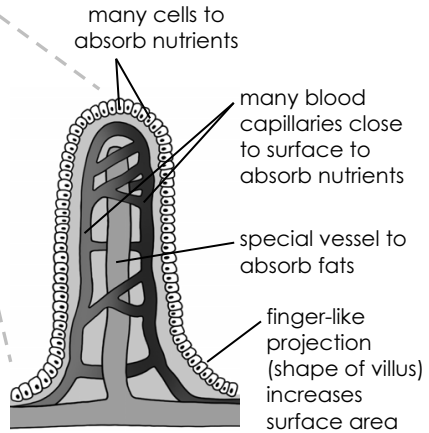
- The small intestine is a long (approximately 5 – 6 m) muscular tube for digestion and absorption.
- Muscles in the intestinal wall contract to slowly propel food through the gut by peristalsis.
- It is the main organ for digestion and absorption.
- Intestinal glands produce intestinal juice containing enzymes that also break down food into soluble particles.
- The walls of the small intestine are highly folded. These folds are lined with millions of **villi** (tiny finger-like projections) that aid in absorption.
- Soluble nutrients are absorbed into the blood capillaries from the small intestine.

NOTE

A highly folded surface increases the total surface area which increases the absorption rate.



Section through small intestine



Structure of a villus

Large Intestine

- The large intestine is shorter than the small intestine, but larger in diameter.
- Water and certain vitamins are absorbed from the semi-solid waste.
- Undigested waste (faeces) moves slowly by peristalsis.
- Mucous glands secrete mucus that allows easier movement of waste through the large intestine.

Rectum

- Faeces is temporarily stored in the rectum until it is released via the anus.

Anus

- It is an opening at the end of the alimentary canal controlled by a sphincter (ring of muscles).
- Egestion of faeces (undigested waste) occurs via the anus.

STRUCTURE AND FUNCTIONS OF THE ACCESSORY ORGANS TO THE ALIMENTARY CANAL

These organs play a role in digestion, but they are not part of the digestive canal (gut).

Tongue

- The tongue moves food around the mouth, between the teeth and mixes it with saliva.
- It pushes the food bolus to the back of the mouth cavity for swallowing.
- The taste buds are special receptors sensitive to chemicals and give rise to the sensation of taste.

Salivary Glands

- 3 pairs of salivary glands secrete saliva into the mouth to lubricate and soften the food, making swallowing easier.
- Saliva contains enzymes which aid the digestion of starch.

Pancreas

- The pancreas is located below the stomach and is connected to the small intestine via a small tube called the pancreatic **duct**.
- The pancreas produces **pancreatic juice** which contains enzymes that break down specific foods.
- It also produces a hormone called **insulin** which helps to control the level of glucose in the blood.

Liver

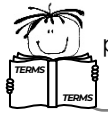
- The liver is the largest gland in the body and is located to the right of the stomach.
- The liver produces **bile** which:
  - dissolves fats and oils
  - helps to neutralise the acidic chyme when it enters the small intestine from the stomach
  - has antiseptic properties
- It detoxifies the blood by breaking down toxins such as alcohol.

Gall Bladder

- It is a small sac located between the lobes of the liver.
- It stores bile produced by the liver.
- It releases bile into the small intestine via a duct when stimulated by the presence of fatty food.

TYPES OF DIGESTION

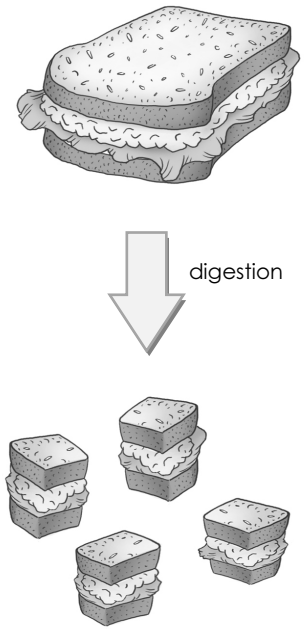
The body cannot use food in the undigested form in which it is ingested. Each food group needs to be broken down into its smallest chemical units (building blocks). This process is called **digestion**.

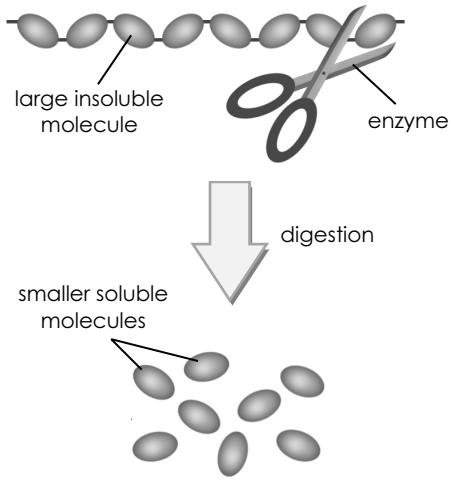


digestion: the breakdown of large, insoluble food particles into smaller, soluble particles (dissolved form) that can be absorbed by the blood and used by the cells

Types of Digestion

Mechanical digestion The physical breaking, crushing and mashing of food into smaller particles. This creates a larger surface area for enzyme action.	**Chemical digestion** The mixing of food with digestive enzymes and hydrochloric acid to break food down on the molecular level.
○ **Mouth** (mastication) – food is broken into smaller particles by teeth and tongue ○ **Stomach** (churning) – food mashed by contraction and relaxation of muscle walls and mixed with gastric juice	○ **Mouth** – saliva contains enzymes to break down starch ○ **Stomach** – gastric juice contains hydrochloric acid and enzymes to break down proteins ○ **Small intestine** – bile dissolves fats; pancreatic juice and intestinal juice contain enzymes to break down carbohydrates, proteins and fats





TOPIC 1 CELLS AS THE BASIC UNITS OF LIFE

Question 1

Give **one word** or **term** for each of the following statements:

1.1 The characteristic where an organism responds to a stimulus.

1.2 The organelle that stores cell sap.

1.3 The fluid substance in which all the organelles are suspended.

1.4 The rigid structure that provides shape to the plant cell.

1.5 The structures in the nucleus that carry hereditary characteristics.

1.6 The stain used to prepare onion cells.

1.7 The green pigment found in chloroplasts which facilitates the process of photosynthesis.

1.8 A photograph of a cell as seen through an electron microscope.

1.9 The process whereby cells become specialised in structure and function.

1.10 The process by which water moves across the cell membrane.

1.11 A characteristic of cell membranes that controls the movement of substances into/out of the cell.

1.12 A group of different tissues working together to perform a particular function.

1.13 Focuses light rays and controls the amount of light passing through the specimen on the stage of the microscope.

1.14 Holds microscope objectives with low and high-power lenses.

1.15 Magnifies the specimen under observation.

1.16 Slowly brings microscope lens closer to or further away from specimen.

1.17 A stain used to observe animal cells under the microscope.

1.18 Unspecialised somatic cells that occur in all organisms.

1.19 Stem cells obtained from human embryos.

1.20 Stem cells obtained from bone marrow, skin and blood.

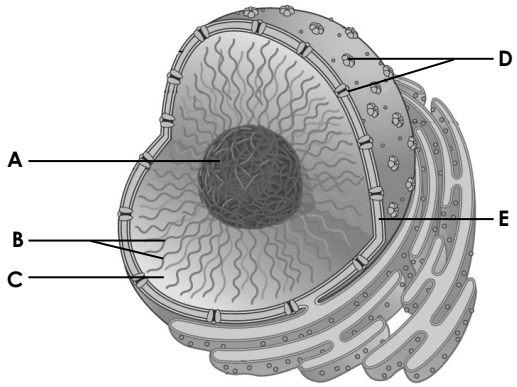
Question 2

Use the text provided and answer the questions that follow.

'The **nucleus** is the largest organelle and contains the genetic information which is passed on from cell to cell when it divides. The nucleus is surrounded by a **nuclear membrane** which has small openings called **nuclear pores** that allow substances to enter/leave the nucleus.

The nucleus consists of **chromatin threads** which thicken to form rod-like chromosomes before the cell divides. The chromatin threads are found in the liquid-like **nucleoplasm**.

A small round body, the **nucleolus**, is also found in the nucleus.'



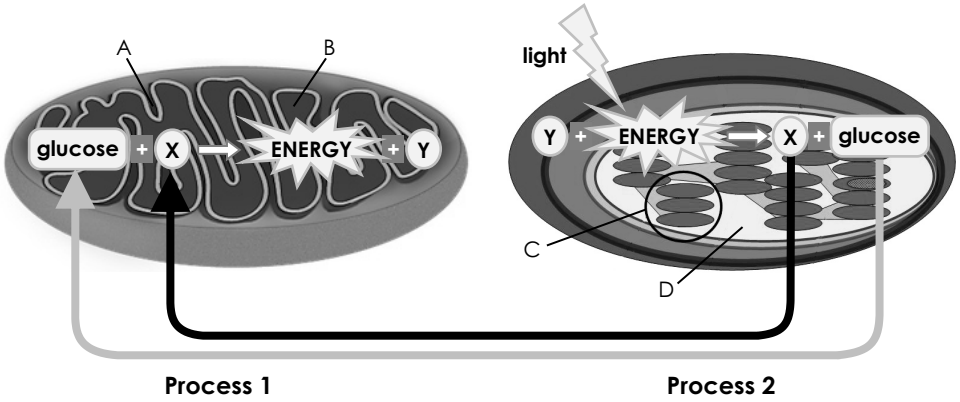
2.1 Provide a suitable heading for the diagram.

2.2 Provide labels A – E.

2.3 You know that the nucleus is a very important organelle in each cell as it controls all the activities of the cell. Using your knowledge and the text provided, briefly explain how the nucleus is able to be the control centre of the cell.

Question 3

The diagram below shows the link between two important organelles, and the processes that they perform.



3.1 Name the organelles in which the following take place:

3.1.1 Process 1 3.1.2 Process 2

3.2 Identify the processes represented by:

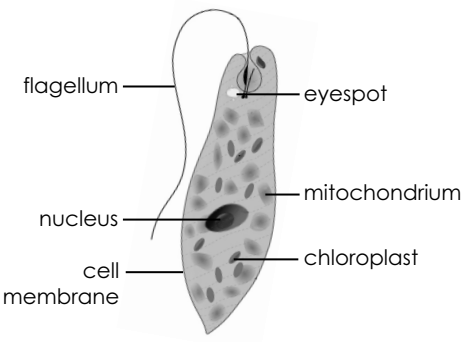
3.2.1 1 3.2.2 2

3.3 Provide labels for the parts A, B, C and D.

3.4 The grey arrow shows that the glucose produced by Process 2 is used in Process 1. What gas is represented by X on the diagrams?

Question 4

The diagram alongside is of a unicellular (one-celled) organism called *Euglena*, that is found in freshwater and has the ability to swim and hence move on its own.



4.1 In your opinion is this organism a plant or an animal? Give reasons which are **visible** in the diagram.

4.2 Which feature in the diagram gives *Euglena* the ability to swim?

4.3 Suggest the role of the eyespot in this organism and give a reason for your answer.

Question 5

A student did the following investigation using potatoes to cut chips. She made sure that all the potato chips were the same size and mass. Three potato chips (group 1) were placed in distilled water, three potato chips were placed in a 5% salt solution (group 2) and three potato chips were placed in a 10% salt solution (group 3) for 24 hours. The average percentage change in mass in each potato chip in each group was recorded. The table below shows the results of the investigation:

The percentage change in the mass of three identical potato chips when left overnight in three different solutions

Group	Solution	Average percentage change in mass (%)
1	distilled water	+23
2	5% salt solution	0
3	10% salt solution	-8

5.1 Which group of potato chips

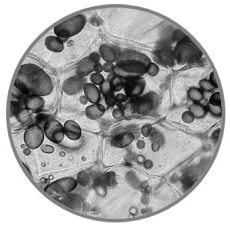
5.1.1 gained the most mass? 5.1.2 lost the most mass?

5.2 In the context of this investigation why do you think it is important to:

5.2.1 use potato chips that are the same size and mass?

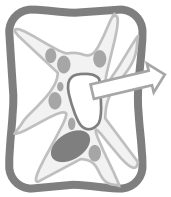
5.2.2 use three potato chips for each solution?

5.3 Before the investigation the student made a microscope slide of the potato tissue and then used the light microscope to observe the cells. The image provided shows what she observed through the microscope under high power.



She drew three rough sketches to illustrate one cell from each group (1, 2 and 3) as viewed under the microscope.

Cell A



Cell B

Cell C

5.3.1 Match up cells **A**, **B** and **C** with the correct group. Write down the group number and corresponding letter of the cell only.

5.3.2 Compare the cells in image A and B.

5.3.3 What do the arrows represent?

5.3.4 Give a reason for the appearance of Cell B using the results from the table and the student's drawing.

5.3.5 What can you conclude from this investigation?

Question 6

Read the passage below and answer the questions that follow.

If the nucleus of a cell, or some other structure such as a chloroplast, is removed from the cell, the isolated part cannot survive on its own. A complete cell is the smallest unit that can lead an independent life. This is neatly illustrated by unicellular *Amoeba*, a tiny animal that shows all the characteristics of living things, despite the fact that it consists of only one cell.

Multicellular animals and plants are made of more than one cell. A human adult's body is composed of approximately 60 billion cells. Instead of each one of these cells performing every function vital for life, it is more efficient for certain cells to become specialised to do particular jobs. A red blood cell, for example, is shaped like a biconcave disc. This shape presents a large surface area through which oxygen can pass into the cell before being transported to all parts of the body. As a result of its shape, a red blood cell is very good at this job.

6.1 Explain why a cell is often described as 'the basic unit of life'.

6.2 Distinguish between *unicellular* and *multicellular* living things.

6.3 A human baby is made up of about 2 billion cells. By how many times is the number of cells in a human adult greater than that in a baby?

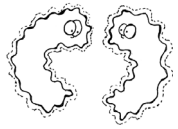
6.4 Use a quote from the passage to define a *tissue*.

6.5 Why is a red blood cell a good example of a cell with a structure ideally suited to its function?

6.6 The lungs (see Respiratory System p. 21) consist of many air sacs called alveoli and are made up of cells which are adapted for their function. How are these cells adapted for their function?

6.7 The small intestine is made up of many villi (see Digestive System p. 61 and Levels of Organisation p. 8) which are lined by specialised column-shaped cells with folds (microvilli) in the cell membrane where nutrients are absorbed. Draw one of the cells that lines the villi. You must include at least **four** labels.

6.8 The passage on p. 65 mentions certain cells becoming 'specialised to do particular jobs'. There are cells in the body that are not specialised for any function.



6.8.1 What is the name given to these unspecialised cells found in all living organisms?

6.8.2 What is the unique characteristic of the cells mentioned in Question 6.8.1?

6.8.3 Give **three** reasons to support research into using these cells for therapy and **three** reasons to oppose these studies.

6.8.4 Suggest **one** reason why parents decide to store unspecialised cells of their children from birth.

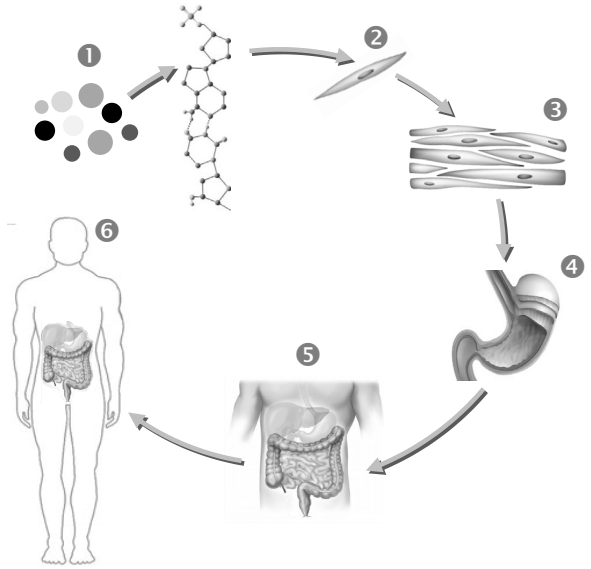
6.8.5 What is *therapeutic cloning*?

6.8.6 Which organ is only found in adult females and may be used as a source of these cells?

Question 7

The diagram below shows the level of organisation in living organisms. The following terms can be used to complete labels 1 – 6.

organ level, tissue level, chemical level, system level, organism level and cellular level



7.1 Which term best describes the following level:

7.1.1 5 7.1.2 3

7.1.3 6 7.1.4 1

7.2 Between which **two** levels do you think '**organelle**' would be? Give a reason for your answer.

7.3 Name the level of organisation that represents:

7.3.1 leaves in plants

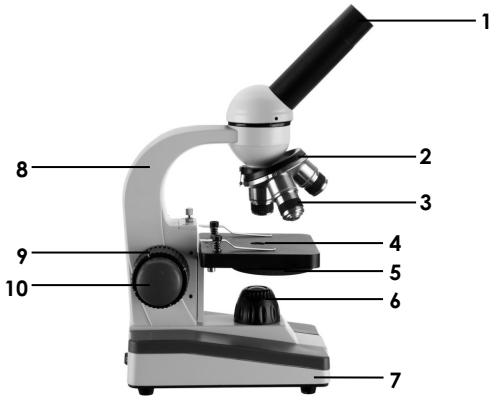
7.3.2 all the organs associated with reproduction in humans

7.3.3 chloroplasts in green plants

7.3.4 the heart in humans

Question 8

The following photograph shows a compound light microscope.



8.1 Give the **number** and **name** of the part of the microscope:

8.1.1 where you would place the slide

8.1.2 that you would adjust when viewing an object under the high power objective lens

8.1.3 that controls the amount of light shining through the object

8.1.4 that you use to change between the power objectives

8.2 The photomicrographs below show the field of view observed by looking through a microscope at some cells.


A


B


C

8.2.1 Does the specimen show plant cells **or** animal cells? Give **one** visible reason for your answer.

8.2.2 Using the letters from the diagrams, indicate which is:

(a) low magnification (b) medium magnification

(c) high magnification

TOPIC 2 SYSTEMS IN THE HUMAN BODY

Question 9

Give **one word** or **term** for each of the following statements:

9.1 Different organs that work together to perform a particular function.

9.2 A digestive juice which is secreted into the mouth.

9.3 A ring of muscle that controls the process of egestion.

9.4 The glands that release a secretion with enzymes that lubricate and digest food in the mouth cavity.

9.5 The organ that produces bile.

9.6 A tube that carries food from the mouth to the stomach.

9.7 Sores that develop when the lining of the gut is damaged.

9.8 The hardening or scarring of the liver in a person with alcoholism.

9.9 The blood vessels that carry blood under pressure and normally contain oxygen-rich blood.

9.10 The component of blood that plays a crucial role in blood clotting.

9.11 The fluid part of blood that contains nutrients and hormones.

9.12 A condition where a person has a blood pressure reading of 140/90 mmHg or higher.

9.13 The organs that supply the blood with oxygen and remove carbon dioxide.

9.14 The tiny blood vessels that join arteries to veins.

9.15 The process by which energy is released from the breakdown of glucose.

9.16 The process whereby particles move from a high concentration to a low concentration.

9.17 Muscles between the ribs that play an important role in breathing.

9.18 Tiny air sacs that make up the lungs.

9.19 The tube that carries air from the nasal cavity to the bronchus.

9.20 A disease caused by the uncontrolled division of cells in the lungs to form a growth.

9.21 A disease that results from inhalation of tiny building material fibres that cause scarring and damage to the lungs.

9.22 A change in the environment that causes a response.

9.23 Special cells or organs that are able to detect a stimulus.

9.24 Muscles or glands in the body that respond to stimuli.

9.25 The type of cells that make up the nervous system.

9.26 The inability to see distant objects clearly.

9.27 An electronic device that is surgically placed under the skin to restore hearing in a person with severe hearing loss.

9.28 Chemicals that cause nerve impulses to travel faster.

9.29 Release of the female gamete from the ovary.

9.30 The sinking of the embryo into the lining of the uterus in pregnancy.

9.31 The part of the female reproductive system where fertilisation occurs.

9.32 The organ that produces male gametes and testosterone.

9.33 The organ that produces the female gamete, oestrogen and progesterone.

9.34 The inability of a person to reproduce naturally.

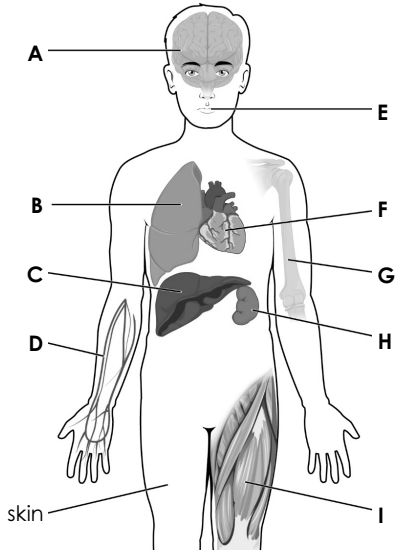
9.35 Treatment for STIs like gonorrhoea, chlamydia or syphilis.

Question 10

10.1 Which system:

10.1.1		**Makes the body move?**
10.1.2		removes waste and "cleans" the blood?
10.1.3		*protects soft organs & gives the body a frame?*
10.1.4		TAKES IN OXYGEN & RELEASES CARBON DIOXIDE?
10.1.5		is the control centre?
10.1.6		**is for eating and drinking?**
10.1.7		delivers blood to the body?
10.1.8		BREAKS DOWN FOOD INTO ABSORBABLE NUTRIENTS
10.1.9		makes you think?
10.1.10		produces offspring?

10.2 Examine the diagram alongside and answer the questions that follow.



10.2.1 Provide labels for the organs labelled B, C, F and H.

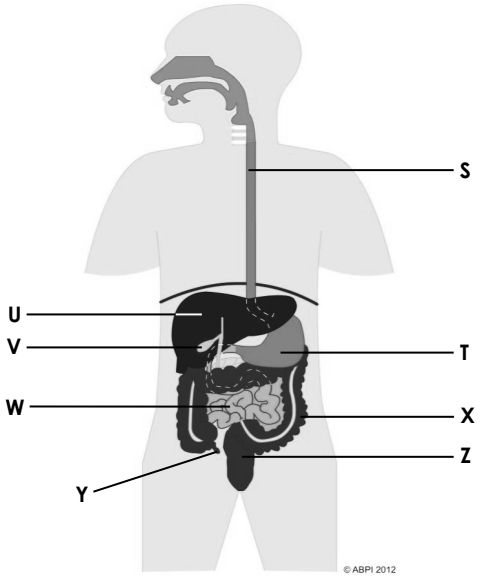
10.2.2 Which letter(s) belong to the circulatory system?

10.2.3 Identify the letter associated with:

(a) fat-digesting bile
(b) a stroke
(c) asbestosis
(d) rickets
(e) antagonistic action
(f) filtration and reabsorption

Question 11

11.1 Examine the diagram below and answer the questions that follow.



11.1.1 Which **letter** represents the organ where:
1 – villi increase the total surface area for absorption
2 – bile is produced to help digest fats
3 – churning mixes food with gastric juice

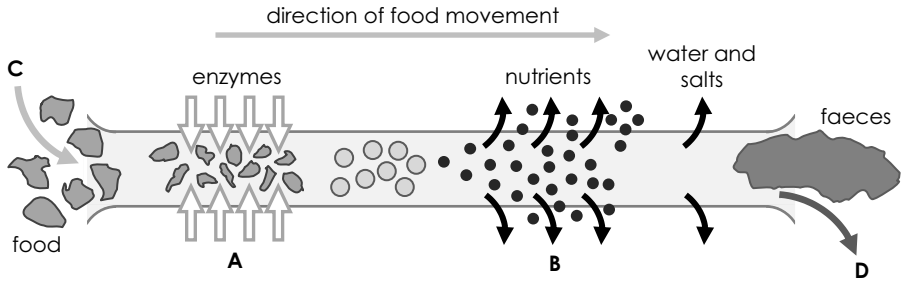
11.1.2 Explain the process of peristalsis and include the **letters** of **three** organs where it occurs.

11.1.3 List the organs which are part of the digestive system that are **not labelled** or **not drawn** in the diagram above.

11.2 Give a brief explanation for each of the following:

11.2.1 ingestion
11.2.2 digestion
11.2.3 absorption
11.2.4 egestion
11.2.5 insoluble molecules
11.2.6 enzymes

11.3 Examine the diagram below and answer the questions that follow.

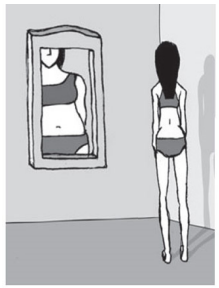


11.3.1 What processes are happening at A, B, C and D?

11.3.2 Briefly explain the role of enzymes in process A.

11.3.3 Explain the role of the blood system in process B.

11.4 The diagram below shows an eating disorder that is associated with the digestive system.



11.4.1 Name the disorder.

11.4.2 Why is this disorder described as a psychological condition?

Question 12

12.1 The following statements describe the structure and functions of blood. Determine if the statements are **true** or **false**. If the statement is false, correct the statement to make it true.

12.1.1 Red blood cells transport oxygen and carbon dioxide.

12.1.2 Blood plasma is responsible for causing the blood to clot.

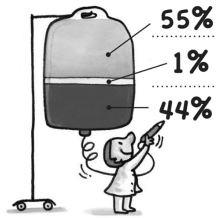
12.1.3 Red blood cells help protect the body from disease-causing organisms.

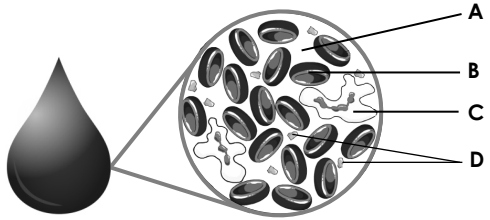
12.1.4 The fluid part of blood is the platelets.

12.1.5 Blood transports nutrients from the digestive system to all parts in the body.

12.1.6 Blood plasma contains nutrients, wastes and hormones that are transported around the body.

12.2 The following diagrams are on the composition of blood.





12.2.1 Provide labels for A, B, C and D.

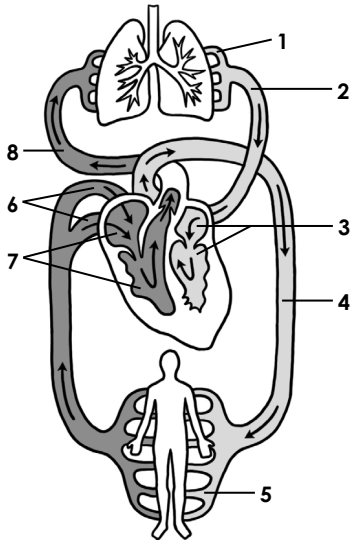
12.2.2 Name the component that comprises ... of blood.

(a) 55%

(b) 1%

(c) 44%

12.3 This diagram shows an overview of the circulatory system. Match the labels **1** – **8** to the statements in Questions 12.3.1 – 12.3.8.



12.3.1 Oxygen-rich blood is pumped from the heart to the body organs via arteries.

12.3.2 Oxygen-poor blood is pumped from the heart to the lungs.

12.3.3 Capillaries are tiny blood vessels that join arteries and veins to form networks all over the body.

12.3.4 Capillaries where oxygen diffuses from the lungs into the blood and carbon dioxide diffuses from the blood into the lungs.

12.3.5 Veins carry oxygen-poor blood back to the heart.

12.3.6 Oxygen-rich blood is carried from the lungs to the heart.

12.3.7 The heart receives oxygen-rich blood from the lungs.

12.3.8 The heart receives oxygen-poor blood from the body organs.

12.4 Read the following and together with your knowledge answer the questions that follow.

What is high blood pressure?

High blood pressure, or hypertension, occurs when your blood pressure increases to unhealthy levels. Your blood pressure measurement takes into account how much blood is passing through your blood vessels and the amount of resistance the blood meets while the heart is pumping. Narrow arteries increase resistance. The narrower your arteries, the higher your blood pressure. Over the long term, increased pressure can cause health issues, including heart disease. Early detection is important. Regular blood pressure readings can help you and your doctor notice any changes. If your blood pressure is elevated, your doctor may ask you to check your blood pressure over a few weeks to see if the number stays elevated or falls back to normal levels. Treatment for hypertension includes both prescription medication and healthy lifestyle changes. If the condition isn't treated, it could lead to health issues, including heart attack and stroke.

Adapted from: https://www.healthline.com/health/high-blood-pressure-hypertension#overview

12.4.1 What is another term for *high blood pressure*?

12.4.2 What is blood pressure?

12.4.3 What causes high blood pressure according to this extract?

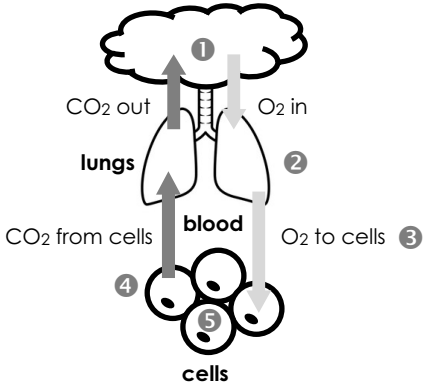
12.4.4 What are the causes of high blood pressure?

12.4.5 List **four** symptoms of high blood pressure.

12.4.6 High blood pressure can lead to health issues including heart attacks and strokes. Briefly describe the cause of each of these diseases.

Question 13

13.1 The diagram below represents part of the respiratory system.



13.1.1 Use the following terms to complete **1** – **5** in the diagram above:

transport of gases, cellular respiration, internal gaseous exchange, external gaseous exchange, breathing

13.1.2 Which process(es) (**1** – **5**) will involve diffusion? Explain your answer.

13.2 The diagrams below relate to some health issues associated with the respiratory system.

Diagram 1

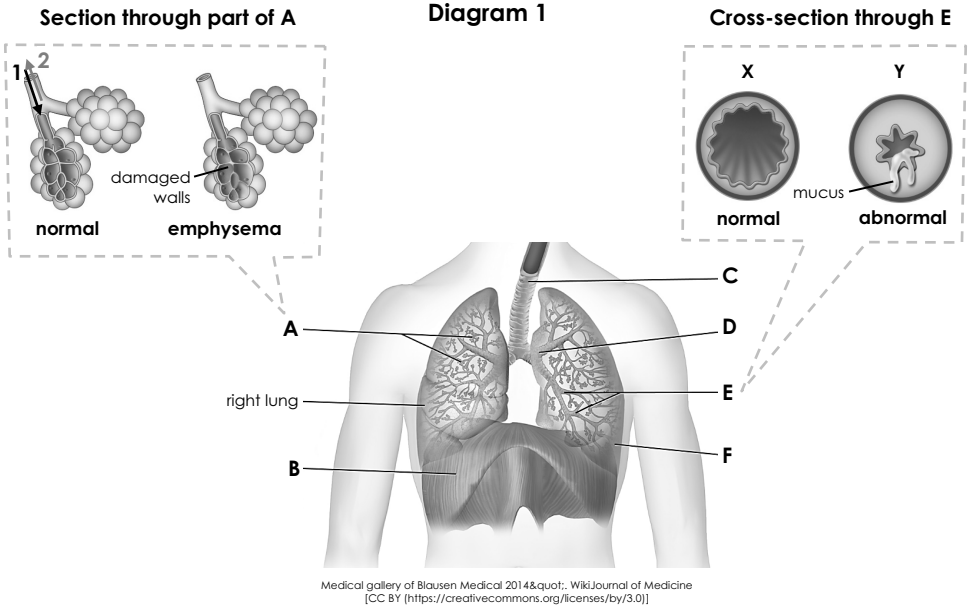


Diagram 2

13.2.1 Identify and give the functions of labels A, B, C and E.

13.2.2 Which gases do arrows 1 and 2 represent?

13.2.3 In Diagram 2 explain the difference between the normal and abnormal cross-sections of label E.

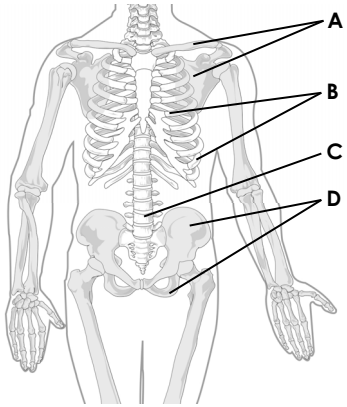
13.2.4 Identify the respiratory disease that is associated with the abnormal condition of structure E.

13.2.5 Explain the link between Diagram 1 and the abnormal condition of E.

13.2.6 A person with emphysema has shortness of breath. This is also a symptom of the disease identified in Question 13.2.4. Using the information in the diagram, explain why both diseases share the same symptom.

Question 14

14.1 The diagram shows part of the human skeleton.



14.1.1 Identify labels A – D.

14.1.2 Differentiate between the following two terms:

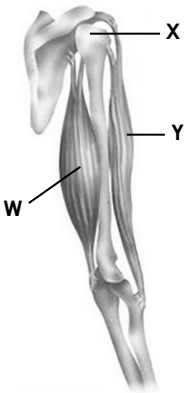
(a) *contraction* and *relaxation* of muscles

(b) *cardiac* and *smooth muscle*

(c) *locomotion* and *movement*

14.1.3 List **two** minerals stored by the bones.

14.2 The diagram shows part of the upper limb.



14.2.1 Label X represents a type of joint. What is meant by a *joint*?

14.2.2 Why is this joint so useful?

14.2.3 What is the difference between this type of joint and the elbow joint?

14.2.4 Explain the relationship between muscles W and Y to bring about the extension movement shown in the diagram.

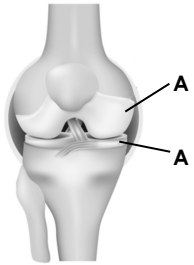
14.2.5 There are **three** types of muscle tissue. Consider the muscle attached to the skeleton.

(a) Name this type of muscle tissue.

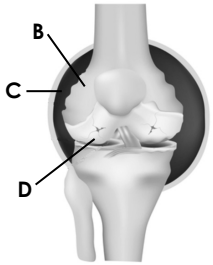
(b) State the function of these muscles.

14.2.6 List **four** functions of the human skeleton.

14.3 A longitudinal section through two knee joints are illustrated below.



Healthy joint



Damaged joint

14.3.1 Suggest which disease is illustrated in the damaged joint.

14.3.2 Write down the **letter only** of the label described by the following:

(a) thinning layer leads to friction and pain between bones

(b) shows swelling due to build-up of fluid in inflamed joint

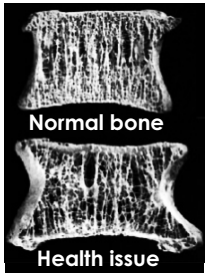
(c) collagen-rich, flexible tissue that reduces friction in the joint

(d) breakdown of hard, mineral-rich tissue

14.3.3 Describe the location and function of cartilage in this joint.

14.3.4 Distinguish between a *ligament* and a *tendon*.

14.4 The table below summarises two health issues of the musculoskeletal system. Complete the table below by writing down the numbers and answers only.

Health issue … 14.4.1 …	Health issue … 14.4.4 …
	
14.4.2 cause 14.4.3 symptoms	14.4.5 cause 14.4.6 symptoms

Question 15

15.1.1 What is the function of the excretory system?

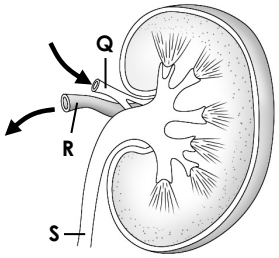
15.1.2 Define *metabolic waste* and list **three** examples.

15.1.3 Distinguish between *excretion* and *egestion*.

15.2 Make a biological drawing of the human excretory system. Include the following labels:

kidney, ureter, bladder, urethra, sphincter

15.3 The diagram alongside shows a longitudinal section through the kidney.



15.3.1 Provide labels for parts Q, R and S.

15.3.2 What is the main function of this organ?

15.3.3 The table below shows the composition of samples of fluid from structures **Q**, **R** and **S**.

	STRUCTURE I	STRUCTURE II	STRUCTURE III
Component	**Concentration**	**Concentration**	**Concentration**
toxins	higher	very high	lower
glucose	higher	none	lower
oxygen	higher	-	lower
salts	higher	high	lower
water	higher	low	lower
proteins	high	none	high

(a) Using **letters only** (Q, R, S), identify structures I, II and III based on the data in the table.

(b) Suggest a reason why:

1 – toxins are lower in structure III

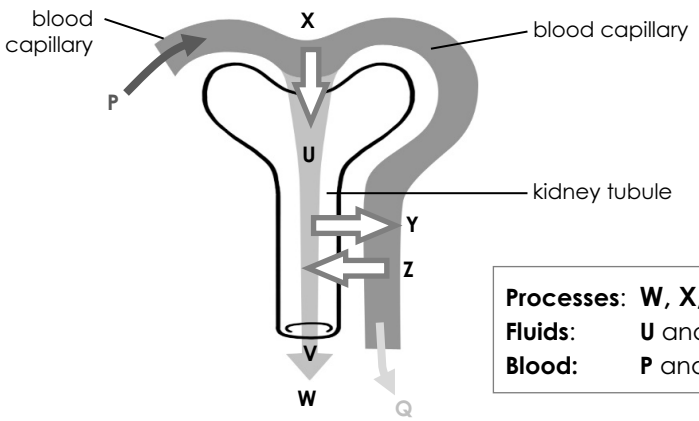
2 – oxygen is lower in structure III

3 – proteins remain the same in structure I and III

4 – glucose is not present in structure II

5 – water is low in structure II

15.4 A simplified diagram to show the process of purifying blood in the kidney tubules.



Processes:	**W**, **X**, **Y** and **Z**
Fluids:	**U** and **V**
Blood:	**P** and **Q**

15.4.1 Identify the processes **W**, **X**, **Y** and **Z** using the terms provided below:

reabsorption, filtration, secretion, excretion

15.4.2 There are three different fluids in the diagram above: blood, urine and filtrate. Identify fluids labelled **U** and **V**.

15.4.3 A sample of blood is taken from **P** as well as point **Q**. Indicate which blood sample is described by each of the following statements. Write down the letter only (P or Q).

(a) purified blood, low in waste substances, returning to the body

(b) unfiltered blood high in useful and waste substances

(c) blood with less water and less oxygen

15.5 Urinary tract infections or 'UTIs' are the second most common kind of infections in humans after respiratory infections. Of all bladder infections, only 20% of them occur in men.

15.5.1 What percentage of bladder infections occur in women?

15.5.2 Why are UTIs more common in women?

15.5.3 Describe the symptoms associated with bladder infections.

15.5.4 Why are antibiotics prescribed as treatment for a patient with a UTI?

15.6 There are various types of kidney stones in size and shape which can cause severe pain if they block excretory tubes.

15.6.1 What causes the formation of these crystals in the kidneys?

15.6.2 Why are some patients treated with ultrasound waves and others undergo surgery for kidney stones?

15.6.3 What are the warning signs that a patient may have kidney stones?

15.7 Renal failure patients have kidneys that are unable to filter and purify the blood. They need dialysis on a regular basis (weekly or daily) for survival. Dialysis machines act as artificial kidneys. The patient's blood is diverted into a dialyser which filters and purifies the blood before it is returned to the body. Diagram **I** shows the process of dialysis. Diagram **II** shows the internal structure of a dialyser with tubes that allow substances to move by diffusion in and out of the blood/ dialysis fluid. The labels A – D indicate the same structures in both diagrams.

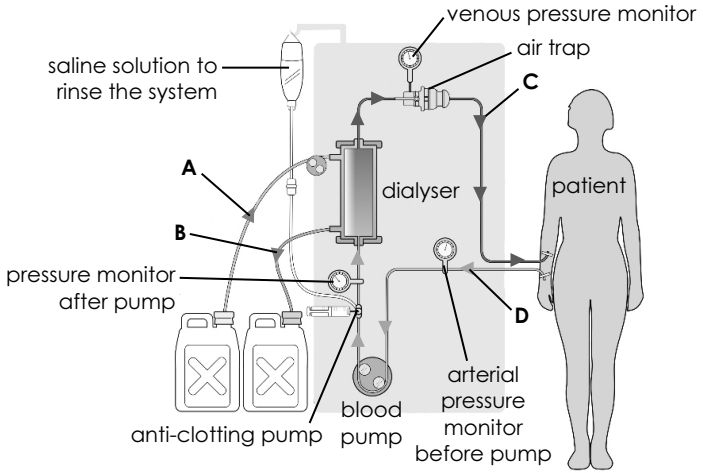


Diagram I

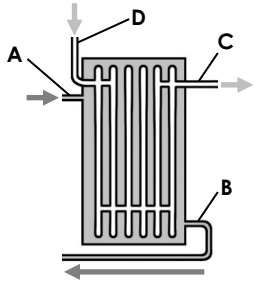


Diagram II

15.7.1 Define the term *dialysis*.

15.7.2 Match up the labels on Diagrams **I** and **II** with the following statements. Write down the correct letter only.

(a) cleaned blood returned to vein

(b) fresh dialysis fluid with correct levels of nutrients and minerals

(c) blood removed from artery for cleaning

(d) used dialysis fluid with waste products from blood

15.7.3 The dialyser tubes in Diagram **II** are membranes that allow certain substances to pass through and not others. What is the term given to this type of membrane?

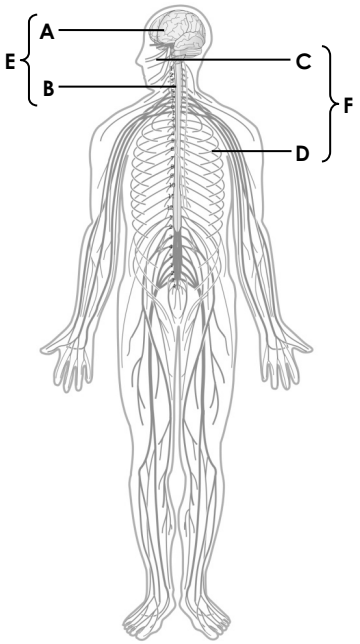
15.7.4 Suggest a reason why the dialyser tubes in Diagram **II** are folded and not straight?

15.7.5 What is the permanent alternative to dialysis for a patient with renal failure?

15.7.6 The treatment for renal failure is very expensive so state hospitals have to make difficult decisions about which patients should receive treatment and who should be denied treatment. Suggest **three** factors that may be considered to reject a patient for dialysis or surgery.

Question 16

16.1 The nervous system is a highly complex system. The central nervous system consists of the brain and spinal cord. The peripheral nervous system consists of nerves from the brain called cranial nerves and spinal nerves that enter/leave the spinal cord.



Medium69, Jmarchn [CC BY-SA 4.0 (https://creativecommons.org/licenses/by-sa/4.0)]

16.1.1 Provide labels for **A**, **B**, **C**, **D**, **E** and **F**.

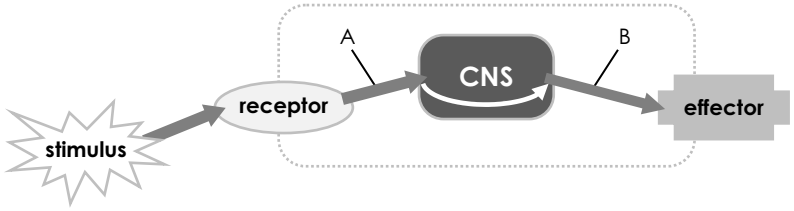
16.1.2 Give the functions of the following parts of the nervous system:

(a) brain (b) spinal cord (c) nerves

16.1.3 Complete the following table (a) to (i):

Sense organ/ receptor	Sense	Stimulus
tongue	(a)	(b)
(c)	sight	(d)
(e)	(f)	sound
(g)	(h)	mechanical
nose	(i)	chemicals

16.2 The diagram below shows the pathway of a nerve impulse for the body to respond to a stimulus:



16.2.1 What is this pathway called?

16.2.2 Identify the type of neuron at:

(a) A (b) B

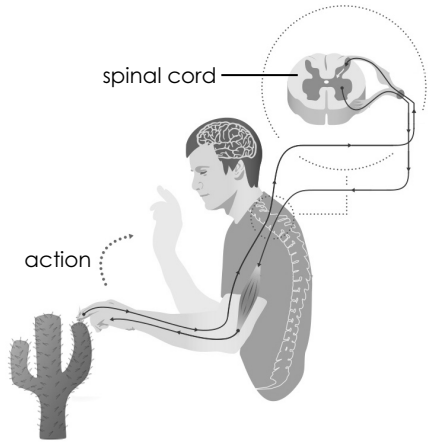
16.2.3 What is the function of neuron:

(a) A (b) B

16.2.4 Explain what is meant by the following:

(a) stimulus (b) effector

16.3 The diagram below shows a nerve pathway.



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16.3.1 Identify the …

(a) stimulus (b) response

(c) effector

16.3.2 In each of the following examples, identify the stimulus (**S**), effector (**E**), and response (**R**):

(a) You put your hand on a hot plate and immediately move your hand away.

(b) It is a hot day and you start to produce sweat to cool the body down.

(c) The pupils of your eyes dilate (widen) when you walk into a dark room.

16.4 Drugs, alcohol and many medicines work by affecting the transmission of nerve impulses.

16.4.1 Distinguish between a *stimulant* and *depressant*.

16.4.2 What effect do each of the following have on the speed of the transmission of nerve impulses:

(a) caffeine (b) alcohol

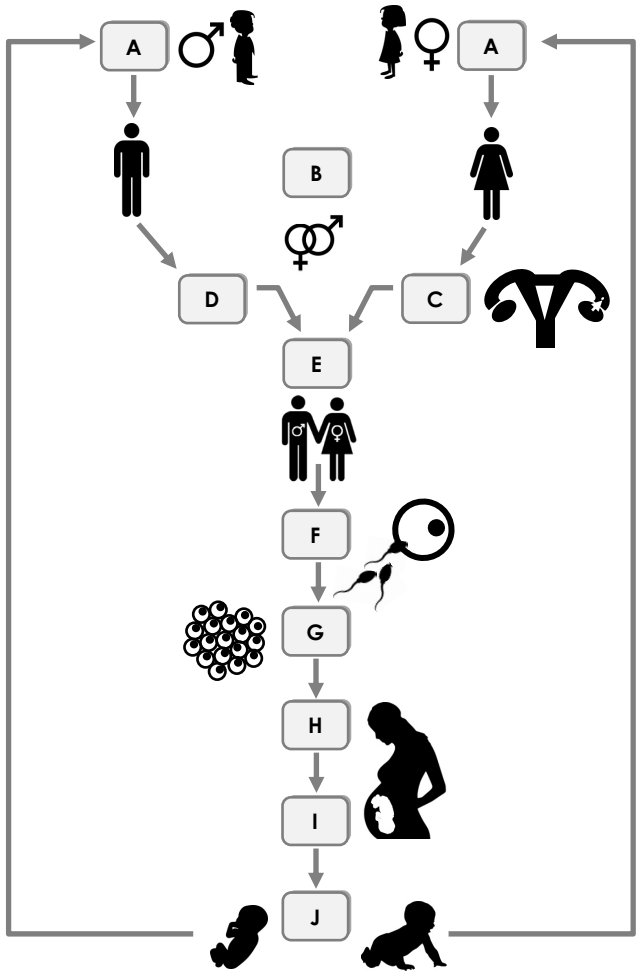
(c) sleeping tablet (d) painkiller

(e) anaesthetic

Question 17

17.1 The diagram below shows the life cycle of humans.

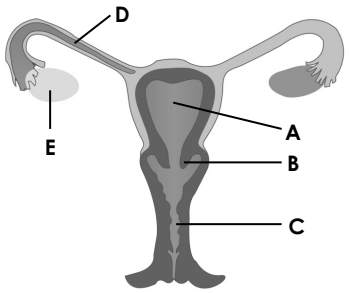
Life cycle of humans



Use the terms in the box below to complete the processes or stages numbered **A** – **J**.

growth and development ; fertilisation ; ovulation ; maturation and puberty ; cell division and embryonic development ; birth ; implantation ; copulation and ejaculation ; sperm production ; reproductively mature adults

17.2 The diagram below shows the basic structure of a human system.



17.2.1 Provide a suitable heading for the diagram.

17.2.2 Provide labels for A, B, C, D and E.

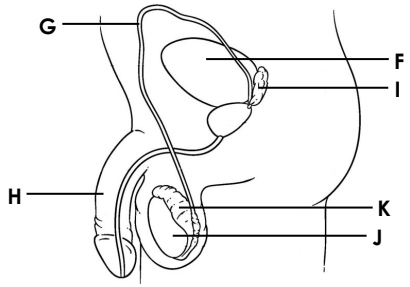
17.2.3 Give the letter **only** of the part:

(a) that produces the egg cell

(b) where the embryo develops and is nourished to form the foetus

(c) that represents the site of fertilisation

17.3 The diagram below shows the side view of the male reproductive system.



17.3.1 Provide labels for G, K and J.

17.3.2 Give the letter of the part that:

(a) produces the sperm

(b) transports the sperm to the urethra

(c) deposits the semen into the female reproductive system

17.4 The following extract refers to some reproductive health issues.

Health issues relating to the reproductive system

Infertility (I)

Infertility is the inability for a couple to reproduce naturally. There are many causes of infertility due to problems in the male or female systems.

Sexually transmitted infections (STIs)

These are infections that are transmitted from one person to another during any type of sexual contact. They are caused by micro-organisms that occur in the body fluids like mucus that lines the vagina, blood or semen.

Foetal Alcohol Syndrome (FAS)

If a mother drinks alcohol regularly while she is pregnant, she may cause many problems for her developing child. Pregnant women who drink heavily have a high risk of having a child that suffers from FAS.

17.4.1 Write down the letter/s only (**I** for infertility, **STIs** and **FAS**) to indicate which condition/s are described in the following statements:

(a) may be prevented with regular condom use

(b) may be treated with antibiotics

(c) healthy lifestyle choices may decrease risk

(d) may be caused by damaged tissues

17.4.2 What is meant by *infertility*?

17.4.3 Give possible reasons for infertility in:

(a) females (b) males

17.4.4 List **three** sexually transmitted infections.

17.4.5 How does a pregnant woman who drinks alcohol increase the chances of her baby developing FAS?

TOPIC 3

HUMAN REPRODUCTION

Question 18

Give **one word** or **term** for each of the following statements:

18.1 The type of reproduction that produces offspring which are genetically identical to the parent.

18.2 Sex cells produced by male and female sex organs.

18.3 The cell that results from the fusion of a sperm and egg cell.

18.4 The gland that releases hormones which trigger the testis and ovary to secrete hormones.

18.5 Molecules which travel in the blood as chemical messengers.

18.6 A female hormone that causes fat deposition on the hips.

18.7 A male hormone that stimulates the production of sperm in the testes.

18.8 A sac-like structure that protects the testes outside the male body.

18.9 A structure where sperm mature and are stored before ejaculation.

18.10 A large accessory gland at the base of the penis which provides fluid to the sperm to form semen.

18.11 Part of a sperm which gives it motility, i.e. the ability to move.

18.12 A process whereby an egg cell is released from the ovary and enters the Fallopian tube.

18.13 A tube lined with cilia that transports the egg cell from the ovary to the uterus.

18.14 The uterine lining that thickens during the menstrual cycle in preparation for implantation of an embryo.

18.15 A muscular tube in the female reproductive system which receives the penis during sexual intercourse.

18.16 Part of the menstrual cycle where the inner lining or endometrium is shed.

18.17 The release of semen from the urethra of the penis.

18.18 A fertilised egg cell.

18.19 A structure that protects the developing foetus from harmful microorganisms and acts as a filter.

18.20 A condition in a developing foetus that is caused by exposure to excess alcohol during pregnancy.

18.21 The time period from fertilisation until birth.

18.22 The membrane that surrounds and protects the foetus during pregnancy.

18.23 A structure that contains blood vessels and connects the foetus to the placenta.

18.24 A structure consisting of both maternal (mother) and embryonic tissue that allows diffusion of useful/waste products.

18.25 The part of the female reproductive system where the mucus thickens to prevent entry of sperm due to hormones in the contraceptive pill.

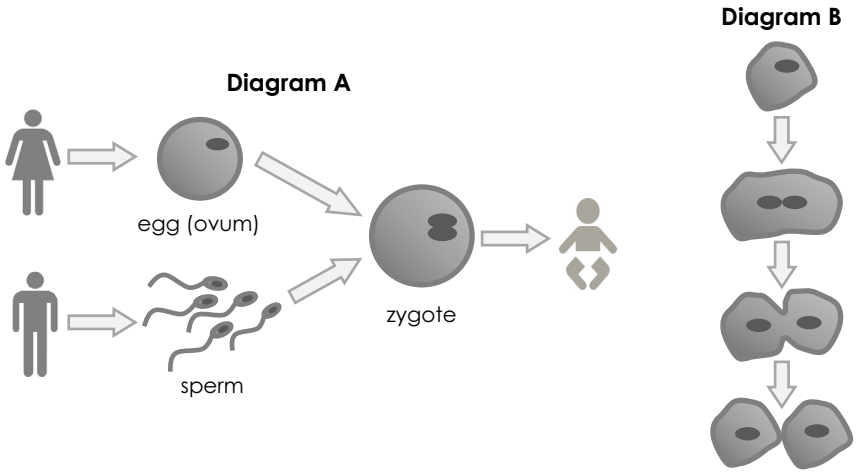
18.26 A form of contraception whereby sexual intercourse is avoided during the fertile period of the menstrual cycle.

18.27 When a woman carries a pregnancy for another female who is unable to fall pregnant.

18.28 The deliberate termination of pregnancy before birth.

Question 19

19.1 Reproduction is an important characteristic of living organisms. Diagrams A and B shows asexual and sexual reproduction.

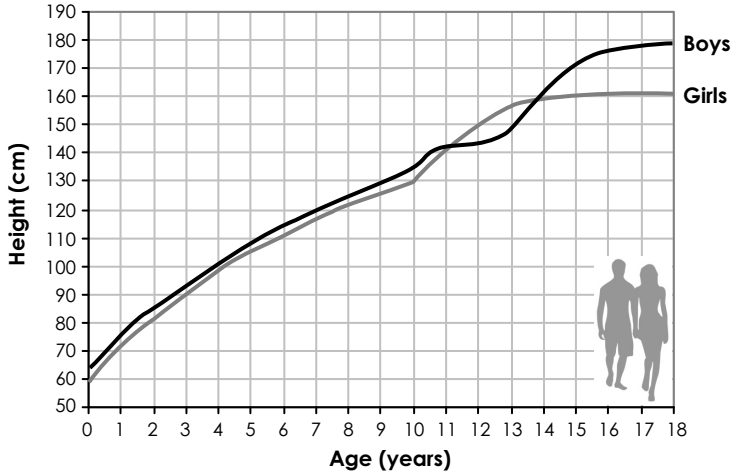


19.1.1 What is the purpose of reproduction?

19.1.2 Which Diagram A or B shows asexual reproduction? Explain.

19.1.3 Which Diagram A or B shows sexual reproduction? Explain.

19.2 The graph shows growth curves for boys and girls.



19.2.1 The graph shows a phase of rapid growth in boys and girls from age 9 to 18 years. Identify this stage in the human life cycle.

19.2.2 Why is this stage important?

19.2.3 Hormones play a significant role in this stage.

(a) What are *hormones*?

(b) Name the male hormone involved.

(c) Name **two** female hormones involved.

19.2.4 Both the male hormone and female hormones mentioned above cause the development of secondary sexual characteristics.

(a) What is a *secondary sexual characteristic*?

(b) List **three** male secondary sexual characteristics that are associated with the skin.

(c) List **three** female secondary sexual characteristics that cause a change in body shape.

19.2.5 According to the graph, determine the average age for the growth spurt in:

(a) girls (b) boys

19.2.6 Using the data provided, what is the youngest age at which girls and boys are most likely to be the same height?

19.2.7 According to the graph, at which age do boys become taller than girls?

Question 20

20.1 The following diagrams (A and B) show the structure of the female reproductive system.

Diagram A

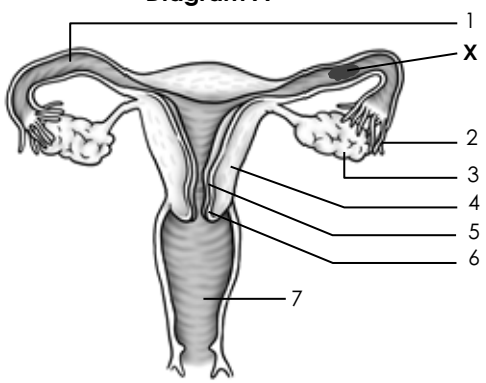
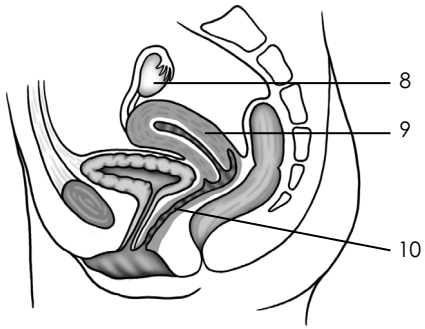


Diagram B



20.1.1 Provide a suitable heading for Diagram B.

20.1.2 Provide labels for 1 – 10.

20.1.3 Write down the number/s which:

(a) form the ova.

(b) has finger-like projections to sweep the released ovum into the Fallopian tube.

(c) is made up of smooth/involuntary muscle and contracts during childbirth.

(d) is shed during menstruation.

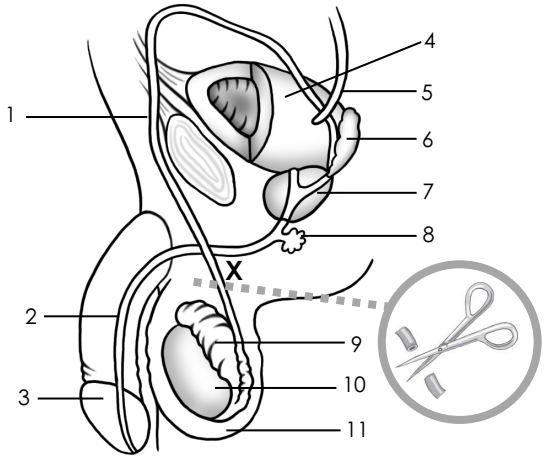
20.1.4 Name the **two** hormones secreted by structure 3.

20.1.5 Suggest what label **X** may represent.

20.1.6 Give the number of the site of fertilisation.

20.1.7 If ovulation occurs on the same side as **X**, why will fertilisation **not** be able to occur?

20.2 The diagram below represents the human male reproductive system.



20.2.1 Give the number and name of the organ that is **not** part of the reproductive system.

20.2.2 Identify parts 1 and 10; for **each** part name the equivalent part in the female which has the same function.

20.2.3 Write down the number and name of the structure that:

(a) produces male gametes

(b) allows the sperm to mature

(c) is one of a pair that releases fluid into the vas deferens to form semen with sperm before entering the urethra

(d) transfers sperm from the testes to the urethra

20.2.4 List, in order, all the structures a sperm cell passes from where it is stored until it is released from the body.

20.2.5 What is the significance of the testes being housed outside the body?

20.2.6 Identify and explain the surgical procedure indicated at **X**.

Question 21

21.1 The table below shows the results of a survey carried out in a maternity hospital:

	Mass of baby when born (kg)	Smoker mother (YES/NO)
Baby 1	2,7	YES
Baby 2	3,5	NO
Baby 3	4,8	NO
Baby 4	3,9	YES
Baby 5	4,6	YES
Baby 6	5,2	NO
Baby 7	3,6	NO
Baby 8	3,4	YES
Baby 9	3,2	YES
Baby 10	3,3	NO
Baby 11	2,9	YES
Baby 12	4,5	NO

21.1.1 Work out the average mass of babies born to:

(a) smokers

(b) non-smokers

21.1.2 Give a possible hypothesis for this survey.

21.1.3 Identify the:

(a) independent variable

(b) dependent variable

21.1.4 Give **one** reason why this investigation is not valid.

21.1.5 How does smoking affect the development of babies in the womb?

21.2.1 Read the following statements and identify the correct sequence of the **four** processes:

(a) formation of gametes - implantation - intercourse - fertilisation

(b) formation of gametes - intercourse - fertilisation - implantation

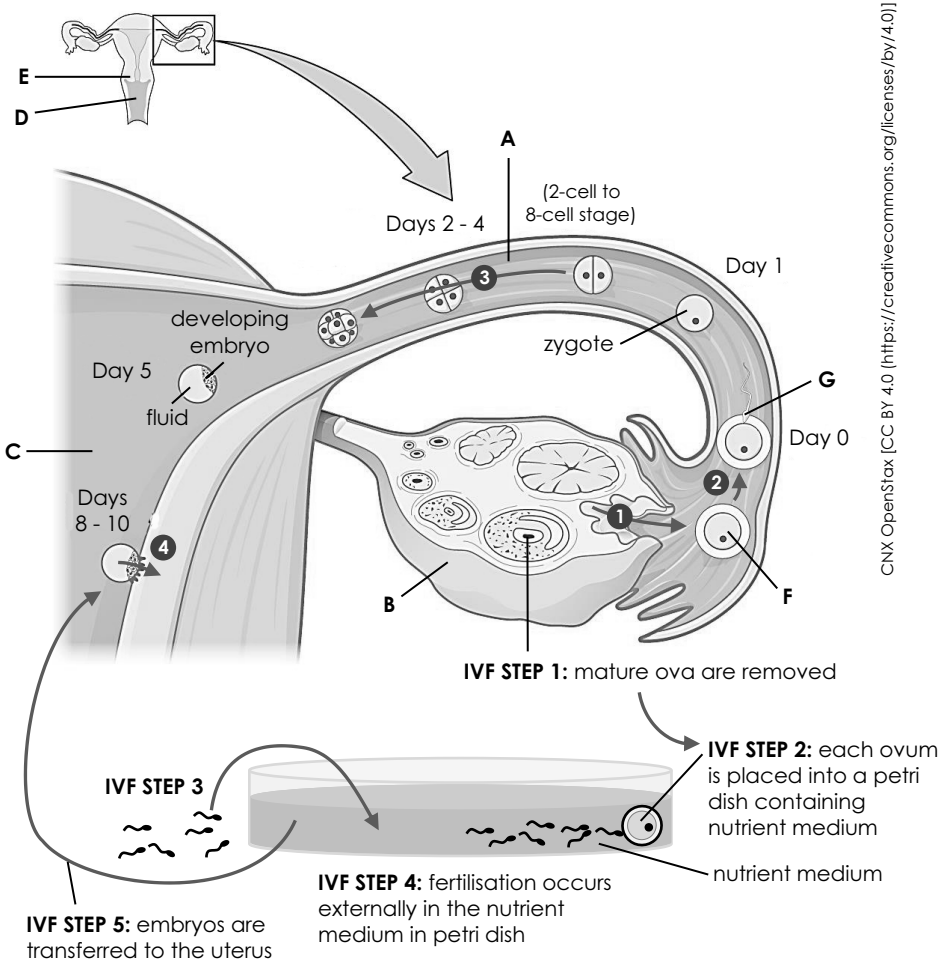
(c) implantation - formation of gametes - intercourse - fertilisation

(d) intercourse - fertilisation - formation of gametes - implantation

(e) fertilisation - implantation - intercourse - formation of gametes

21.2.2 Explain each of the **four** processes mentioned in Question 21.2.1 above.

21.3 The following diagram illustrates the pathway of natural fertilisation and *in vitro* fertilisation (IVF).



21.3.1 Provide labels for A – G.

21.3.2 Briefly explain what is involved at **IVF STEP 3**.

21.3.3 Draw a detailed diagram of the cell labelled G.

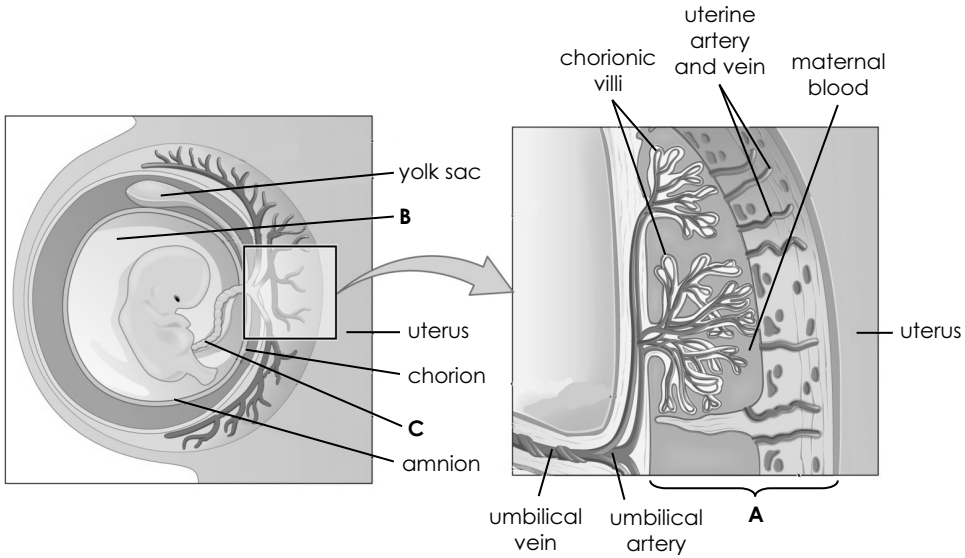
21.3.4 Identify the processes labelled ❶ – ❹.

21.3.5 What stage/time in the menstrual cycle would the placement of the embryo be unlikely to succeed? Give a reason.

21.3.6 Babies produced by IVF are sometimes called 'test tube babies'. Why is this description misleading?

21.3.7 Explain why IVF can cause multiple births (e.g. twins).

21.4 The development and nourishment of the embryo is illustrated in the diagrams below.



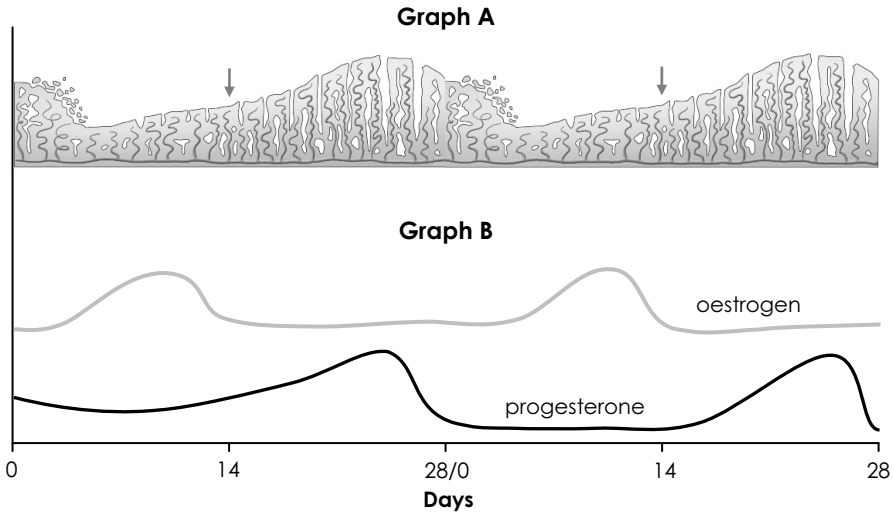
21.4.1 Identify A and explain why it is important that the maternal and embryo blood is in close contact.

21.4.2 Provide a label for B and give a function.

21.4.3 Describe the structure and function of C.

21.4.4 The chorion is the outer embryonic membrane visible in the diagram. It forms chorionic villi that grow into the lining of the uterus to form the placenta. Suggest a reason for the formation of so many finger-like outgrowths.

21.5 Graph A represents the thickness of the endometrium over TWO menstrual cycles. Graph B represents the concentration of progesterone and oestrogen in the blood of a mature woman over the same period of time. The arrows represent an important event that occurs during the menstrual cycle.



21.5.1 What significant event during the menstrual cycle is represented by the arrows?

21.5.2 Explain what is meant by *the fertile period* in the menstrual cycle.

21.5.3 Provide evidence from the graph that indicates fertilisation and implantation did not occur.

21.5.4 Which organ in the female's body is responsible for secreting progesterone and oestrogen?

21.5.5 According to the graph, which hormone decreases to cause breakdown of the endometrium (menstruation)?

21.6 The following questions refer to the illustration of a pregnant woman provided alongside.

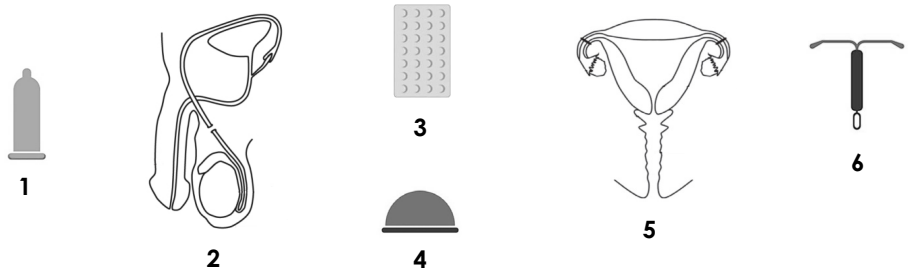
21.6.1 List the **two** harmful toxins that the pregnant mother is exposing to her unborn foetus.

21.6.2 The unborn foetus can develop FAS. What does FAS stand for?

21.6.3 List **three** characteristics of a baby that is born with FAS.

21.6.4 Describe the role of the placenta in protecting the foetus from harmful substances in the mother's blood.

21.7 The diagram below shows different contraceptive methods. Examine and answer the questions that follow.



21.7.1 Match the following types of contraception with 1 – 5. Write down the **letter** and **number only**.

A surgical method (tubal ligation)

B surgical method (vasectomy)

C intra-uterine device

D condom

E diaphragm

F contraceptive pill

21.7.2 Write down the number(s) only of the method that:

(a) result in a permanent form of contraception

(b) prevent ovulation

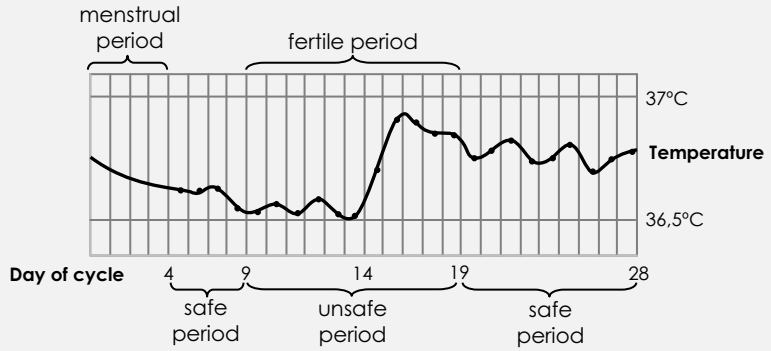
(c) prevent sperm to reach and fertilise an egg

(d) help prevent the transmission of sexually transmitted infections (STIs)

21.7.3 The extract below discusses alternative forms of contraception.

The safe period or rhythm method of contraception

This contraceptive method is completely natural. Partners using this method don't have sex during the most fertile time of the woman's cycle to avoid a pregnancy. This is around the time of ovulation when the egg is in the Fallopian tubes. A rise in body temperature occurs immediately after ovulation. The couple only have sex on 'safe days'. This is not a very reliable method as the woman needs to have a very regular cycle to successfully prevent pregnancy. Many women fall pregnant using this method.



(a) On which day did ovulation occur? Explain.

(b) What is meant by *safe period* and *unsafe period*?

(c) Explain what happens to the thickness of the endometrium during the menstrual cycle.

TOPIC 4 CIRCULATORY AND RESPIRATORY SYSTEMS

Question 22

Give **one word** or **term** for each of the following statements:

22.1 Windpipe that transports air to and from the lungs.

22.2 A dome-shaped respiratory muscle that plays an important role in inhalation and exhalation

22.3 Respiratory muscles found between the ribs.

22.4 Tiny tubes that transport air to and from the alveoli.

22.5 Structure at the top of the trachea that contains the vocal cords.

22.6 A flap of cartilage on top of the larynx that prevents food entering the trachea during swallowing.

22.7 The physical process of keeping the lungs ventilated by inhalation and exhalation.

22.8 A pair of air tubes that are kept open by cartilage rings.

22.9 Tiny air tubes that lack cartilage rings.

22.10 The shape of the diaphragm during exhalation.

22.11 The muscles responsible for lifting the ribs upwards and outwards during inhalation.

22.12 The process whereby gases move by diffusion in the body.

22.13 The movement of molecules from a high concentration to a low concentration.

22.14 The part of the lungs where gaseous exchange occurs.

22.15 The process that occurs in every cell, using oxygen and releasing carbon dioxide.

22.16 Blood that has a high concentration of oxygen.

22.17 Blood that has a high concentration of carbon dioxide.

22.18 The air sacs where oxygen moves from a high concentration to a lower concentration in the blood.

22.19 The gas that moves by diffusion from a high concentration in the blood to a low concentration in the lungs.

22.20 The organelle where the process of cellular respiration occurs.

22.21 The chamber of the heart with the thickest wall.

22.22 The structures that prevent the backflow of blood in the heart.

22.23 The smaller chambers of the heart that receive blood from veins.

22.24 The larger chambers of the heart that pump blood away from the heart.

22.25 The only artery to carry deoxygenated blood.

22.26 Blood vessels which carry blood away from the heart.

22.27 The wall that separates the left side of the heart from the right side.

22.28 Blood vessels with thick muscle walls that carry blood under pressure.

22.29 Blood vessels that have permeable walls for diffusion of substances.

22.30 Blood vessels with valves that carry blood under low pressure.

22.31 The type of circulation in humans where blood passes through the heart twice in one complete circuit.

22.32 The type of circulation that involves the heart, lungs and back to the heart.

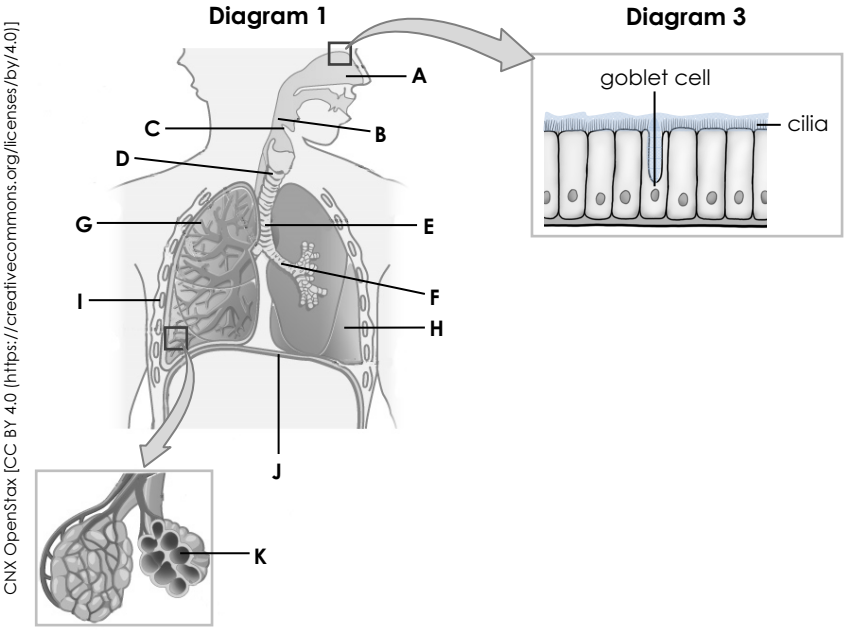
22.33 The type of circulation that involves the heart, body organs and back to the heart.

22.34 The chamber of the heart that receives oxygenated blood from the lungs.

22.35 The type of circulatory system where the blood stays in blood vessels.

Question 23

23.1 The air passages which transport air to and from the lungs can be divided into the upper respiratory tract and the lower respiratory tract. The upper respiratory tract consists of the nasal cavity, pharynx and larynx. The lower respiratory tract consists of trachea, bronchi and bronchioli. Diagrams 1, 2 and 3 illustrate different parts of the respiratory system.



23.1.1 In Diagram 1 and 2 write down the letters of the labels which form part of the:

(a) upper respiratory tract (b) lower respiratory tract

23.1.2 Diagram 3 shows that the air passage labelled A is lined with a tissue that secretes mucus. What is the function of this mucus?

23.1.3 The alveolus (label K) is an efficient gaseous exchange surface. List **four** features of the lungs (label H) that meet the requirements of an efficient gaseous exchange surface.

23.1.4 Label C plays a role in swallowing. Explain how this flap of cartilage works to protect the air passages.

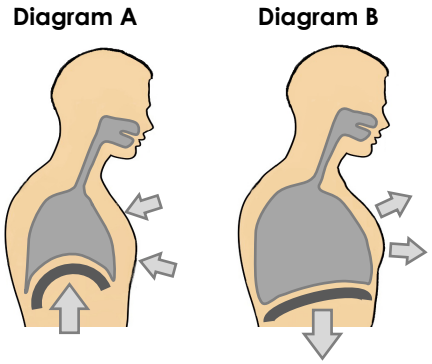
23.1.5 What is the main difference between structure F and G in terms of support?

23.1.6 Name the breathing muscle found at J and give the role of this muscle.

23.1.7 Name the breathing muscles that are found between the structures labelled I that increase/decrease the width of the thoracic cavity for breathing.

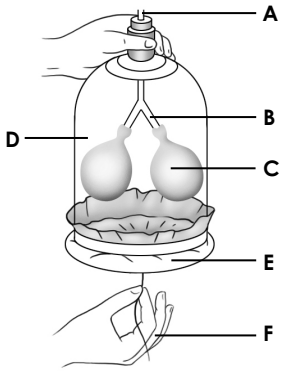
23.1.8 Why do you think a lower respiratory infection is more serious than an upper respiratory infection?

23.2 Breathing involves the mechanisms of inhalation (inspiration) and exhalation (expiration) which are illustrated in the diagrams provided. Complete the table, (1) – (11), to compare the two mechanisms.



Process __ (1) __ illustrated in Diagram __ (2) __	Process __ (3) __ illustrated in Diagram __ (4) __
Diaphragm contracts	(5)
(6)	chest cavity decreases in length
(7)	external intercostal muscles relax
ribs move up and out therefore chest cavity increases in width	(8)
volume increases and pressure decreases	(9)
(10)	air flows out
lungs become inflated	(11)

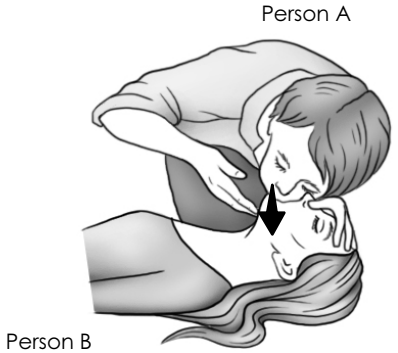
23.3 The diagram shows the apparatus used to demonstrate a particular aspect of human breathing.



23.3.1 What body parts are represented by each part labelled B, C and E?

23.3.2 If E is pulled down by hand at F, will the balloons labelled C inflate or deflate? Explain your answer.

23.4 Person A arrives at a scene of an accident and sees that person B is not breathing. Person A has completed a first aid course and performs mouth-to-mouth resuscitation as well as chest compressions on person B.



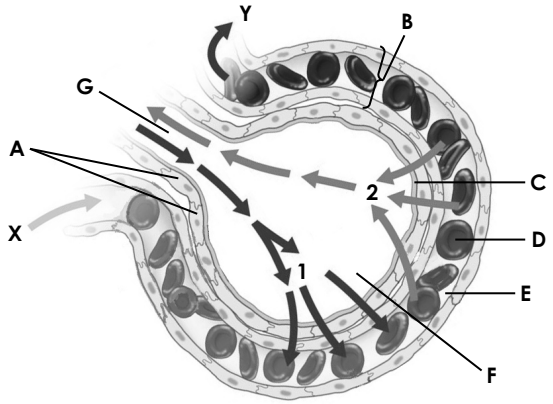
23.4.1 Exhaled air from person A moves into person B according to the direction of the arrow. What action does the arrow represent for person B?

23.4.2 What happens to the volume of person B's lungs during this process?

23.4.3 Identify the muscles that relax in person A during exhalation as shown.

23.4.4 Suggest a reason for chest compressions that should accompany mouth-to-mouth resuscitation.

23.5 Diagram to illustrate the structure of the functional unit of the lung and its associated blood capillary.



23.5.1 Provide labels for A, D, F and G.

23.5.2 Identify the gas indicated by:

(a) pathway 1 (b) pathway 2

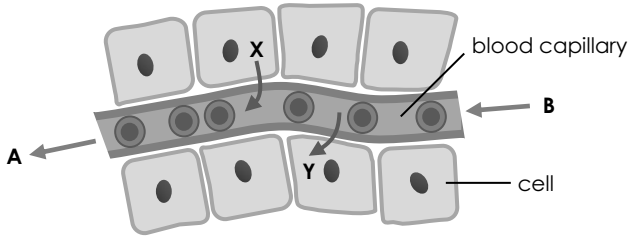
23.5.3 Explain the difference in the blood at X and Y.

23.5.4 Use the **letters** and the **names** of the relevant parts on the diagram to explain how the gas following pathway 1 moves from the alveolus into the blood.

23.5.5 After the process of gaseous exchange what is the fate of the gas which followed:

(a) pathway 1 (b) pathway 2

23.6 Diagram to illustrate the process of gaseous exchange in the tissues.



23.6.1 Identify respiratory gases X and Y.

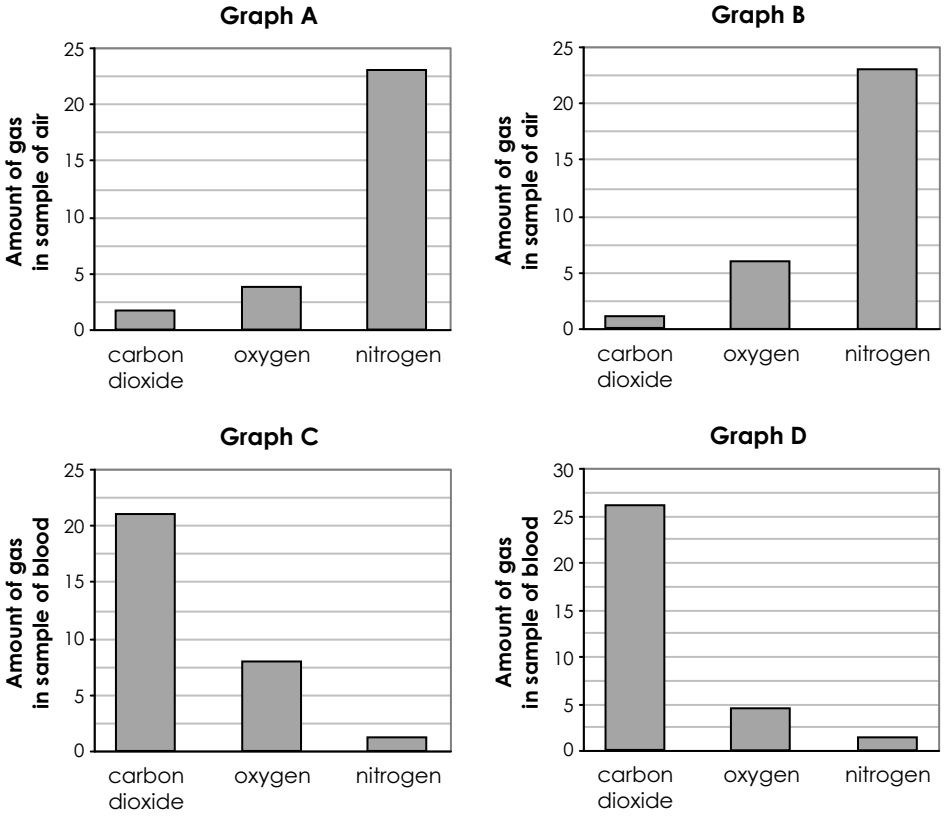
23.6.2 Discuss the process of gaseous exchange between the blood and the respiring cells.

23.6.3 Give the origin and composition of blood at B.

23.7 Various investigations were carried out on the respiratory system and the results obtained are illustrated in the graphs below.

Graphs A and B show the changes between air breathed in and air breathed out.

Graphs C and D show the changes between blood going to the lungs and blood moving away from the lungs.



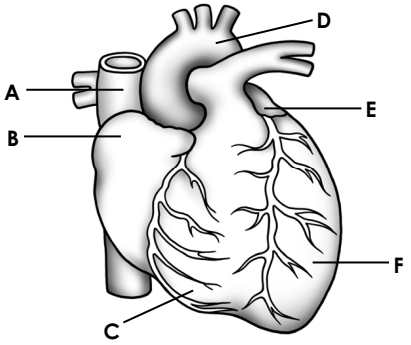
23.7.1 Which graph illustrates the process of inhalation? Give a reason for your answer.

23.7.2 Explain why the percentage of oxygen between graphs A and B is different.

23.7.3 Which graph shows the flow of blood to the lungs? Give **two** reasons for your answer.

Question 24

24.1 Examine the diagram below and answer the questions that follow.



24.1.1 Provide a suitable heading for this diagram.

24.1.2 Use the following statements to help you identify the structures of the heart labelled A – F.

A = a blood vessel which brings deoxygenated blood from the tissues to the heart

B = the chamber of the heart that receives deoxygenated blood from the body

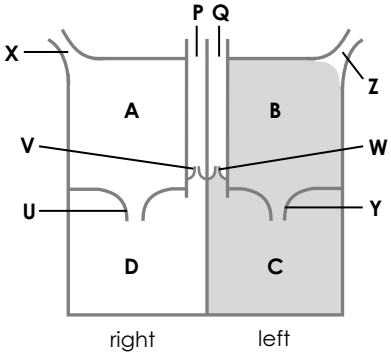
C = the chamber of the heart that pumps deoxygenated blood to the lungs

D = a blood vessel that carries oxygenated blood from the heart to the body

E = the chamber of the heart that receives oxygenated blood from the lungs

F = the chamber of the heart that pumps the oxygenated blood to the body

24.2 The diagram alongside illustrates a simplified mammalian heart and the associated blood vessels.



24.2.1 Use the letters on the diagram to trace the direction of blood flow through the left side of the heart.

24.2.2 State the name of the blood vessels X and Z.

24.2.3 Write down the letter only of the valve that prevents backflow of blood into the:

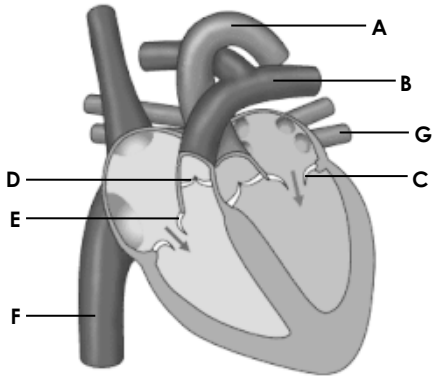
(a) left ventricle (b) left atrium

24.3 Flow of blood through the heart.

Complete the paragraph below by filling in the missing words (1) – (9):

Respiring cells produce ___ (1) ___. Blood from the cells is called ___ (2) ___ blood. This blood drains into the superior and ___ (3) ___ ___. It enters the upper chamber on the right side of the heart called the ___ (4) ___. The blood then flows through the ___ (5) ___ and into the right ___ (6) ___. When the heart contracts, blood is forced out via a blood vessel called the ___ (7) ___ and it goes to the lungs to release carbon dioxide and absorb oxygen. This ___ (8) ___ blood returns to the left atrium of the heart via the ___ (9) ___.

24.4 The diagram shows the internal structure of the heart.



24.4.1 Using letters only, identify:

(a) a vein carrying oxygenated blood

(b) a vein carrying deoxygenated blood

24.4.2 Tabulate **three** differences in **structure** between blood vessels labelled A and F.

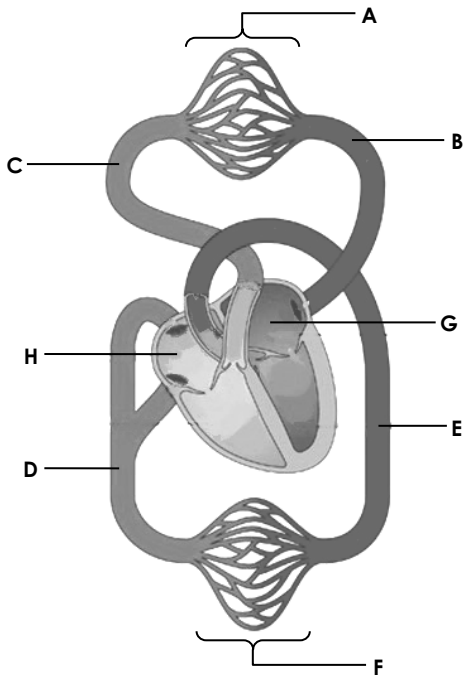
24.4.3 List **two** ways in which a capillary is adapted for its function of delivering nutrients and oxygen to the cells.

24.5 Write the **letter only** of each property of blood vessels from the list below into the correct column of the table provided. Each letter may only be used once.

Arteries	Veins	Capillaries

(a) carry blood to the heart
(b) have thick elastic walls
(c) have walls one cell thick
(d) carry blood under high pressure
(e) have thin muscular walls
(f) oxygen and nutrients pass through the walls
(g) have valves to prevent backflow
(h) blood flows through in pulses
(i) have fast blood flow
(j) have a wider lumen
(k) have no valves
(l) have oxygenated blood that gradually becomes deoxygenated blood

24.6 The human circulatory system.

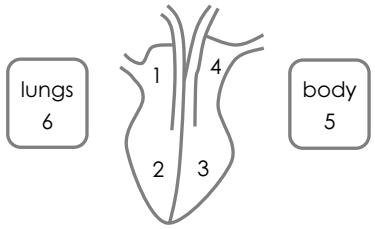


24.6.1 Define a *double circulatory system*.

24.6.2 Using letters from the diagram explain the following:
(a) pulmonary circuit (b) systemic circuit

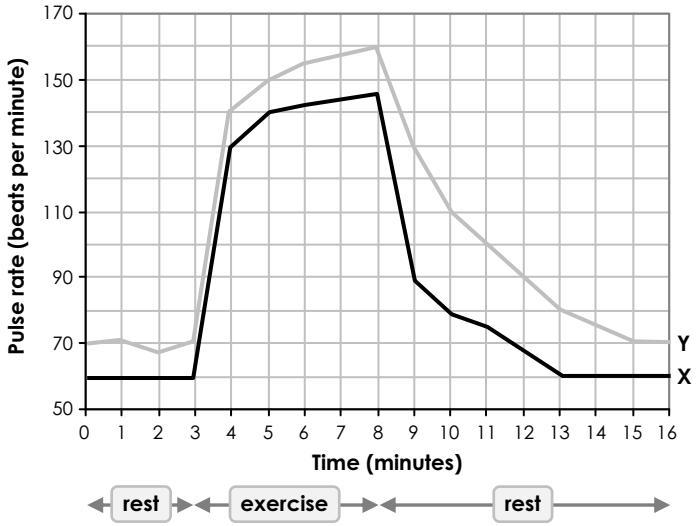
24.6.3 Provide labels for C, H and B.

24.7 Blood circulation in humans is represented by the simplified diagram alongside.



Redraw the accompanying diagram and indicate the arteries and veins that link the heart to the lungs and body respectively. Name the blood vessels and indicate the direction of the blood flow using arrowheads on the lines.

24.8 The following graph refers to the pulse rates of two students X and Y. Student X is a cross country runner and therefore trains regularly, but Y does not undertake regular physical exercise.



NOTE
The time of rest after exercise until the pulse rate returns to normal, is known as the recovery period.

24.8.1 State the resting pulse rate for student Y.

24.8.2 What was the pulse rate for student Y 1 minute after exercise came to a halt?

24.8.3 Identify **two** effects of training on the pulse rate of student X **from the graph**.

24.8.4 The steps in the procedure used to **measure the length of recovery time after vigorous exercise** are given below, but in the incorrect order. Arrange the steps in the correct order. Write down only the numbers of the steps in your answer.

1. Exercise vigorously for 3 minutes.
2. Calculate the time taken for pulse to return to normal.
3. Take pulse rate at 1 minute intervals until normal pulse is recorded.

24.8.5 Identify the dependent variable for this investigation.

24.8.6 Identify the independent variable for this investigation.

HINT: *It is not exercise and rest.*

24.8.7 This procedure was used to compare the recovery times of five college students. Two students missed lunch and two studied late the night before, while another went to sleep early.

(a) Explain why this is not a valid test.

(b) Suggest how the investigation could be improved to make it more reliable.

24.9 The following extract relates to the respiratory and circulatory systems.

The importance of living a healthy lifestyle

Our hearts work beat by beat, second by second for 24 hours a day, never resting. The number one cause of death among women and men, is cardiovascular disease. High blood pressure, high cholesterol, smoking, obesity, and lack of physical activity can greatly increase a person's chance of developing cardiovascular disease. One of the main effects of an unhealthy lifestyle is the emergence of plaque, which is made of fat and cholesterol. It builds up in arteries close to the heart and can result in cardiovascular disease. Leading a healthy lifestyle is important to prevent cardiovascular disease.

24.9.1 What do you think is meant by *cardiovascular disease*?

24.9.2 What increases a person's chance of developing cardiovascular disease?

24.9.3 What is *plaque*?

24.9.4 How do you think the build-up of *plaque* can result in cardiovascular disease?

24.9.5 A person can prevent cardiovascular disease by leading a healthy lifestyle. What is *a healthy lifestyle*?

24.9.6 '*Smoking affects both the respiratory system and the circulatory system.*'

(a) Explain how smoking causes smoker's cough.

(b) Explain how smoking affects the alveoli.

(c) Smoking causes breathlessness due to damaged alveoli. How does this affect the functioning of the heart?

24.10 Imagine that you are an oxygen molecule, trace your journey from the moment you are drawn into the nostril until you arrive at a body cell ready to be used in cellular respiration. You must include all the places you visit and the processes in which you are involved. Give your answer in point form in a vertically arranged flow chart.

DIGESTIVE SYSTEM

Question 25

Give **one word** or **term** for each of the following statements:

25.1 Eating the right kinds of food in the right quantities and proportions to maintain healthy tissues.

25.2 A liquid in which nutrients and minerals are dissolved.

25.3 The universal solvent.

25.4 A chemical compound found in plant cell walls that plays an important role in animal digestion.

25.5 A food group that occurs in muscles and plays an important role in growth.

25.6 Inorganic nutrients that are needed in small quantities and play an important role in normal cell functioning.

25.7 Organic nutrients that are needed in small quantities and play an important role in normal cell functioning.

25.8 A chemical that is used to test for the presence of starch in food.

25.9 A chemical that is used to test for the presence of fat or oil in food.

25.10 A condition caused by a lack or excess of food.

25.11 A state of malnutrition caused by the intake of too many carbohydrates and resulting in excess fat.

25.12 A condition caused by a lack of a certain nutrient or vitamin.

25.13 A disorder where the body cannot regulate the sugar/glucose levels in the blood.

25.14 An additive that improves the taste of food.

25.15 An additive that enhances the shelf life of a product to keep it fresher for longer.

25.16 The diet observed in the religious Jewish community.

25.17 A positive result for the presence of fat or oils in food.

25.18 The process whereby absorbed food becomes part of the cells.

25.19 The chewing of food by the teeth with the help of the tongue.

25.20 Partially digested liquid which leaves the stomach and enters the small intestine.

25.21 A substance secreted by the stomach to create an acidic environment.

25.22 A hormone that plays a vital role in regulating blood sugar levels.

25.23 The process whereby muscles rhythmically contract to push food along the alimentary canal.

25.24 Powerful contractions and movement of the stomach wall to squeeze and mix the food.

25.25 Protein molecules that speed up chemical reactions and play a vital role in building up or breaking down molecules.

25.26 Glands in the small intestine that produce intestinal juice.

25.27 The finger-like folds in the small intestine that increase surface area for absorption of nutrients.

25.28 An opening at the end of the alimentary canal with a sphincter muscle to control egestion.

25.29 The biological term to describe egested material.

25.30 The largest gland in the body that detoxifies the blood.

25.31 The gland that releases hormones into the blood and digestive enzymes into the small intestine.

25.32 A digestive juice with antiseptic properties that helps neutralise the acidic chyme.

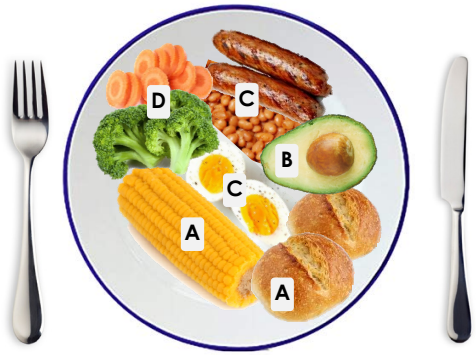
25.33 The organ that stores and releases the bile into the small intestine.

25.34 The type of digestion where food is physically broken into smaller pieces to create a larger surface area.

25.35 The type of digestion which involves enzymes to break down food at the molecular level.

Question 26

26.1 A balanced diet means that you get a variety of foods in the correct amounts.



26.1.1 Why do we need to eat food?

26.1.2 Identify the main food group which is provided by groups A, B, C and D.

26.1.3 Which group A, B, C or D:

(a) is vital for normal cell functioning, growth and development

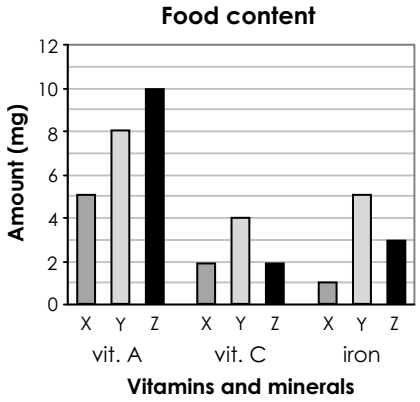
(b) is used for growth and to repair cells

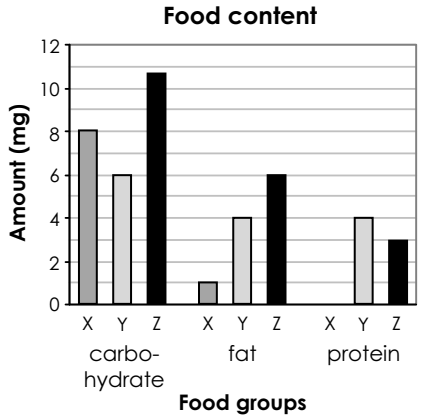
(c) serves as the body's main source of energy

(d) used as an energy reserve and provides insulation

26.1.4 Explain why both water and fibre are an important part of a balanced or healthy diet.

26.2 Many school children do not eat breakfast. It has been suggested that this has affected school results. The Minister of Health decided to provide cereal to school-going children in certain areas of the province. They studied the amount of carbohydrates, fat, protein, iron and vitamins A and C of **one** serving in **three** cereals **X**, **Y** and **Z**. The bar graphs below show the relative amounts of each category in the **three** cereals **X**, **Y** and **Z**.





26.2.1 A health official noticed that children from a particular area suffered from anaemia. Which cereal should they recommend? Give a reason for your answer.

26.2.2 Some children in certain areas are suffering from scurvy. Which cereal should they be getting? Give a reason for your answer.

26.2.3 If some children have kwashiorkor, which food group are they lacking? Other than cereal, which other foods would you recommend that they include in their diet?

26.2.4 The recommended daily allowance (RDA) of iron is 15 mg.

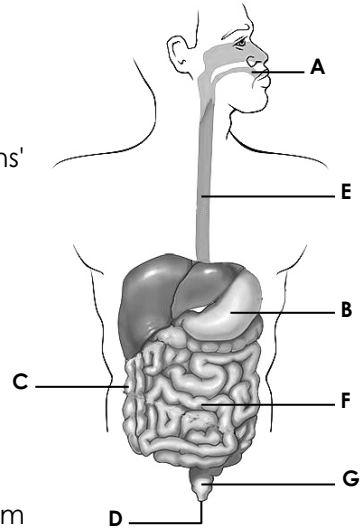
(a) How many mg of iron is provided by cereal Y?

(b) How many servings of cereal Y are needed to obtain the RDA of iron? Show your working.

26.2.5 The daily food intake of children should be approximately 15% protein, 30% fat and 55% carbohydrate. Based on this information, which cereal would be recommended for the children? Explain how you obtained your answer.

Question 27

27.1 Diagram to show part of the digestive system in humans.



27.1.1 Suggest a reason why 'Diagram of the alimentary canal of humans' is not a suitable heading for this diagram.

27.1.2 Identify labels A – G.

27.1.3 Write down the **letter only** of the structure where each of the following occur:

(a) ingestion

(b) egestion

(c) digestion in an acidic medium

(d) secretion of intestinal juice

(e) villi

(f) main site of absorption of nutrients

27.2 The following statements are **true** or **false**. Determine whether the statement is true or false, if false correct the statement to make it true.

27.2.1 Chemical digestion starts in the stomach as the stomach secretes gastric juice.

27.2.2 Mechanical digestion starts in the mouth by the chewing action of teeth and tongue.

27.2.3 Peristalsis is the rhythmical contractions of muscles found in the wall of the alimentary canal that help to push the food forward.

27.2.4 Bile is a digestive juice which is secreted and stored in the gall bladder.

27.2.5 Villi, which are folds in the small intestine, increase the surface area for assimilation.

27.2.6 Intestinal juice contains enzymes which break down food in mechanical digestion.

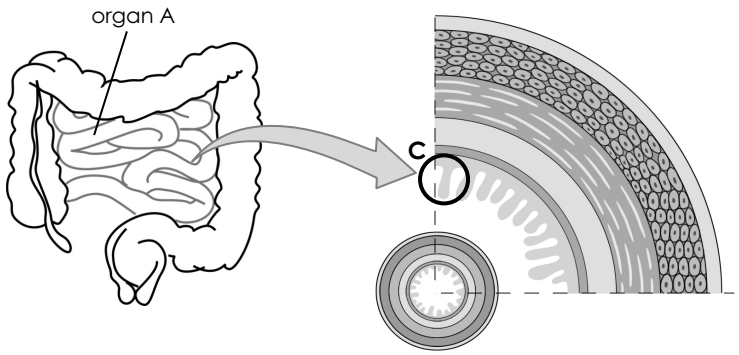
27.2.7 Saliva, gastric juice and intestinal juice all contain enzymes which break food down into simple soluble molecules.

27.2.8 Nutrients must be broken down into simple and soluble chemicals for absorption.

27.2.9 The rectum is a sphincter muscle which helps to expel faeces in the process of egestion.

27.2.10 Faeces contains roughage and digested food materials.

27.3 Diagrams showing organ A from the alimentary canal and a cross-section through part of organ A.



27.3.1 Organ A is part of the alimentary canal. Identify A and the magnified finger-like projection C.

27.3.2 Draw a fully labelled diagram of a longitudinal section of C.

27.3.3 Explain how structure C is adapted for the process of absorption.

27.4 Some organs associated with the human digestive system are listed in the box below.

mouth ; tongue ; salivary glands ; epiglottis ; trachea ; oesophagus ; liver ; gall bladder ; stomach ; duodenum ; small intestine ; large intestine ; rectum ; anus

27.4.1 Identify the organ/s which:

(a) are accessory organs to the alimentary canal

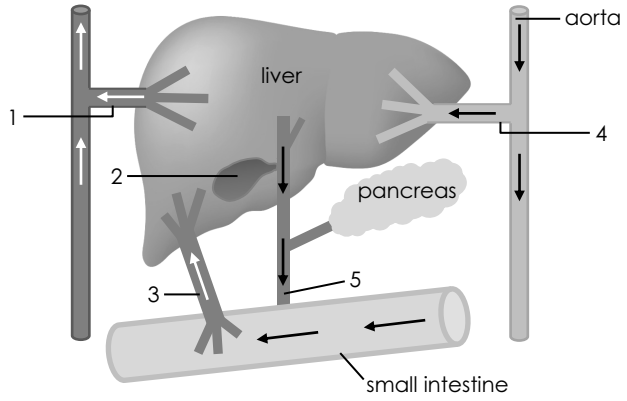
(b) are **not** part of the digestive system

(c) secrete digestive juices

27.4.2 Complete the table (1) – (10) below:

Digestive juice	Secreted by	Digestive functions
(1)	(2)	dissolves fats and oils
(3)	(4)	contains enzymes which break down starch
(5)	pancreas	(6)
(7)	(8)	has enzymes which start protein digestion and function in an acidic environment
intestinal juice	(9)	(10)

27.5 Diagram to show the mammalian liver with some related organs, structures and blood vessels (not drawn to scale).



NOTE

1, 3 and 4 are blood vessels and 5 is a tube called the bile duct.

27.5.1 Use the diagram to answer the following questions.

(a) Identify organ 2.

(b) Give **two** functions of the liquid stored in organ 2.

(c) Which part transports the contents of organ 2 and pancreatic juice into the small intestine?

(d) Describe how the small intestine is well-adapted for its role in absorption of digested food.

27.5.2 Use the text provided below, your knowledge of the circulatory system and the diagram provided of the liver to answer the questions that follow.

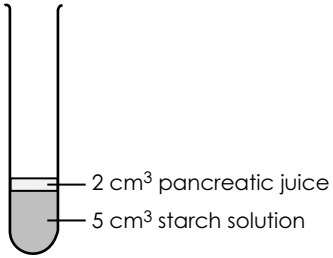
'The liver has multiple functions, and it is often referred to as the body's chemical processing factory as it plays a very important role in processing the nutrients that are absorbed from the small intestine.'

- The hepatic artery carries oxygenated blood from the aorta to the liver.
- The hepatic portal vein takes blood from the small intestine to the liver.
- The hepatic vein carries blood away from the liver to the vena cava.

(a) Identify blood vessel 1, 3 and 4.

(b) How do absorbed nutrients get to the liver?

27.6 A mixture of starch and pancreatic juice, as shown in the diagram, was kept at 37°C.



Samples were taken from the mixture after **one** minute and then after **ten** minutes. The samples were tested using a starch test. The table below shows the results:

	Sample 1 (after 1 minute)	**Sample 2 (after 10 minutes)**
Starch test	positive	negative

27.6.1 Briefly explain how you would perform the starch test.

27.6.2 What can you conclude from the result of sample 1?

27.6.3 What can you conclude from the result of sample 2?

27.6.4 Explain the difference in sample 1 and sample 2.

27.7 Digestion of food involves breaking down the large insoluble molecules into smaller soluble molecules. These smaller molecules can therefore be absorbed from the intestines into the blood and then carried to every single cell in the body. Fibre, cellulose or roughage is an important part of food that humans cannot break down into a simple soluble molecules. It enters our digestive system as part of food entering the mouth and leaves via the anus as part of faeces.

27.7.1 Which food (meat or vegetables) will be a rich source of fibre?

27.7.2 Give a reason for your answer in Question 27.7.1.

27.7.3 Imagine you are a fibre molecule. Trace your journey from the mouth until you leave the body via the anus as faeces. Give your answer in the form of a flow diagram.

MODULE 2 MATTER and MATERIALS

TOPIC 1 COMPOUNDS

US 7509

TOPIC 2 CHEMICAL REACTIONS

US 7509; 7511

TOPIC 3 REACTIONS OF METALS WITH OXYGEN

US 7507; 7508; 7509; 7511; 7513

TOPIC 4 REACTIONS OF NON-METALS WITH OXYGEN

US 7507; 7508; 7509; 7511; 7513

TOPIC 5 ACIDS, BASES AND pH VALUE

US 7508; 7509; 7511; 7513

TOPIC 6 REACTIONS OF ACIDS WITH BASES

US 7507; 7508; 7509; 7511; 7513

TOPIC 7 REACTIONS OF ACIDS WITH METALS

US 7508; 7509

MATTER and MATERIALS

US 7507

Demonstrate an understanding of the concept of science

	SO1	SO2	SO3	SO4	SO5
TOPIC 3					X
TOPIC 4					X
TOPIC 6					X

US 7508

Conduct an investigation in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 3		X	X	X
TOPIC 4		X	X	X
TOPIC 5		X	X	X
TOPIC 6		X	X	X
TOPIC 7		X	X	X

US 7509

Apply basic concepts and principles in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 1	X		X	X
TOPIC 2	X	X		X
TOPIC 3	X	X		X
TOPIC 4	X	X		X
TOPIC 5	X	X	X	X
TOPIC 6	X	X	X	X
TOPIC 7	X	X	X	X

US 7511

Analyse how scientific skills and knowledge contribute to sustainable use of resources

	SO1	SO2	SO3	SO4
TOPIC 2				X
TOPIC 3		X		X
TOPIC 4	X	X	X	
TOPIC 5		X		
TOPIC 6			X	

US 7513

Assess the impact of scientific innovation on quality of life

	SO1	SO2	SO3	SO4
TOPIC 3	X	X		
TOPIC 4		X		
TOPIC 5				X
TOPIC 6	X	X		

TOPIC 1: COMPOUNDS

US 7509: SO 1 – AC 1-3; SO 3 – AC 1; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to compounds
- Interpret scientific evidence to name compounds
- Apply knowledge and skills to use the Periodic Table, classify elements and name compounds

Resources

- Class text & Study guide
- Periodic table of elements

TOPIC 2: CHEMICAL REACTIONS

US 7509: SO 1 – AC 1-3; SO 2 – 1-4; SO 4 – AC 1-2

US 7511: SO 4 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to chemical reactions
- Demonstrate the structure of molecules and balancing equations
- Apply knowledge and skills to balance equations
- Describe how scientific knowledge and skills are illustrated in balancing equations

Resources

- Class text & Study guide
- Periodic table of elements

TOPIC 3: REACTIONS OF METAL WITH OXYGEN

US 7507: SO 5 – AC 1-2

US 7508: SO 2 – AC 1-3; SO 3 – AC 1, 3; SO 4 – AC 1

US 7509: SO 1 – AC 1-3; SO 2 – AC 1-3; SO 4 – AC 1-2

US 7511: SO 2 – AC 1, 3; SO 4 – AC 1

US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of science in rusting and oxidation
- Devise and implement a procedure to investigate the reactions of metals with oxygen
- Gather relevant data regarding oxidation reactions
- Define concepts and principles relating to oxidation reactions
- Demonstrate reactions of metals with oxygen
- Apply knowledge and skills to oxidation reactions
- Explain ways of preventing the formation of rust
- Determine the impact of anti-rust technology on the quality of life

Resources

- Class text & Study guide
- Steel wool, magnesium ribbon
- Deflagrating spoon and Bunsen burner
- Glass jar
- Gloves, safety goggles and lab coat

TOPIC 4: REACTIONS OF NON-METAL WITH OXYGEN

US 7507: SO 5 – AC 1

US 7508: SO 2 – AC 1-3; SO 3 – AC 1, 3, 4; SO 4 – AC 1

US 7509: SO 1 – AC 1-3; SO 2 – AC 1, 2, 4; SO 4 – AC 1-2

US 7511: SO 1 – AC 1-2; SO 2 – AC 1; SO 3 – AC 1-2

US 7513: SO 2 – AC 1-3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of non-metal reactions with oxygen
- Devise and implement a procedure to investigate the reactions of non-metals with oxygen
- Gather relevant data regarding oxidation reactions
- Define concepts and principles relating to non-metal reactions with oxygen
- Demonstrate reactions of non-metals with oxygen
- Understand and describe the interaction of humans with natural resources and mismanagement impact
- Apply knowledge and skills regarding oxidation reactions
- Determine the impact of non-metal reactions with oxygen on the quality of life

Resources

- Class text & Study guide
- Sulphur
- Deflagrating spoon and Bunsen burner
- Glass jar
- Gloves, safety goggles and lab coat

TOPIC 5: ACIDS, BASES AND pH VALUES

US 7508: SO 2 – AC 1, 3; SO 3 – AC 1-3; SO 4 – AC 1-2

US 7509: SO 1 – AC 1-3; SO 2 – AC 1-3; SO 3 – AC 1-3; SO 4 – AC 2, 4

US 7511: SO 2 – AC 1

US 7513: SO 4 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of non-metal reactions with oxygen
- Devise and implement a procedure to investigate acids and bases
- Gather and organise relevant data regarding acids and bases
- Define concepts and principles relating to acids and bases
- Demonstrate pH measurement and neutralisation reactions
- Interpret scientific evidence and apply knowledge and skills regarding acids and bases
- Explain how natural resources can be used to produce indicators

Resources

- Class text & Study guide
- Natural indicators such as red cabbage and turmeric
- Practical equipment p. 111
- Practical equipment p. 113

TOPIC 6: REACTIONS OF ACIDS WITH BASES

US 7507: SO 5 – AC 1-2

US 7508: SO 2 – AC 1-4; SO 3 – AC 1-4; SO 4 – AC 1

US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1, 2, 4

US 7511: SO 3 – AC 1

US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Understand the applications of the reactions between acids and bases in life
- Devise and implement a procedure to investigate acid-base reactions
- Gather relevant data regarding acid-base reactions
- Define concepts and principles relating to acid-base reactions
- Demonstrate acid-base reactions
- Interpret scientific evidence and apply knowledge and skills regarding acid-base reactions
- Describe the effect of acid rain
- Explain the application of acid-base reactions in technological developments

Resources

- Class text & Study guide
- Practical equipment p. 115
- Practical equipment p. 117
- Practical equipment p. 118

TOPIC 7: REACTIONS OF ACIDS WITH METALS

US 7507: SO 5 – AC 1-2

US 7508: SO 2 – AC 1-4; SO 3 – AC 1-4; SO 4 – AC 1

US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1, 2, 4

US 7511: SO 3 – AC 1

US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Devise and implement a procedure to investigate the reactions between acids and metals
- Gather relevant data regarding the reactions between acids and metals
- Define concepts and principles relating to acid-metal reactions
- Demonstrate reactions between acids and metals
- Interpret scientific evidence and apply knowledge and skills regarding acid-metal reactions

Resources

- Class text & Study guide
- Practical equipment p. 121

TOPIC 1 COMPOUNDS

US 7509: SO 1 – AC 1-3; SO 3 – AC 1; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to compounds
- Interpret scientific evidence to name compounds
- Apply knowledge and skills to use the Periodic Table, classify elements and name compounds

UNIT 1 REVISE GRADE 8 KNOWLEDGE

- We can separate matter into three types – **elements**, **compounds** and **mixtures**.
- All matter consists of tiny particles too small for us to see.
- Different types of matter have different types of particles.
- The particles in **elements** are **atoms**. Each atom of a particular element is identical to every other atom of that element.
- The particles in **compounds** are **molecules** or **ions***. The molecules of a compound consist of two or more different atoms. Each molecule of a particular compound is identical to every other molecule of that compound.

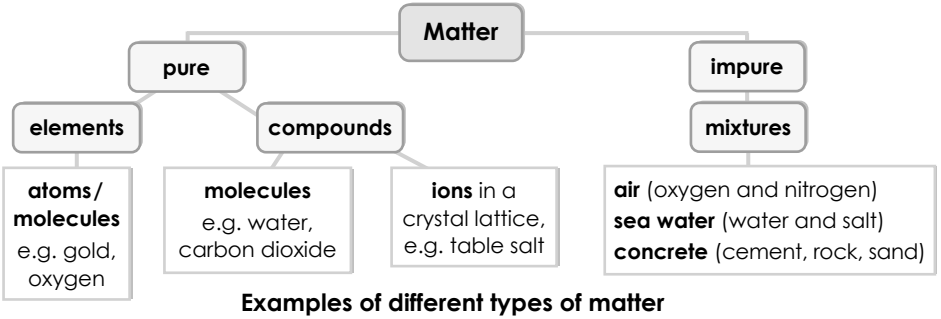
NOTE

**Some compounds, i.e. ionic compounds, consist of + and - ions packed in crystal lattices.*

- The particles in **mixtures** can be atoms or molecules or both. There are at least two different elements and/or compounds in any mixture.

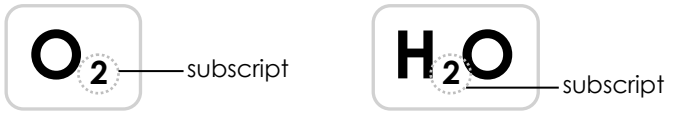
NOTE

The common names are used for these examples of elements, compounds and mixtures.

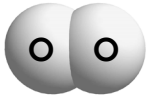


Examples of different types of matter

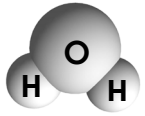
- Molecules are made of two or more atoms. The atoms are bonded (joined) together in fixed ways.
- Each different combination of atoms forms a different molecule.
- If all the atoms in a molecule are the **same**, it is an **element**.
- If the atoms in a molecule are **different**, then it is a **compound**.
- The properties of the molecules in a compound are very different from the properties of their atoms in their respective elements.
- We show the **number of atoms** of each element in a molecule using **a subscript** after the element symbol, e.g.:



  - O_2 means there are two oxygen atoms in the molecule (i.e. a molecule of the element oxygen in air)
  - H_2O means there are two hydrogen atoms and one oxygen atom in the molecule (i.e. a molecule of the compound water)



Two oxygen atoms form an oxygen molecule



Two hydrogen atoms and one oxygen atom form a water molecule

- The properties of air and water are very different even though both substances contain oxygen.

NOTE

Some elements occur in nature as small diatomic (or polyatomic) molecules, i.e. with two (or more) similar atoms joined, to form a more stable unit, e.g. H_2, O_2, Br_2.

THE PERIODIC TABLE

The **Periodic Table** is a list of the elements. They are listed in order of the increasing atomic number of their atoms.

- Atoms are the smallest particles that make up matter. They consist of **sub-atomic particles** – neutrons, protons and electrons.
- The **nucleus** of the atom contains the **neutrons** (neutral / no charge) and the **protons** (positive charge).
- A cloud of **electrons** (negative charge) surrounds the nucleus.
- The **atomic number** is the number of protons in the nucleus of the atom.

NOTE

*In diagrams we use symbols for neutrons (**n**), protons (**p^+**) and electrons (**e^-**).*

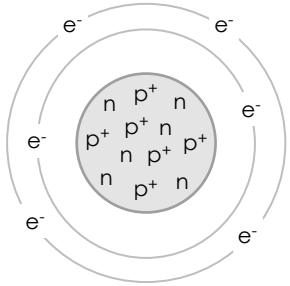


Diagram of a carbon atom

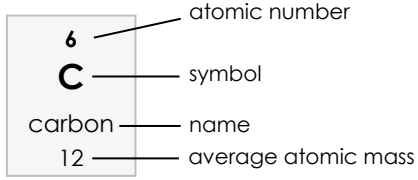
NOTE

This carbon atom has six protons, six neutrons and six electrons.

THE ARRANGEMENT OF ELEMENTS IN THE PERIODIC TABLE

Look at the Periodic Table on p. 96.

- Each element is represented by a block which contains the element's symbol, name, atomic number and atomic mass.



- The names of elements often originate from Greek or Latin words, e.g.:
  - Ca for calcium from Latin *calx* (limestone)
  - He for helium from Greek *Helios* (sun)
  - K for potassium from Latin *kalium* and Arabic *qali* (alkali)
  - Fe for iron from Latin *ferrum* (iron)
- The symbol of an element is usually the first letter (capital / upper case) of its name, followed by a second letter (lower case) if necessary, e.g. C for carbon and Ca for calcium.
- Elements are arranged in horizontal **rows** called **periods**. The rows are numbered period 1, period 2, etc. from the top downwards. There are 7 periods of known elements.
- Elements are also arranged in vertical **columns** called **groups** that are numbered group 1, group 2, etc. from left to right. There are only 18 groups.
- Elements in a particular group have similar properties and behave/ react in the same way.
  - Group 1 are soft metals that react violently with water and oxygen. They are called the **alkali metals**.
  - Group 2 are harder metals that react less violently with water and oxygen. They are called the **alkali earth metals**.
  - Groups 3 to 12 are **transition metals** with a complicated chemical composition, e.g. gold or platinum.
  - Group 17 are very reactive non-metals. They are called the **halogens**. They usually occur as diatomic molecules.
  - Group 18 are gaseous elements that do not react with any other substances. They are called the **noble gases**.
- Each element has a unique position. We describe the position by the period and group to which it belongs, e.g. Mg is in period 3, group 2.

NOTE

*Different atoms of the same element have the same number of protons but can have different numbers of neutrons (and thus different masses). So the **atomic mass** of an element is the **average mass of the atoms**.*

THE PERIODIC TABLE

GROUPS 1 – 18 in vertical **columns**

PERIODS 1 – 7 in horizontal **rows**

atomic number

6
C
Carbon
12,01

symbol
name
atomic mass

metal
metalloid (semi-metal)
non-metal

I 1	II 2											III 13	IV 14	V 15	VI 16	VII 17	VIII 18
1 H Hydrogen 1																	2 He Helium 4
3 Li Lithium 7	4 Be Beryllium 9											5 B Boron 11	6 C Carbon 12	7 N Nitrogen 14	8 O Oxygen 16	9 F Fluorine 19	10 Ne Neon 20
11 Na Sodium 23	12 Mg Magnesium 24	3	4	5	6	7	8	9	10	11	12	13 Al Aluminium 27	14 Si Silicon 28	15 P Phosphorus 31	16 S Sulphur 32	17 Cl Chlorine 35,5	18 Ar Argon 40
19 K Potassium 39	20 Ca Calcium 40	21 Sc Scandium 45	22 Ti Titanium 48	23 V Vanadium 51	24 Cr Chromium 52	25 Mn Manganese 55	26 Fe Iron 56	27 Co Cobalt 59	28 Ni Nickel 59	29 Cu Copper 63,5	30 Zn Zinc 65	31 Ga Gallium 70	32 Ge Germanium 73	33 As Arsenic 75	34 Se Selenium 79	35 Br Bromine 80	36 Kr Krypton 84
37 Rb Rubidium 86	38 Sr Strontium 88	39 Y Yttrium 89	40 Zr Zirconium 91	41 Nb Niobium 93	42 Mo Molybdenum 96	43 Tc Technetium 99	44 Ru Ruthenium 101	45 Rh Rhodium 103	46 Pd Palladium 106	47 Ag Silver 108	48 Cd Cadmium 112	49 In Indium 115	50 Sn Tin 119	51 Sb Antimony 122	52 Te Tellurium 128	53 I Iodine 127	54 Xe Xenon 131
55 Cs Caesium 133	56 Ba Barium 137	71 Lu Lutetium 175	72 Hf Hafnium 179	73 Ta Tantalum 181	74 W Tungsten 184	75 Re Rhenium 186	76 Os Osmium 190	77 Ir Iridium 192	78 Pt Platinum 195	79 Au Gold 197	80 Hg Mercury 201	81 Tl Thallium 204	82 Pb Lead 207	83 Bi Bismuth 209	84 Po Polonium 209	85 At Astatine 210	86 Rn Radon 222
87 Fr Francium 223	88 Ra Radium 226	103 Lr Lawrencium 262	104 Rf Rutherfordium 261	105 Db Dubnium 262	106 Sg Seaborgium 263	107 Bh Bohrium 264	108 Hs Hassium 265	109 Mt Meitnerium 268	110 Ds Damstadtium 269	111 Rg Roentgenium 272	112 Cn Copernicium 227	113 Nh Nihonium	114 Fl Flerovium 289	115 Mc Moskovium	116 Lv Livermorium 289	117 Ts Tennessine	118 Og Oganesson 293

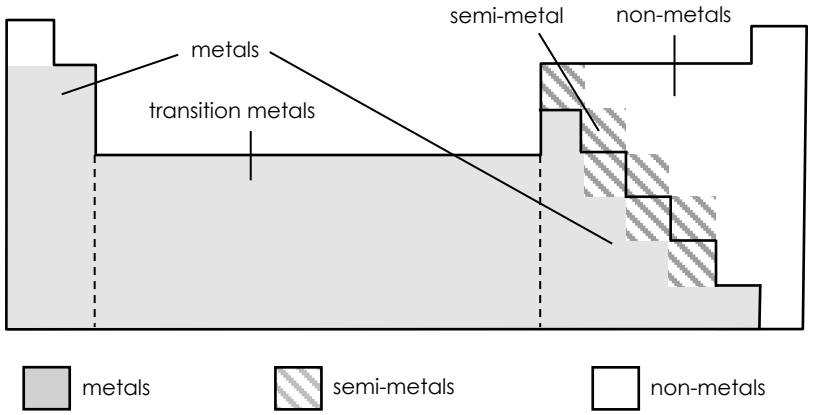
Lanthanide series	57 La Lanthanum 136,9	58 Ce Cerium 140,1	59 Pr Praseodymium 140,9	60 Nd Neodymium 144,2	61 Pm Promethium 146,9	62 Sm Samarium 150,4	63 Eu Europium 152,0	64 Gd Gadolinium 157,3	65 Tb Terbium 158,9	66 Dy Dysprosium 162,5	67 Ho Holmium 164,9	68 Er Erbium 167,3	69 Tm Thulium 168,9	70 Yb Ytterbium 173,0
Actinide series	89 Ac Actinium 227,0	90 Th Thorium 232,0	91 Pa Protactinium 231,0	92 U Uranium 238,0	93 Np Neptunium 237,0	94 Pu Plutonium 244,1	95 Am Americium 243,1	96 Cm Curium 247,1	97 Bk Berkelium 247,1	98 Cf Californium 251,1	99 Es Einsteinium 252,0	100 Fm Fermium 257,1	101 Md Mendelevium 258,1	102 No Nobelium 259,1

CLASSIFYING ELEMENTS: METALS, NON-METALS, AND SEMI-METALS

- Some elements can be classified as **metals** because they have properties in common with other well-known metals like copper, iron and aluminium. These elements are in the centre and on the **left-hand side** of the Periodic Table.
- The properties of metals include being shiny, strong, flexible solids at room temperature (except liquid mercury). They are also good conductors of electricity and heat.
- Elements that lack metal properties are classified as **non-metals**. These elements are found on the **right-hand side** of the Periodic Table, including hydrogen (H) in group 1.
- Most non-metals occur as solids or gases at room temperature, the only exception is bromine (Br_2), which is a liquid. They are non-conductors of electricity and heat.
- There are more metals than non-metals.
- An even smaller number of elements have a mixture of metal and non-metal properties. These elements are called **semi-metals**.

NOTE

Semi-metals *are also known as metalloids in the Periodic Table (see p. 96).*



The positioning of metals, semi-metals and non-metals in the Periodic Table

THE FIRST TWENTY ELEMENTS IN THE PERIODIC TABLE

Learn the names and symbols of the first twenty elements in the Periodic Table. Also learn numbers 26, 29 and 30. You do not need to learn their positions but you will be expected to go from name to symbol or from symbol to name.

Atomic number	Symbol	Name
1	H	hydrogen
2	He	helium
3	Li	lithium
4	Be	beryllium
5	B	boron
6	C	carbon
7	N	nitrogen
8	O	oxygen
9	F	fluorine
10	Ne	neon
11	Na	sodium
12	Mg	magnesium
13	Aℓ	aluminium
14	Si	silicon
15	P	phosphorus
16	S	sulphur
17	Cℓ	chlorine
18	Ar	argon
19	K	potassium
20	Ca	calcium
26	Fe	iron
29	Cu	copper
30	Zn	zinc

UNIT 3

NAMES OF COMPOUNDS

Over time, compounds were given **common** names, e.g. water, ammonia and vinegar. These common names do not usually state which elements make up the compound. **Scientific** names tell us which elements are in a compound and sometimes how many atoms are in each molecule.

There are two main groups of compounds – those containing both metals and non-metals, and those containing only non-metals. The rules for naming these two groups are different.

NAMING COMPOUNDS CONTAINING A METAL AND A NON-METAL

- These compounds have 2-part names:
  - the first part is the name of the metal
  - the second part is the name of the non-metal, but the ending is changed to **-ide**, e.g.:

    'oxygen' becomes 'ox**ide**', 'bromine' becomes 'brom**ide**'.

- **Examples of compounds** (metal + non-metal)**:**
  - $CuC\ell_2$ is made of copper and chlorine. It is called copper chloride.
  - MgS is made of magnesium and sulphur. It is called magnesium sulphide.

NOTE

Use the Periodic Table to recognise which elements are metals and which are non-metals.

NAMING COMPOUNDS CONTAINING A METAL AND TWO NON-METALS, ONE OF WHICH IS OXYGEN

- The first part of the 2-part name is the name of the metal.
- The second part is the name of the first non-metal, but the ending is changed to **-ate** to show that **oxygen** is also part of the compound.
- **Examples of compounds** (metal + 2 non-metals including oxygen)**:**
  - Na_2SO_4 is made of sodium, sulphur and oxygen. It is called sodium sulph**ate**.
  - $CaCO_3$ is made of calcium, carbon and oxygen. It is called calcium carbon**ate**.

More examples:

$MgSO_4$	magnesium sulphate	KNO_3	potassium nitrate
Na_2CO_3	sodium carbonate	$A\ell PO_4$	aluminium phosphate

EXCEPTIONS TO THE -ATE ENDING RULE

- If the two **non-metals** in a compound are **hydrogen** and **oxygen**, then use **-ide** as a name ending. The second part of their name is **'hydroxide'**, e.g.: KOH is named potassium **hydroxide**.

More examples:

NaOH	sodium hydroxide	$Ca(OH)_2$	calcium hydroxide
$A\ell(OH)_3$	aluminium hydroxide		

- If compounds have the same elements, but with differing numbers of oxygen atoms, then use the name ending **-ite** for the compound with **fewer oxygen** atoms.

  For example, two different compounds with sodium, sulphur and oxygen are: Na_2SO_4 (sodium sulph**ate**) and Na_2SO_3 (sodium sulph**ite**).

More examples:

K_2SO_4	potassium sulphate	K_2SO_3	potassium sulphite
$CaSO_4$	calcium sulphate	$CaSO_3$	calcium sulphite
$NaNO_3$	sodium nitrate	$NaNO_2$	sodium nitrite
$Cu(NO_3)_2$	copper nitrate	$Cu(NO_2)_2$	copper nitrite

NAMING COMPOUNDS CONTAINING TWO NON-METALS

- These compounds also have 2-part names:
  - the first part is the name of the non-metal that is more to the left or lower down in the Periodic Table.

- the second part is the name of the non-metal that is to the right or higher up in the Periodic Table, but the ending is changed to **-ide**, e.g.: 'nitrogen' becomes 'nitr**ide**', 'chlorine' becomes 'chlor**ide**'.

- Compounds with two non-metals use prefixes in their name to show the number of atoms of each element. Prefixes for 1 to 10 atoms:

mon(o)-	1*	di-/bi-	2*
tri-	3*	tetr(a)-	4*
pent(a)-	5	hex(a)-	6
hept(a)-	7	oct(a)-	8107
non(a)-	9	dec(a)-	10

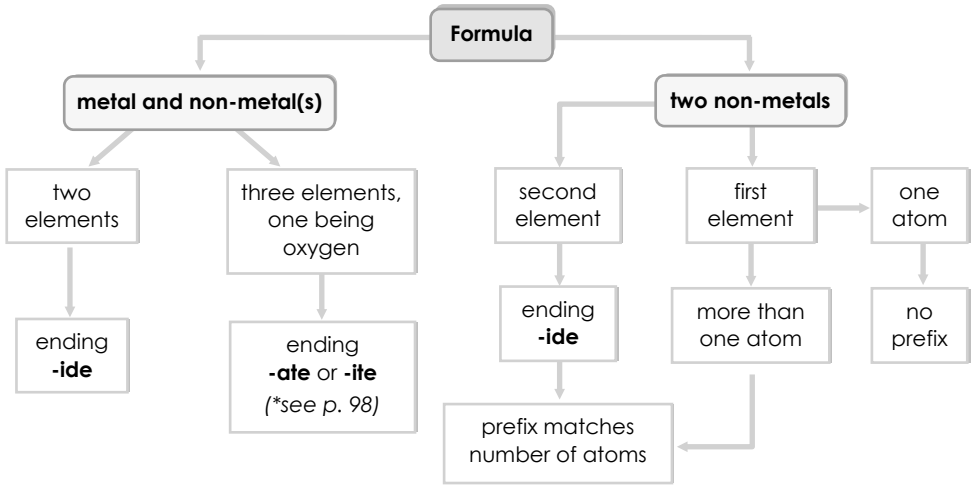
NOTE
**The first four prefixes will be used in Grade 9.*

prefix: letters that are placed **before** a word to change its meaning, e.g. **mon**oxide (1 oxygen atom) or **di**oxide (O_2) or **tri**oxide (O_3).

- A prefix is not used with two non-metals when there is only one atom of the first element, e.g.: SiO_2 is silicon dioxide, not monosilicon dioxide.

- **Examples of compounds** (2 non-metals)**:**
  - HBr has one hydrogen atom and one bromine atom. It is called hydrogen bromide.
  - CO_2 has one carbon atom and two oxygen atoms. It is called carbon dioxide.
  - $NC\ell_3$ has one nitrogen atom and three chlorine atoms. It is called nitrogen trichloride.

COMPOUND: non-metal + non-metal



Flow diagram for naming some compounds from the formula

NOTE
Generally the element more to the left or lower down in the Periodic Table is first in the name of the compound.

Substances with more than one metal are called **alloys**, e.g. brass and steel. Alloys are mixtures of metals rather than molecules with a fixed number of atoms in each molecule.

TOPIC 2 CHEMICAL REACTIONS

US 7509: SO 1 – AC 1-3; SO 2 – 1-4; SO 4 – AC 1-2
US 7511: SO 4 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to chemical reactions
- Demonstrate the structure of molecules and balancing equations
- Apply knowledge and skills to balance equations
- Describe how scientific knowledge and skills are illustrated in balancing equations

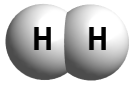
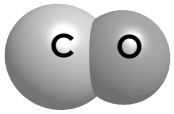
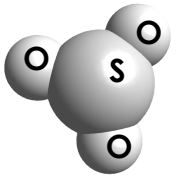
- Atoms can join up or separate during a **chemical reaction**. Molecules break up and atoms join up in new arrangements.

- The substances that react together are called the **reactants**. The substances that form during the reaction are called the **products**.

- There are many possible arrangements of atoms in reactants and products.

- All the atoms that are present before a reaction takes place, are still present after the reaction is completed. This is known as the **Law of Conservation of Atoms**.

- We can draw pictures or **models** of molecules that show each atom in the molecule. We can also write a **formula** for the molecule using the element symbols from the Periodic Table. We use subscripts after each element symbol to give the number of atoms of that particular element in the molecule, e.g. subscript **3** in SO_3 indicates 3 oxygen atoms.

Model			
Formula	H_2	CO	SO_3
Name	Hydrogen	Carbon monoxide	Sulphur trioxide

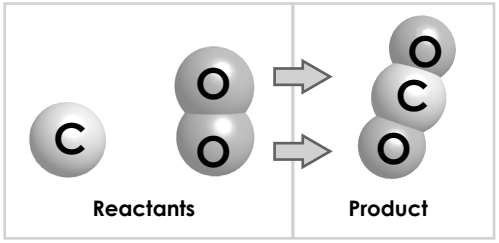
Compare the model to the formula and the name of each molecule

NOTE

*There are seven elements that naturally occur as **diatomic molecules**, i.e. with two atoms of the same element in each molecule. The seven elements and their formulas are: hydrogen (H_2), nitrogen (N_2), oxygen (O_2), fluorine (F_2), chlorine (Cl_2), bromine (Br_2) and iodine (I_2). These elements are all non-metals.*

UNIT 1 CHEMICAL EQUATIONS TO REPRESENT REACTIONS

- We use a model to illustrate what happens during a chemical reaction.



The number of each kind of atom remains the same in the reactants and the product

- We can write a sentence that describes what happens during a chemical reaction. We use the verb '**reacts with**' if there is more than one reactant, and the phrase '**to form**' to show the change from reactants to products.
- This sentence can be written as a **word equation**. We use '**+**' for 'reacts with' and '**→**' for 'to form'.
- We write the **reactants** on the left and the **products** on the right. We read the reaction from **left to right**.
- The names of substances can be replaced by formulas to write a chemical equation with '**+**' between any two reactants or any two products, and '**→**' separating the products from the reactants.

Example: Carbon reacts with oxygen to form carbon dioxide:

$$\underbrace{\text{carbon} + \text{oxygen}}_{\text{reactants: carbon + oxygen}} \rightarrow \underbrace{\text{carbon dioxide}}_{\text{product: carbon dioxide}}$$

$$\underbrace{C + O_2}_{\text{reactants: carbon + oxygen}} \rightarrow \underbrace{CO_2}_{\text{product: carbon dioxide}}$$

- Compare the chemical equation above with the models of the same reaction opposite.
  - The subscripts in a formula give the number of atoms of the preceding element only, e.g. in CO_2, there are 2 oxygen atoms.
  - Oxygen is one of the elements that occurs as diatomic molecules.
  - Visualise the two oxygen atoms separate from each other and then individually join with the carbon atom to form the product.

UNIT 2 BALANCED EQUATIONS

We now know that the number of atoms of each element has to be the same on each side of the equation, i.e. before and after the reaction has occurred.

A chemical equation, where the reactants and the products have the same number of atoms of each element, is called a **balanced equation**.

We also know that each type of compound has a **fixed ratio** of atoms which cannot change. The number of atoms in a specific molecule therefore must stay the same, e.g. CO_2 (1 C atom and 2 O atoms).

The only way we can balance the chemical equation is to add increasing **numbers of molecules** to the reactants (on the left-hand side) and/or products (on the right-hand side) until the **numbers of atoms** are **equal** on **both sides of the equation**. This number placed in front of the formula to balance the equation is called the **coefficient**. This method is called **balancing by inspection**.

$2CO_2$

coefficient (**number of** carbon dioxide **molecules**)

subscript (**number of** oxygen **atoms**)

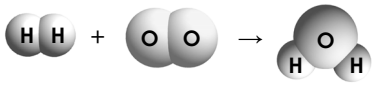
EXAMPLE 1

BALANCING CHEMICAL EQUATIONS BY INSPECTION

Hydrogen reacts with oxygen to form water. Hydrogen burns with a pale blue flame to form water.

hydrogen + oxygen → water

$H_2 + O_2 \rightarrow H_2O$



LHS = left-hand side

RHS = right-hand side

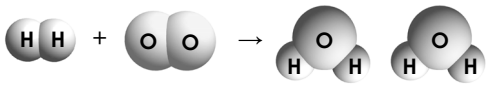
reactants **product**

LHS: two hydrogen atoms, two oxygen atoms

RHS: two hydrogen atoms, one oxygen atom

- *The oxygens are not balanced ∴ add a water molecule to balance the oxygen atoms by inserting the **coefficient** 2 in front of the water molecule.*

$H_2 + O_2 \rightarrow \mathbf{2}H_2O$

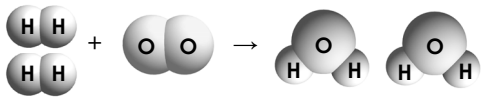


two hydrogen atoms, two oxygen atoms

four hydrogen atoms, two oxygen atoms

- *The oxygen atoms are now balanced but the hydrogen atoms are **not** balanced. There are two hydrogen atoms on the left-hand side and four on the right-hand side. Add a second hydrogen molecule (two atoms) by inserting a **coefficient** 2 in front of the hydrogen molecule on the left-hand side.*

$\mathbf{2}H_2 + O_2 \rightarrow \mathbf{2}H_2O$



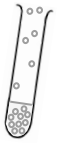
***Caution:** do not add single oxygen or hydrogen atoms – they only come in pairs as diatomic molecules.*

- *Now both the oxygen atoms and the hydrogen atoms are balanced, so the chemical equation is balanced.*

EXAMPLE 2

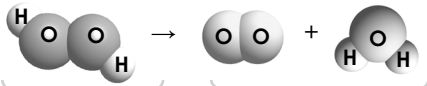
BALANCING CHEMICAL EQUATIONS BY INSPECTION

Hydrogen peroxide decomposes to form oxygen and water. Hydrogen peroxide releases oxygen bubbles when warmed.



hydrogen peroxide → oxygen + water

$H_2O_2 \rightarrow O_2 + H_2O$

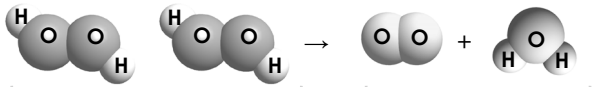


LHS: two hydrogen atoms, two oxygen atoms

RHS: two hydrogen atoms, three oxygen atoms

- *There are too few oxygen atoms on the left-hand side. Add a second hydrogen peroxide molecule by inserting a **coefficient** 2 in front of the hydrogen peroxide formula.*

$\mathbf{2}H_2O_2 \rightarrow O_2 + H_2O$

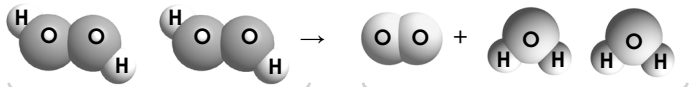


four hydrogen atoms, four oxygen atoms

two hydrogen atoms, three oxygen atoms

- *Now there are too few oxygen and hydrogen atoms on the right-hand side. Add a second water molecule by inserting a **coefficient** 2 in front of the water formula.*

$\mathbf{2}H_2O_2 \rightarrow O_2 + \mathbf{2}H_2O$



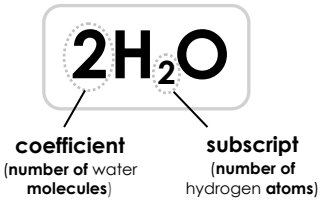
four hydrogen atoms, four oxygen atoms

four hydrogen atoms, four oxygen atoms

***Hint:** add molecules one at a time to the side with fewer atoms – even if that side then ends up with more atoms of that element.*

- *Now both the oxygen atoms and the hydrogen atoms are balanced, so the chemical equation is balanced.*

- The **subscripts** after the element symbols show the **number of atoms** of each element.
- If there is only one atom of an element, then the '1' is left out.
- The **coefficients** in front of the molecules give the **number of molecules**.



- To find the number of atoms after balancing, **multiply** the coefficient by the subscript for each element in the compound, e.g.:
  $2H_2O$: $(2 \times 2)H + (2 \times 1)O = 4H + 2O$

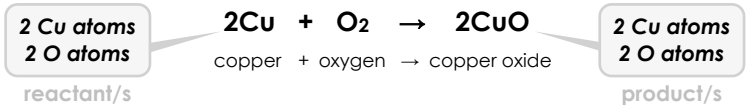
NOTE

Both preceding examples contain only hydrogen and oxygen atoms and water is formed in both reactions. They are, however, very different reactions because of the different reactants that start the reaction.

NOTE

*When balancing equations, **do not** change the subscripts, only change the **coefficients** (balancing number).*

- A **balanced equation** has the same **number** and **type** of **atoms** in the **reactant(s)** and in the **product(s)**, e.g.:



TOPIC 3

REACTIONS OF METALS WITH OXYGEN

US 7507: SO 5 – AC 1-2
US 7508: SO 2 – AC 1-3; SO 3 – AC 1, 3; SO 4 – AC 1
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-3; SO 4 – AC 1-2
US 7511: SO 2 – AC 1, 3; SO 4 – AC 1
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of science in rusting and oxidation
- Devise and implement a procedure to investigate the reactions of metals with oxygen
- Gather relevant data regarding oxidation reactions
- Define concepts and principles relating to oxidation reactions
- Demonstrate reactions of metals with oxygen
- Apply knowledge and skills to oxidation reactions
- Explain ways of preventing the formation of rust
- Determine the impact of anti-rust technology on the quality of life

- Any chemical reaction can be represented using **models** of the atoms, or written as a **word equation**, or written as a **chemical equation**.
- All chemical reactions have to balance – the same number of atoms of each element has to appear in the reactants and products.
- Now we will apply these principles to groups of chemical reactions that follow a similar reaction pattern in the group.

UNIT 1

THE GENERAL REACTION OF METALS WITH OXYGEN

- **Oxygen** is a colourless, odourless gas and forms a large part (21%) of our atmosphere. It is more **reactive** than nitrogen which is called **inert** as it does not react easily.

REACTIONS WITH OXYGEN

Oxygen is a very reactive element and reacts readily with many other substances. Reactions with oxygen are also known as oxidation reactions. The product formed is an **oxide**.

Over time **metals** such as copper and silver become dull and brown. This is because a layer of copper and silver oxide forms on the surface due to exposure to oxygen in the air.

Some **fruits** such as apples and bananas turn brown during a reaction with oxygen. Even the **human body** is broken down by reactions with oxygen and these days it is common to drink antioxidants on a regular basis.

During a reaction with oxygen many substances undergo **corrosion** or degradation to some extent *(see p. 105)*.

- Reactions with oxygen at room temperature often take place very slowly, and some substances will only react with oxygen when heated, e.g. burning wood or coal in a fire.
- Reactions that involve the burning of substances are known as **combustion** reactions. During the combustion of a metal, it reacts with oxygen to form a **metal oxide**.

NOTE

Alkali metals, e.g. Na and K, are very reactive and will spontaneously react with the oxygen in the air. They do not occur as pure elements in nature and are covered with oil when stored in a laboratory.

NOTE

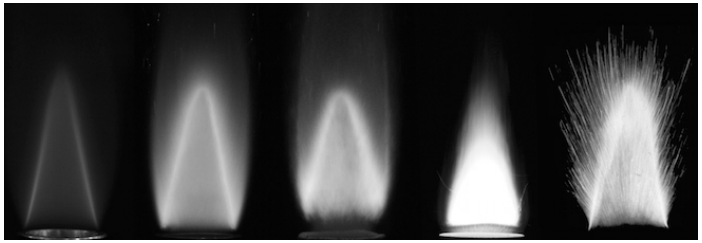
The burning of metals is not often observed in nature, and is best demonstrated by a teacher in a laboratory.

- Some metal burning reactions may be quite violent and safety precautions should be followed.

SAFETY PRECAUTIONS

A demonstrator must maintain a safe distance from the reaction and use a small piece of the metal. Also, use a screen, gloves, goggles and a laboratory coat.

- With each demonstration, notice the **colour** of the metal reactant, the colour of the flame and the **appearance** of the oxide product.
- Changes in the physical properties between reactants and products are an indication that there has been a **chemical change**.
- Any chemical change can be written as a **chemical reaction**.

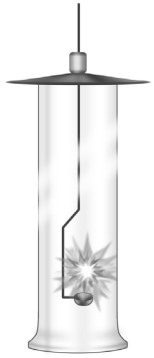


Source: Alternative Fuels Laboratory/McGill University

methane iron aluminium boron/ aluminium zirconium

The combustion of different substances

- Metals burn best in pure oxygen. Pure oxygen can be prepared in a laboratory and held in a gas jar until needed.
- Place the metal on a deflagrating spoon. Hold the metal in the flame of a Bunsen burner. When sufficiently heated, carefully lower the spoon into a gas jar filled with oxygen.
- Close the gas jar with a cover in case the oxide forms a cloud. Do not breathe in this cloud as it can be harmful.



Metal burning in oxygen

- The reactants are a metal and oxygen. The product is a metal oxide. We can write this as the general word equation:

metal + oxygen → metal oxide

- We can now apply this general equation to iron and magnesium reacting with oxygen.

UNIT 2 REACTION OF IRON WITH OXYGEN

- We use **steel wool** for this demonstration as the thin strands provide a large surface area for heating the metal.
- Hold the steel wool in the flame using a deflagrating spoon. The strands of iron will glow with an orange colour and create a shower of tiny orange sparks.
- When the hot steel wool is lowered into the gas jar with pure oxygen, the iron glows more brightly. The reaction happens faster in the gas jar because the oxygen is more concentrated.
- The reaction is finished when the steel wool stops glowing. Remove the remaining mass and wait for it to cool.
- Look carefully at samples of the reactant and the product.
- The reactant (steel wool) is **pale grey** and quite **flexible**. You can change its shape without breaking it.
- The product, **iron oxide**, is similar in shape to the steel wool but is **dark grey (almost black)** and **brittle**. It crumbles into little pieces when you bend it.
- These observations of changes in the properties of the substance, are evidence of a possible chemical change.

- We can write the word equation as:

iron + oxygen → iron oxide

- and the chemical equation as:

$Fe + O_2 \rightarrow Fe_2O_3$

- The chemical equation is not yet balanced. There are three oxygen atoms on the right-hand side and two on the left-hand side. Work towards the smallest common multiple of 2 and 3, i.e. 6. So put a coefficient **2** in front of the Fe_2O_3 product and a coefficient **3** in front of O_2.

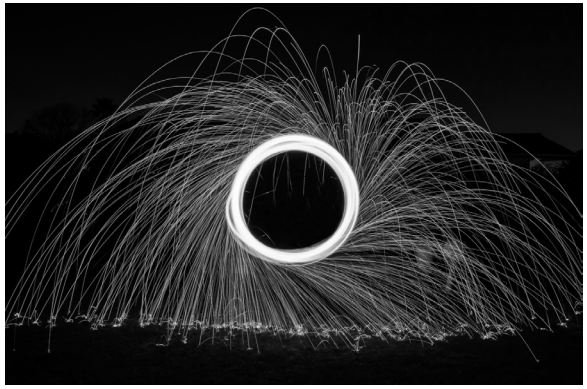
$Fe + 3O_2 \rightarrow 2Fe_2O_3$

- Now there are too few iron atoms on the left hand side. Add a coefficient **4** in front of the Fe reactant.

$4Fe + 3O_2 \rightarrow 2Fe_2O_3$

[4 iron atoms and 6 oxygen atoms] = [4 iron atoms and 6 oxygen atoms]

- Now there are four iron atoms and six oxygen atoms on both sides of the equation, so it is balanced.



Reaction of iron with oxygen

NOTE

Remember oxygen is one of seven elements that form diatomic molecules. Oxygen atoms always come in pairs and the molecule is written as O_2.

$2Fe_2O_3$

change the **coefficient** (number of molecules)

do **not** change the **subscript** (number of atoms)

UNIT 3

REACTION OF MAGNESIUM WITH OXYGEN

- We use a thin strip of magnesium, called **magnesium ribbon**, for this demonstration as magnesium powder reacts too quickly.

- Coil the magnesium ribbon around a deflagrating spoon and light the tip of the ribbon. It will start to glow with a **bright white** light. Do not look directly at the light as it can cause eye damage.

- Lower the hot, glowing magnesium into the pure oxygen in the gas jar. The reaction is very fast, the light is even brighter and the ribbon burns up rapidly.

- Remove the deflagrating spoon. Cooling is rapid. The surface of the gas jar and spoon may be coated in a white powder.

- Look carefully at samples of the reactant and the product.

- The reactant (magnesium) is **shiny** and **flexible**. You can bend it without breaking it.

- The product, **magnesium oxide**, is a **white powder**. Run the tip of your finger over the powder. It is **crumbly**.

- The reactant and the product have very different properties. Both the colour and the strength of the reactant has changed. These observations are evidence of a possible chemical change.

- We can write the word equation as:

magnesium + oxygen → magnesium oxide

- and the chemical equation as:

$Mg + O_2 \rightarrow MgO$

- The chemical equation is not yet balanced. There are fewer oxygen atoms on the right-hand side, so put a 2 in front of the MgO product.

$Mg + O_2 \rightarrow 2MgO$

- Now there are too few magnesium atoms on the left-hand side. Add a 2 in front of the Mg reactant.

2 Mg atoms 2 O atoms	$2Mg + O_2 \rightarrow 2MgO$	2 Mg atoms 2 O atoms
reactant/s		product/s

- Now there are two magnesium atoms and two oxygen atoms on both sides of the equation, so it is balanced.

Magnesium ribbon burning

NOTE

The magnesium oxide product has one metal atom and one oxygen atom in its compound. Not all oxides have this ratio of metal to oxygen. You are not expected to be able to write formulae of all oxides in Grade 9.

UNIT 4

FORMATION OF RUST

- **Rust** is a natural phenomenon observed when metals are exposed to the environment. It can cause **damage** to objects made of iron. Useful items like cars and tools have to be protected against rusting.

- Rusting of iron is a slow process at room temperature to form an **iron oxide** compound. The rust has a **red-brown** colour and is **crumbly**.
- Rust is a mixture of different oxides and hydroxides of iron. These compounds form when the iron reacts with oxygen and water.
- Here are some of the reactions that form rust:

$$2Fe + O_2 \rightarrow 2FeO$$

$$FeO + H_2O \rightarrow Fe(OH)_2$$

$$4FeO + 3O_2 \rightarrow 2Fe_2O_3$$

$$Fe_2O_3 + 3H_2O \rightarrow 2Fe(OH)_3$$

- Rusting happens on the **surface** of the metal. Because it is crumbly, pieces of rust can fall off and expose lower layers of iron to rusting. Eventually the object is weakened by the rusting process.
- **Steel** is a mixture containing iron so it can also rust. Steel is used in the construction of buildings, bridges and other large structures. If too much rusting occurs, the structure is weakened.

NOTE

*Other materials can also be weakened by a reaction with oxygen. Any weakening by a chemical reaction is known as **corrosion**. Rusting is a special form of corrosion involving iron.*

Not all materials corrode to the same extent:

- *more reactive metals corrode faster, e.g. zinc or iron,*
- *less reactive metals like silver, gold, tin or platinum do not corrode at all and*
- *metals like aluminium and chromium react slowly with oxygen to form a thin layer of aluminium oxide and chromium oxide on the surface that protects the metal underneath.*

UNIT 5

WAYS TO PREVENT RUSTING

- Most methods of preventing rusting form a barrier to keep oxygen and water away from the surface of the iron.
  - **Painting:** A layer of paint prevents oxygen or water coming into contact with the iron. Painting has to be done at regular intervals as part of a maintenance programme. This method is not effective with moving parts of machines as the paint can easily chip and let in water and oxygen.
  - **Oiling:** A thin layer of oil prevents oxygen from coming into contact with the iron. Oil repels water too. Oil is very effective in preventing rust on moving parts of machines, but must be reapplied more frequently than paint.
  - **Galvanising:** Metals like zinc and chromium form a hard oxide layer when they corrode. This corrosion layer stops the reaction process and forms a protective layer. A coating of one of these metals protects the iron underneath. The coating is applied by dipping the iron object in melted zinc or by spraying on the chromium.

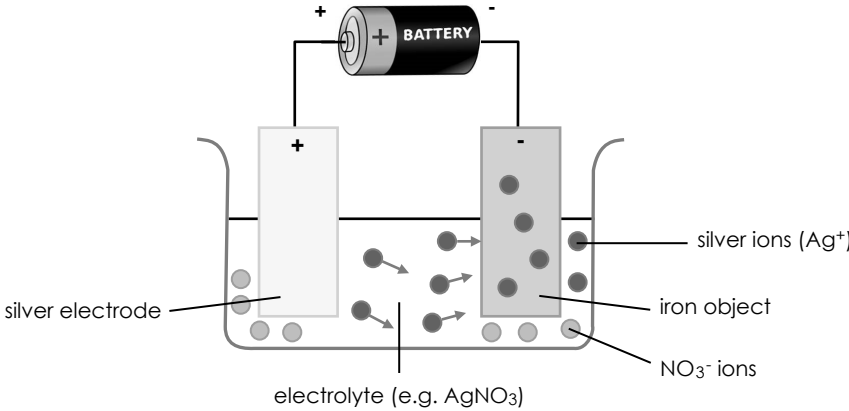
Zinc (electro) plating/ galvanising

Hot dip galvanising

NOTE

In a reaction with oxygen, zinc is more reactive than iron and chromium is less reactive than iron, but in both cases a protective layer forms that protect the iron against corrosion.

- **Electroplating:** Metals like tin and silver do not corrode. The iron object is placed in a solution of tin or silver. Electricity is used to coat the iron with the metal in the solution. One electric wire is connected to the object and the other electric wire is connected to a piece of the corresponding metal (tin or silver).



EXAMPLES

Examples of galvanising and electroplating:

- *Zinc coating: zinc plates for roofs of buildings, galvanised fences, steel gates, burglar bars*
- *Tin coating: the inside of cans in the canning industry*
- *Aluminium or chrome finish: bathroom taps and fittings, buffers, hubcaps of cars, motorbikes, etc.*
- *Silver or other shiny metal coatings: costume jewellery, cutlery*

Chrome-plated taps

Galvanised tub

Gold-plated watch

- If a more reactive metal is attached to iron or steel, that metal will react with oxygen instead of the iron. Magnesium and calcium are examples of more reactive metals that are used in this method called **cathodic protection**. Hulls of ships have rods of magnesium that are replaced regularly to prevent corrosion.

TOPIC 4 REACTIONS OF NON-METALS WITH OXYGEN

US 7507: SO 5 – AC 1
US 7508: SO 2 – AC 1-3; SO 3 – AC 1, 3, 4; SO 4 – AC 1
US 7509: SO 1 – AC 1-3; SO 2 – AC 1, 2, 4; SO 4 – AC 1-2
US 7511: SO 1 – AC 1-2; SO 2 – AC 1; SO 3 – AC 1-2
US 7513: SO 2 – AC 1-3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of non-metal reactions with oxygen
- Devise and implement a procedure to investigate the reactions of non-metals with oxygen
- Gather relevant data regarding oxidation reactions
- Define concepts and principles relating to non-metal reactions with oxygen
- Demonstrate reactions of non-metals with oxygen
- Understand and describe the interaction of humans with natural resources and mismanagement impact
- Apply knowledge and skills regarding oxidation reactions
- Determine the impact of non-metal reactions with oxygen on the quality of life

- Non-metals react with oxygen in a similar way as metals and we can write balanced chemical equations.
- Unlike metals, the naming rules can be used to write the formula for the product when the name of the product is given.

UNIT 1 THE GENERAL REACTION OF NON-METALS WITH OXYGEN

- The reactions where non-metals **burn** in oxygen are also called **combustion** reactions.
- The same method used with metals is used to demonstrate these reactions.
- In each demonstration, notice the **colour** of the non-metal reactant, the colour of the flame and the **appearance** of the oxide product.
- Changes in the physical properties between reactants and products are an indication that there has been a chemical change.
- The reactants are a non-metal and oxygen. The product is a non-metal oxide. We can write this as the general word equation:

non-metal + oxygen → non-metal oxide

- We can apply this general equation to both carbon and sulphur reacting with oxygen.

UNIT 2 REACTION OF CARBON WITH WATER

- Carbon occurs in many forms – soot, coal, charcoal, graphite and diamond are all forms of almost pure carbon. Charcoal is ideal for this demonstration.
- Grind the charcoal into a black powder. Scoop some powder into the deflagrating spoon and heat in the Bunsen burner flame. Lower the heated carbon into the gas jar with oxygen.

Coal burning

- The carbon glows orange and burns with an **orange flame** in the gas jar. The product is an invisible gas.
- The reactant and the product look very different which suggests that a chemical change occurred.
- We can write the word equation as:

carbon + oxygen → carbon dioxide

- and the chemical equation as:

$$C + O_2 \rightarrow CO_2$$

- The chemical equation is balanced. There is one carbon atom and two oxygen atoms on each side of the reaction equation. We do not need to add any more atoms to either side.

NOTE

Test for carbon dioxide: *clear lime water turns milky/cloudy when carbon dioxide is bubbled through it.*

CARBON DIOXIDE POLLUTION

Too much carbon dioxide in the atmosphere is a likely cause of **global warming**. People burn large amounts of carbon-containing fuels for energy. We need to find other ways of providing energy if we want to limit and reverse global warming.

Coal-burning power station

UNIT 3

REACTION OF SULPHUR WITH OXYGEN

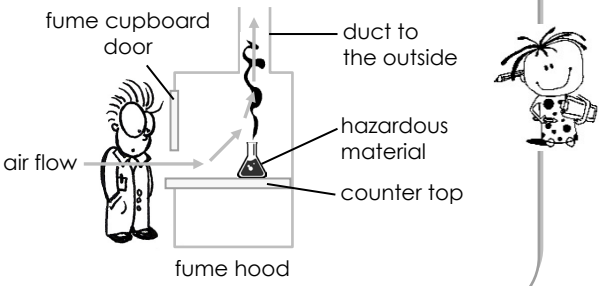
- Sulphur is a bright yellow, strong-smelling element. It is available as a powder or in sticks called roll sulphur.
- Use the powdered form of sulphur or grind a portion of roll sulphur to powder in a pestle and mortar.

Pestle and mortar

- Scoop some powdered sulphur into the deflagrating spoon and heat in the Bunsen burner flame.
- The sulphur will melt to form a brown transparent liquid. This is a physical change, not a chemical change.

NOTE

Inhalation of sulphur dioxide gas causes irritation and breathing difficulties. The experiment must be demonstrated using small quantities of sulphur in a fume cupboard in a chemistry laboratory or outdoors.



- Lower the melted sulphur into the gas jar containing oxygen. The sulphur burns with a beautiful **blue flame**.
- The product is a choking **colourless gas**. The reactant and the product look very different. This difference suggests that a chemical change occurred.

Match burning

- We can write the word equation as:

sulphur + oxygen → sulphur dioxide

- and the chemical equation as:

$$S + O_2 \rightarrow SO_2$$

- The chemical equation is balanced. There is one sulphur atom and two oxygen atoms on each side of the reaction equation. We do not need to add any more atoms to either side.

SULPHUR DIOXIDE POLLUTION

Sulphur dioxide gas reacts with water in the atmosphere to make sulphurous acid. This acid dissolves in water in the clouds and falls as **acid rain**. Acid rain damages plants and buildings.

BURNING COAL

We burn coal in power stations to generate electricity. Coal consists mostly of carbon. Coal in South Africa also has a high sulphur content. Burning coal releases a lot of carbon dioxide and sulphur dioxide gas into the atmosphere. Both gases in the atmosphere cause environmental problems.

TOPIC 5 ACIDS, BASES AND pH VALUE

US 7508: SO 2 – AC 1, 3; SO 3 – AC 1-3; SO 4 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-3; SO 3 – AC 1-3; SO 4 – AC 2, 4
US 7511: SO 2 – AC 1
US 7513: SO 4 – AC 1

Lesson Outcomes

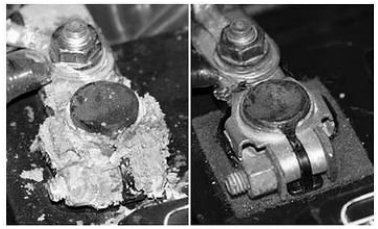
By the end of this topic, learners should be able to:

- Devise and implement a procedure to investigate acids and bases
- Gather and organise relevant data regarding acids and bases
- Define concepts and principles relating to acids and bases
- Demonstrate pH measurement and neutralisation reactions
- Interpret scientific evidence and apply knowledge and skills regarding acids and bases
- Explain how natural resources can be used to produce indicators

Compounds can be sorted into different groups based on whether they are acidic or basic/alkaline or neutral substances, i.e.:

- **acids**
- **bases**
- **neutral substances**

- Each group of substances has similar physical and chemical properties. These properties are determined by:
  - the **elements** in the compound
  - the **arrangement** of the **atoms**
- Acids taste **sour** and are **corrosive**.
- Bases taste **bitter**, feel **soapy**, and are also **corrosive**.
- Corrosion is a chemical process. The corrosive compound reacts with a material through direct contact. The material is damaged and weakened.
- Neutral substances do not cause chemical damage to materials.
- Acids and bases can be **weak** or **strong**. A strong acid or base is more corrosive than a weak acid or base.



Corrosion build-up on a battery terminal

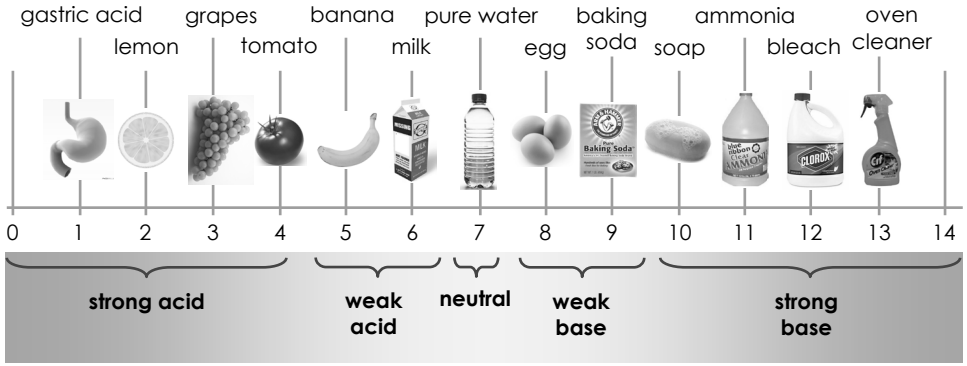
NOTE

*The use of the word 'group' in this context is different to a 'group' of elements in a column of the Periodic Table. The groups in this topic consist of **different compounds with similar properties**.*

UNIT 1 CONCEPT OF pH VALUE

- A **pH scale** is used to compare acids, bases and neutral substances.
- The pH scale also indicates whether acids and bases are **strong** or **weak**.
- The values on the pH scale range from 0 to 14. Different pH values match different strengths of acids and bases:
  - strong acids: pH of 0 – 4
  - weak acids: pH of 5/6
  - neutral substances: pH of 7
  - weak bases: pH of 8/9
  - strong bases: pH of 10 – 14

The pH scale



- A substance can be identified as an acid, neutral or a base by measuring its pH value. Substances must be in a liquid phase or dissolved in water to measure pH.
- There are two ways to measure pH:
  - pH is measured with a **pH meter**. Compare the values to the pH scale to determine whether the substance is acid/base/ neutral.
  - use an **indicator** (see explanation below) to show whether the substance is an acid, neutral or a base.

pH meter

The 'H' in pH refers to the role of hydrogen atoms in acid-base chemistry. All acids contain hydrogen (H).

INDICATORS

- Some substances have a different colour in an acid compared to their colour in a base. They are known as indicators. We add an indicator to a substance to **indicate** whether the substance is an acid or a base.

NOTE

'To indicate' means to show. In this topic, the colour of the indicator shows whether the substance is an acid or a base.

- **Natural** indicators can be extracted from plants like different types of berries, turmeric, red cabbage and red onions:
  - The juice of berries is diluted for use as an indicator.
  - Turmeric is a spice that can be dissolved in water.
  - The vegetables (cabbage and onions) must be boiled to dissolve the indicator in water.

  Add drops of the indicator solution to the substance that is to be tested to observe a colour change.

- Litmus can be extracted from certain lichens and dissolved in water. Small strips of paper, soaked in litmus and then dried, are called **litmus paper**. Dip the litmus paper in the substance to be tested to observe a colour change.
- Some indicators are large man-made molecules like **phenolphthalein** and **bromothymol blue** that are dissolved in alcohol. A few drops are added to the substance to be tested to observe a colour change.
- The following table shows the colour of these indicators for different pH conditions.

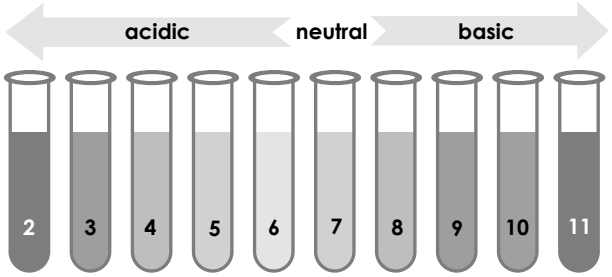
Indicator	Colour in acid	Colour when neutral	Colour in base
Turmeric water	yellow	yellow	red
Red cabbage water	red	purple	blue – green – yellow
Red onion water	red	violet	green
Litmus paper	red	unchanged	blue
Phenolphthalein	colourless	colourless	pink
Bromothymol blue	yellow	green	blue

NOTE

The indicators on the table can only be used to identify a substance as an acid or a base. They cannot be used to tell whether the acid or base is strong or weak. Only some indicators can identify a substance or mixture as neutral.

- A **universal indicator** is a combination of indicators and has different colours for weak and strong acids and bases.
- The colour of the universal indicator gives the pH value of the substance tested.
- A typical universal indicator shows a range of colours at different pH values and distinguishes between strong and weak acids or bases.

Universal indicator



Solutions with different pH values

Colour	red	orange	yellow	green	blue	indigo	violet
pH range	0, 1, 2, 3	4, 5	6	7	8, 9, 10, 11	12, 13	14
Strength	strong acid	weak acid	very weak acid	neutral substance	weak base	strong base	very strong base

- Acids will turn the universal indicator red, orange or yellow, depending on the strength of the acid.
- Bases will turn the universal indicator blue, indigo or violet.
- Neutral substances will turn the universal indicator green.

NOTE

The sequence of colours of the universal indicator is the same as the colours of the rainbow. This makes the indicator colours easier to remember.

Turmeric

Red cabbage

Red onion

Hydrangea: pink in acid and blue in alkaline soils

Examples of natural indicators

NOTE

Pink and blue hydrangeas are an example in nature where the acidity of the soil determines the colour of the flowers.

PRACTICAL INVESTIGATION

Testing Household Substances

An assortment of household acids and bases

- Many household substances can be tested to see if they are acidic, neutral or basic.
- Use different indicators with the same substances so that you can compare colours and confirm your results.
- The substances to be tested have to be in the liquid phase. Some solid substances will need to be ground to a fine powder. All solid substances should be dissolved in water to make a solution. Liquid substances like liquid soap and dishwashing liquid should be diluted with water to see the colour changes easily.

Requirements

- substances to be tested in small beakers
- watch glasses
- droppers (one for each substance to prevent contamination)
- natural and laboratory indicators
- universal indicator

Method

Method

1. Place a small sample of the substance (liquid or in solution) onto the watch glass.
2. Place one drop of the indicator with the sample.
3. Observe the colour of the indicator and record it in a table.
4. Repeat with each combination of substance and indicator.

NOTE

Wash the watch glass thoroughly between tests to avoid contamination.

5. Decide for each substance whether it is an acid, a neutral substance or a base.

Observations and Discussion

Sample data from testing household substances with indicators

Substance	Colour of universal indicator	Colour of litmus	Colour of red cabbage water	Colour of bromothymol blue
Vinegar	orange	red	red	yellow
Milk	yellow	red	red	yellow
Lemon juice	red	red	red	yellow
Bicarbonate of soda	blue	blue	green	blue
Salt water	green	unchanged	purple	green

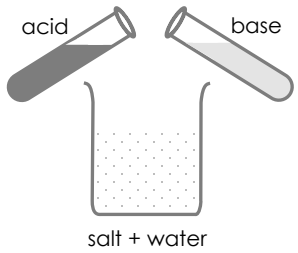
- Other substances to test include tap water, Ceylon tea, rooibos tea, coffee, orange juice, fizzy drinks, tartaric acid, washing powder, dishwashing liquid, hand soap, toothpaste and milk of magnesia.
- Substances that should indicate as acidic: vinegar, milk, lemon juice, dishwashing liquid (if it contains lemon), Ceylon tea, coffee, orange juice, fizzy drinks, tartaric acid.
- Substances that should indicate as neutral: tap water, salt water.
- Substances that should indicate as basic: bicarbonate of soda, rooibos tea, washing powder, hand soap, toothpaste, milk of magnesia.
- The universal indicator will give the pH values that distinguish between weak/strong acids and bases. Possible results may be:
  - pH 2: vinegar, lemon juice, cola
  - pH 3: orange juice, tartaric acid
  - pH 5: coffee, 'Sprite'
  - pH 6: Ceylon tea, milk
  - pH 7: tap water, salt water
  - pH 8: rooibos tea
  - pH 9: bicarbonate of soda, toothpaste
  - pH 10: milk of magnesia, washing powder, hand soap

UNIT 2

NEUTRALISATION AND pH

- Strong acids and bases are corrosive, so have to be handled with care.
- Strong acids have a pH of 0 or 1. Strong bases have a pH of 13 or 14.
- If an acid reacts with a base, they lose their corrosive properties. The products of the reaction are typically a mixture of **salt** and **water**. This mixture is neutral so the reaction is called a **neutralisation** reaction. The pH of the products is about 7.
- The **amount** of acid and base mixed together is important:
  - if too much acid is added and some unreacted acid remains in the mixture: the pH of the mixture will be **below 7**
  - if too much base is added and some unreacted base remains behind: the pH of the mixture will be **above 7**
  - if the right amount of both acid and base is added and both reactants are used up completely: the pH of the mixture will **be 7**

- There are some acid-base neutralisation reactions where the pH of the product depends on the relative strengths of the acids and bases:
  - if the **acid** is the **stronger** of the two: the **pH** of the acidic salt produced could be **5 or 6**
  - if the **base** is the **stronger** of the two: the **pH** of the basic salt produced could be **8 or 9**
- Examples of **strong acids** are hydrochloric acid (**$HC\ell$**), nitric acid (**HNO_3**) and sulphuric acid (**H_2SO_4**).
- **Non-metal oxides**, e.g. carbon dioxide (CO_2) and sulphur dioxide (SO_2), are typically **acidic** when dissolved in water and their strength varies (*see Topic 4*).
- Examples of **strong bases** are metal hydroxides like sodium hydroxide (**NaOH**) and potassium hydroxide (**KOH**).
- **Metal oxides**, e.g. magnesium oxide (MgO), and metal carbonates are typically **basic** when dissolved in water and their strength varies.
- An indicator is added to the mixture to show the changes in pH. Good indicators are sensitive to changes in pH.
  - Just one drop of base can change the mixture from acidic to basic and one drop of acid can change the mixture from basic to acidic.
  - When one drop of base/acid changes the colour of the indicator then we have reached the **end point** of the neutralisation reaction.
- Most of the **household** substances tested in the previous Practical Investigation are **weak acids** or **weak bases**.
- The practical investigation that follows shows the **end point of a neutralisation reaction**.



PRACTICAL INVESTIGATION

Neutralising Vinegar and Bicarbonate of Soda

Requirements

- small beakers
- bicarbonate of soda
- universal indicator
- white vinegar
- teaspoon
- dropper

Method

1. Pour about 20 mℓ of vinegar or diluted ethanoic acid into a small beaker.
2. Add some drops of universal indicator to the vinegar and observe the colour of the indicator.
3. Add a small amount of bicarbonate of soda and observe the reaction.
4. Add more bicarbonate of soda repeatedly in small quantities until the indicator shows a pH greater than 7. There may now be some solid bicarbonate at the bottom of the container.
5. Add drops of vinegar until the indicator turns green. If you add too much vinegar then stir the mixture to dissolve more bicarbonate of soda.

Observations

- The universal indicator turns red in the vinegar (Step 2).
- The mixture produces bubbles when adding the bicarbonate of soda (Step 3).
- The colour of the indicator changes from red to orange and then to yellow, depending on how much of the vinegar is used up. The colour changes to blue once all the vinegar is used up and an excess bicarbonate of soda occurs (Step 4).
- If enough vinegar is added to react with all of the dissolved bicarbonate of soda, the indicator will turn green (Step 5).

▶▶ Discussion

Discussion

- The bubbles are carbon dioxide gas.
- The end point is reached when the universal indicator turns green. Equivalent amounts of vinegar and bicarbonate of soda has been added and both reactants have been used up completely.
- The word equation for this reaction is:

  ethanoic acid + sodium bicarbonate → sodium ethanoate + carbon dioxide + water
- The acid contributes a hydrogen (H) atom to form a water molecule. The bicarbonate (HCO_3^-) forms carbon dioxide (CO_2) gas and the remaining oxygen and hydrogen atoms are part of the water molecule.
- The remainders of the acid and the base combine to form the salt.

Names in chemistry can be confusing. The common names of the reactants are vinegar and bicarbonate of soda. Their chemical names are ethanoic acid (sometimes called acetic acid) and sodium bicarbonate.

TOPIC 6 REACTIONS OF ACIDS WITH BASES

US 7507: SO 5 – AC 1-2
US 7508: SO 2 – AC 1-4; SO 3 – AC 1-4; SO 4 – AC 1
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1, 2, 4
US 7511: SO 3 – AC 1
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Understand the applications of the reactions between acids and bases in life
- Devise and implement a procedure to investigate acid-base reactions
- Gather relevant data regarding acid-base reactions
- Define concepts and principles relating to acid-base reactions
- Demonstrate acid-base reactions
- Interpret scientific evidence and apply knowledge and skills regarding acid-base reactions
- Describe the effect of acid rain
- Explain the application of acid-base reactions in technological developments

Acids can react with a variety of different substances. If a group of reactions yield similar products in a similar way, we can group the reactions together. Identifying similar patterns of reactions can be used to predict other reactions. Eventually you can write a **general reaction** for all the reactions in the group.

All the reactions in this topic are generally known as **neutralisation reactions**. One of the reactants is an acid, but the corrosive character of the acid is not present in the products. We say the acid has been neutralised by the other reactant, which is a base.

UNIT 1 THE GENERAL REACTION OF AN ACID WITH A METAL OXIDE (BASE)

- The reaction between a metal and oxygen produces a **metal oxide**.
- We can test the pH of the metal oxide when it has dissolved in water. The pH will be greater than 7, so it is a base. When the metal oxide dissolves in water, it is ready to react with the acid.
- The general word equation for the reaction is:

  acid + metal oxide → salt + water
- The term '**salt**' is used in chemistry for a wide range of neutral compounds that contain a metal and one or more non-metal elements. All salts can be produced from the reaction between an acid and a base. Typical examples are potassium chloride ($KC\ell$), sodium nitrate ($NaNO_3$) and aluminium sulphate ($A\ell_2(SO_4)_3$).

NOTE

The salt we use for cooking and on our food is sodium chloride ($NaC\ell$). It is sometimes referred to as table salt. It belongs to the class of compounds classified as salts.

- Example of a reaction between an acid and a metal oxide (base):

  nitric acid + calcium oxide → calcium nitrate + water

  $$\mathbf{2HNO_3 + CaO \rightarrow Ca(NO_3)_2 + H_2O}$$
- The acid contributes a hydrogen (H) atom and the metal oxide contributes an oxygen (O) atom to form a water molecule.
- The remainders of the acid and the base combine to form the salt. The metal part of the salt comes from the oxide (calcium). The non-metal part of the salt comes from the acid (nitrate).
- The reaction equation is balanced when two molecules of nitric acid react with one molecule of calcium oxide.

NOTE

*Many of the Practical Investigations in this topic use dilute acid. If you have to dilute acid, **always** add the acid to the water and never the other way round. The larger amount of water absorbs the heat quickly and the mixture remains in the container.*

If you pour water onto concentrated acid it will boil almost immediately because of the heat from the reaction. The acid-water mixture may splash out of the container and cause acid burns.

PRACTICAL INVESTIGATION

Observe the Reaction Between an Acid and an Oxide

Requirements

- small beakers
- magnesium oxide powder
- spatula or teaspoon
- water
- dilute hydrochloric acid
- universal indicator

Method

1. Pour about 10 cm^3 of water into the beaker. Add about quarter of a teaspoon of magnesium oxide to the water and stir. (Swirl the mixture repeatedly to keep the undissolved magnesium oxide suspended in the mixture.)
2. Add a few drops of universal indicator and note the colour.
3. Slowly add hydrochloric acid to the beaker, while swirling the mixture until it turns green. (When the colour starts to change, add the acid drop by drop.)
4. Keep swirling the mixture and observe any changes.
5. Slowly add more acid so that the mixture turns yellow.
6. Again, keep swirling the mixture and observe.

Observations and Discussion

- Magnesium oxide is only slightly soluble in water. There should be some solid magnesium oxide remaining suspended in the mixture so that it appears milky (Step 1). (If left for a while, the magnesium oxide that does not dissolve will settle at the bottom.)
- The indicator turns violet in the mixture of magnesium oxide and water. This shows that the dissolved magnesium oxide is strongly basic (Step 2).
- The mixture turns green when enough acid has been added to neutralise the dissolved magnesium oxide (Step 3).
- The neutralisation reaction:

hydrochloric acid + magnesium oxide → magnesium chloride + water

$$\mathbf{2HC\ell + MgO \rightarrow MgC\ell_2 + H_2O}$$

- The solution turns from green back to blue (Step 4). This shows that, with the swirling, more magnesium oxide has dissolved in the water making the solution basic again.
- The solution turns yellow when all the dissolved magnesium oxide has been neutralised and there is an excess acid (Step 5).
- As you continue to swirl the mixture, the colour first changes from yellow to green and then from green to blue to violet. More magnesium oxide dissolves in the water and neutralises the remaining acid to make the solution basic again (Step 6).
- Steps 5 and 6 and the corresponding colour change can be repeated until all the magnesium oxide in the mixture has been dissolved. The solution will then be transparent. The final colour will depend on whether there is more acid or oxide.

Conclusion

The oxide neutralised the acid and formed a salt and water.
The salt is magnesium chloride.

NOTE

Too much hydrochloric acid in your stomach can cause ulcers. Milk of magnesia is used to neutralise the acid in the stomach. Magnesium oxide is the active ingredient in milk of magnesia and gives it a milky white appearance, hence the name.

THE pH OF NON-METAL OXIDE SOLUTIONS

- The reaction between a non-metal and oxygen produces a **non-metal oxide**.
- Non-metal oxides form acidic solutions when they dissolve in water. The solution can be mildly corrosive, with a pH just less than 7, or very corrosive, with a pH of 2 or lower. The corrosive potential depends on the type and the concentration of the non-metal oxide solution.
- Both carbon dioxide and sulphur dioxide dissolve easily in water.
- The dissolving reaction for **carbon dioxide** in water is:

  $$CO_2 + H_2O \rightarrow H_2CO_3$$

  - The product is **carbonic acid**.
  - This acid is found in all fizzy drinks because it contains carbon dioxide dissolved in water.
  - You can test the pH of a colourless fizzy drink (e.g. 'Sprite'): add a few drops of universal indicator and note the orange or red colour.
  - When a small amount of carbon dioxide in the atmosphere dissolves in rain water, giving it a pH of about 5,6, it is called acid rain.

- The dissolving reaction for **sulphur dioxide** in water is:

  $$SO_2 + H_2O \rightarrow H_2SO_3$$

  - The product is **sulphurous acid**.
  - Sulphurous acid can have a pH of 2, which makes it responsible for most of the corrosive damage done by acid rain.
- Acid rain can be very harmful to the environment.
  - Acid rain makes the water in rivers and lakes more acidic (pH decreases). The soil that absorbs the rain becomes more acidic. The low pH kills plants and animals if they are less tolerant of changes in pH.
  - Acid rain can also damage human-made materials, like zinc roofs, and structures made of marble, limestone and concrete.

UNIT 2 THE GENERAL REACTION OF AN ACID WITH A METAL HYDROXIDE (BASE)

- **Metal hydroxides** are formed during the reaction of a metal with water or of a soluble metal oxide with water.
- Metal hydroxides are bases.
- The group 1 metals, e.g. Li, Na and K, react violently with water to form LiOH, NaOH and KOH. The group 1 metal hydroxides are very strong bases.
- An acid and a metal hydroxide neutralise each other when they react. The general word equation for the reaction is:

  acid + metal hydroxide → salt + water

- Example of a reaction between an acid and a metal hydroxide:

  hydrochloric acid + sodium hydroxide → sodium chloride + water

  $$HC\ell + NaOH \rightarrow NaC\ell + H_2O$$

- The acid contributes a hydrogen (H) and the base contributes a hydroxide (OH) to form a water molecule.
- The remainders of the acid and the base combine to form the salt.

PRACTICAL INVESTIGATION

Preparation of a Salt

Requirements

- small beaker
- 2 × droppers
- dilute hydrochloric acid
- dilute sodium hydroxide solution
- watch glass
- universal indicator solution

Method

1. Pour about 10 cm^3 of the sodium hydroxide solution into the beaker.
2. Add a few drops of universal indicator and note the colour.
3. Slowly add hydrochloric acid to the beaker while swirling the mixture in the beaker.
4. When the colour starts to change, add the acid slowly, drop by drop, until the mixture is green.
5. If the mixture turns yellow or red you have added too much acid. Add a small amount of sodium hydroxide solution to turn the indicator back to the starting colour and repeat Steps 3 and 4.
6. Pour a sample of the green mixture into the watch glass and allow the water to evaporate. Note: this step may take a few days.
7. Cautiously taste the residue in the watch glass once the liquid is completely evaporated.

NOTE

This is one of the very few times that it is considered safe to taste a chemical in the laboratory.

Observations and Discussion

- The indicator starts off blue and turns gradually to green. This shows that the base is being neutralised.
- If you add more acid, the indicator turns yellow or red. These colours show that there is now excess acid in the mixture.
- After the water has evaporated, a grainy substance remains in the watch glass. This grainy substance tastes salty, showing that the reaction formed a salt.
- The grainy substance may also taste bitter. The bitter taste is the indicator that also remains behind on the watch glass.

Conclusion

The acid and the base neutralised each other and formed a salt. The salt is sodium chloride (NaCℓ).

PREDICTING THE NAME OF THE SALT WHEN ACIDS REACT WITH OXIDES OR HYDROXIDES

- All acids contain hydrogen. To form water, the acid donates one hydrogen atom to the hydroxide (OH) part or two hydrogen atoms to the oxide (O) part of the base.
- The remainder of the acid becomes the non-metal part of the salt.

EXAMPLES

Acid	Non-metal part of the salt
$HC\ell$	$C\ell$
HNO_3	NO_3
H_2SO_4	SO_4

- The remainder of the base (after removal of the hydroxide or oxide ions) becomes the metal part of the salt.

EXAMPLES

Base (hydroxides and oxides)	Metal part of the salt
NaOH	Na
K_2O	K
$Ca(OH)_2$	Ca
$A\ell_2O_3$	Aℓ

- The two parts (metal part from the base and non-metal part from the acid) are then combined to form the salt, e.g. NaCℓ.

- An interesting **exception** to the rule about a metal part from the base is ammonium hydroxide. The remainder of this base, after removal of the hydroxide, is **ammonium (NH_4)**. Ammonium consists only of non-metal elements so the ammonium salt that is formed contains only non-metals.

ammonium hydroxide + nitric acid → ammonium nitrate + water

$NH_4OH + HNO_3 \rightarrow NH_4NO_3 + H_2O$

- Ammonium nitrate makes an excellent **fertiliser** because it has a high percentage of nitrogen.

UNIT 3

THE GENERAL REACTION OF AN ACID WITH A METAL CARBONATE (BASE)

- **Metal carbonates** are weak bases.
- An acid and a metal carbonate neutralise each other when they react. The general word equation for the reaction is:

acid + metal carbonate → salt + carbon dioxide + water

- Example of a reaction between an acid and a metal carbonate:

hydrochloric acid + potassium carbonate →
potassium chloride + carbon dioxide + water

$2HC\ell + K_2CO_3 \rightarrow 2KC\ell + CO_2 + H_2O$

- The acid contributes the hydrogen atoms to form the water molecule.
- The carbonate (CO_3) forms carbon dioxide (CO_2) gas and the remaining oxygen atom becomes part of the water molecule.
- The remainders of the acid and the base combine to form the salt.

PRACTICAL INVESTIGATION

Test the Gas Released during the Reaction Between an Acid and a Carbonate

Requirements

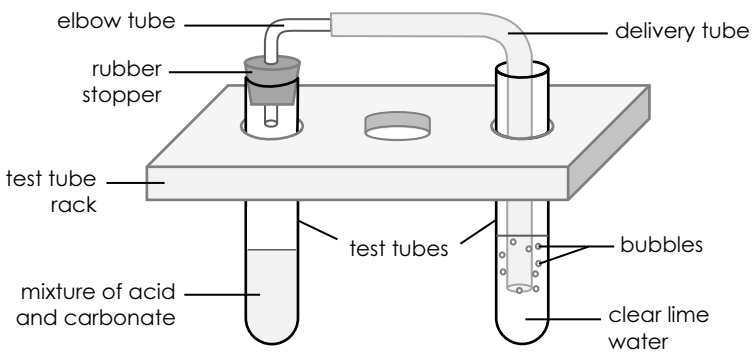
- dilute hydrochloric acid solution
- calcium carbonate powder (chalk dust)
- clear lime water
- two test tubes in test tube rack
- rubber stopper fitted with glass elbow tube and rubber delivery tube
- spatula or teaspoon

Method

Method

1. Assemble the rubber stopper, elbow tube and delivery tube as shown in the diagram. Make sure the rubber stopper fits the test tube tightly to seal it.

Practical set up for testing for carbon dioxide



2. Half fill one test tube with lime water and stand it in the rack.
3. Put at least one teaspoon of calcium carbonate powder into the other test tube and stand it in the rack. The two test tubes must be standing close enough together that when the rubber stopper fits into the test tube holding the calcium carbonate, the end of the delivery tube can be below the level of the lime water.
4. Add a generous amount of hydrochloric acid to the calcium carbonate to half fill the test tube. Then quickly close the test tube with the rubber stopper.
5. Push the other end of the delivery tube into the lime water.
6. Observe the changes in both test tubes.

Observations and Discussion

- The reaction starts as soon as the hydrochloric acid is added to the calcium carbonate. Frothing occurs and gas is released into the elbow tube.
- Here is the reaction:

$$2HC\ell + CaCO_3 \rightarrow CaC\ell_2 + CO_2 + H_2O$$

- Gas bubbles escape from the end of the delivery tube and pass through the lime water. Initially the lime water stays clear because the first few bubbles are air that was already in the elbow tube and the delivery tube. Later bubbles contain the gas from the reaction.
- The lime water starts to turn milky. This proves that the gas released during the reaction is carbon dioxide.

Conclusion

The calcium carbonate neutralises the hydrochloric acid to produce a salt, water and carbon dioxide gas. The gas is identified as carbon dioxide using clear lime water.

NOTE

Carbon dioxide turns clear lime water milky. It is the only known gas that has this effect. When the lime water turns milky we have conclusive proof that the gas is carbon dioxide.

Lime water is a solution of calcium hydroxide. The new substance creating the milky effect is insoluble white calcium carbonate.

carbon dioxide + calcium hydroxide → calcium carbonate + water

$$CO_2 + Ca(OH)_2 \rightarrow CaCO_3 + H_2O$$

PREDICTING THE NAME OF THE SALT WHEN AN ACID REACTS WITH A CARBONATE

- All **carbonates** have a group of atoms made up of one carbon and three oxygen atoms (**CO_3**). The atoms in the carbon dioxide product (CO_2) originate from this group. There is one oxygen atom remaining.
- The acid donates two hydrogen atoms to this remaining oxygen atom to form the water molecule.
- As before, the remainder of the acid becomes the non-metal part of the salt.

- The remainder of the carbonate is almost always a metal. This metal becomes part of the salt. If you know the name or formula of the acid and the carbonate you can name the salt that is formed.

EXAMPLES

Acid	Carbonate	Salt formed
hydrochloric acid	potassium carbonate	potassium chloride
sulphuric acid	lithium carbonate	lithium sulphate
nitric acid	sodium carbonate	sodium nitrate
ethanoic acid (vinegar)	magnesium carbonate	magnesium ethanoate

- All these reactions occur in the presence of water, so the salt formed remains dissolved in the water.

UNIT 4

APPLICATIONS OF REACTIONS OF ACIDS WITH BASES

We use acids and bases in many ways. There are also economic uses of these chemical substances.

- We add **bicarbonate of soda** ($NaHCO_3$) to **bread** dough or a cake mix. It releases carbon dioxide gas which makes the dough or mix 'rise'.

- Most swimming pools have a carefully controlled pH. We add **pool acid** when we need to lower the pH and we add soda ash (sodium carbonate) when we need to raise the pH.
- **Bee stings** are painful because they inject an **acid** under your skin. Bicarbonate of soda will help relieve the stinging because it neutralises the acid.

- **Wasp stings** are also painful – they inject a **base** under your skin so it has to be treated with a weak acid like vinegar.
- Too much **acid** in the **stomach** causes indigestion and heartburn. **Antacids** are a group of medicines used to neutralise excess stomach acid. Typically they contain bases like calcium carbonate, magnesium carbonate, magnesium hydroxide and aluminium hydroxide.

- The inside of the **mouth** is usually slightly **acidic** after a meal. Acids can damage tooth enamel and lead to tooth decay. **Toothpaste** is weakly **basic** and leaves the mouth slightly basic after brushing the teeth.

- Most **soils** are slightly **acidic**. Most vegetable crops like acid soils. Most flower crops grow better in neutral or basic soils. Farmers can use limestone to make soils less acidic. The chemical formula for limestone is $CaCO_3$. By adding a carbonate to the soil, the pH can be raised for crops that prefer a more basic soil.

TOPIC 7

REACTIONS OF ACIDS WITH METALS

US 7507: SO 5 – AC 1-2
US 7508: SO 2 – AC 1-4; SO 3 – AC 1-4; SO 4 – AC 1
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1, 2, 4
US 7511: SO 3 – AC 1
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Devise and implement a procedure to investigate the reactions between acids and metals
- Gather relevant data regarding the reactions between acids and metals
- Define concepts and principles relating to acid-metal reactions
- Demonstrate reactions between acids and metals
- Interpret scientific evidence and apply knowledge and skills regarding acid-metal reactions

Metals are very useful materials in a wide range of objects. Unfortunately many metals react with acids when they are in contact with each other and cause corrosion and damage.

UNIT 1

THE GENERAL REACTION OF AN ACID WITH A METAL

- The reaction between an acid and a metal produces a **salt** and **hydrogen gas**. The general word equation of the reaction is:

acid + metal → salt + hydrogen

- The acid provides the non-metal part of the salt. This part combines with the metal to form the salt product.
- Unlike the reactions with hydroxides, oxides and carbonates, there is no oxygen available from the reactants to form water. Instead, the **acid loses hydrogen** atoms to form hydrogen gas.

PREDICTING THE NAME OF THE SALT WHEN AN ACID REACTS WITH A METAL

- If you know the metal and the acid you can predict the salt that is formed.

EXAMPLES

Acid	Metal	Salt formed
hydrochloric acid	potassium	potassium chloride
sulphuric acid	calcium	calcium sulphate
nitric acid	sodium	sodium nitrate
ethanoic acid (vinegar)	magnesium	magnesium ethanoate

- A typical reaction can be represented using a word equation or a chemical equation, e.g.:

sulphuric acid + lithium → lithium sulphate + hydrogen gas

$$H_2SO_4 + 2Li \rightarrow Li_2SO_4 + H_2$$

- Remember to balance the chemical equation by counting the number of atoms of each element on both sides.
- Add coefficients where necessary. In this example, the '2' in front of Li balances the equation.

PRACTICAL INVESTIGATION

Test the Gas Released during the Reaction Between an Acid and a Metal

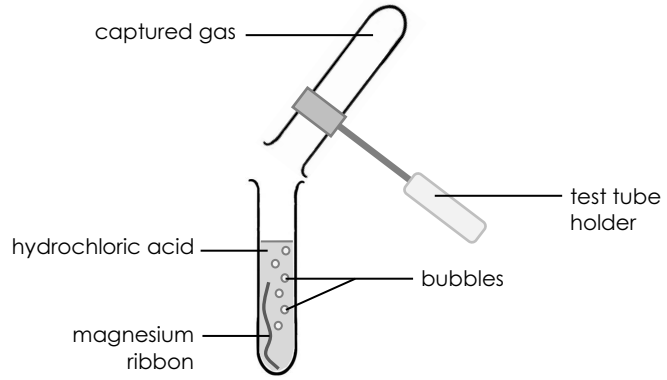
Requirements

- dilute hydrochloric acid solution
- 2 cm piece of magnesium ribbon
- test tube holder
- two test tubes
- matches

Method

1. Place the magnesium ribbon in one of the test tubes.
2. Pour sufficient hydrochloric acid into the test tube to cover the magnesium and observe any changes that occur.
3. Hold the second test tube upside down over the first test tube to catch any gases escaping from the reaction. Use the test tube holder to hold the test tube.

How to capture a gas that is lighter than air



4

4 After a while move the first test tube to the side. Light a match and hold it to the mouth of the second (upside-down) test tube. Record your observations.

Observations and Discussion

- The reaction starts as soon as the hydrochloric acid is poured on to the magnesium. Bubbles form on the surface of the metal and rise in the liquid. The gas in the bubbles is colourless.
- The balanced chemical reaction is:

$$2HC\ell + Mg \rightarrow MgC\ell_2 + H_2$$

- The gas bubbles escape from the first test tube but can be collected in the second test tube.
- The gas can be lit with a burning match. The gas will burn with a blue flame. If there is enough gas, the burning is rapid and a popping sound can be heard. This proves that the gas released during the reaction is hydrogen.

NOTE

Observing in science involves using any of our senses, e.g. seeing or hearing or smelling.

- Heat is produced from the burning of the hydrogen, so it is best to hold the test tube with a test tube holder.

Conclusion

- The magnesium neutralises the hydrochloric acid to produce a salt and hydrogen gas. The gas is identified as hydrogen using the 'squeaky pop' test.

NOTE

Hydrogen burns quickly with a pale blue flame. The rapid burning of the hydrogen sucks air into the test tube to produce a distinctive squeak or popping sound, hence the name 'squeaky pop' test. This test is regarded as conclusive proof that the gas is hydrogen.

MODULE 2 QUESTIONS

TOPIC 1 COMPOUNDS

Question 1

1.1 For each element given in the table below, provide its symbol, group number, period number, atomic number and mass number.

Element	Symbol	Group number	Period number	Atomic number	Mass number
Fluorine	1.1.1	1.1.2	1.1.3	1.1.4	1.1.5
Phosphorus	1.1.6	1.1.7	1.1.8	1.1.9	1.1.10
Calcium	1.1.11	1.1.12	1.1.13	1.1.14	1.1.15
Silicon	1.1.16	1.1.17	1.1.18	1.1.19	1.1.20
Lithium	1.1.21	1.1.22	1.1.23	1.1.24	1.1.25
Boron	1.1.26	1.1.27	1.1.28	1.1.29	1.1.30

1.2 Which of these elements are metals?

1.3 Which of these elements are semi-metals?

Question 2

Each element has a name, symbol, atomic number and mass number in the Periodic Table. Use the Periodic Table (see p. 96) to complete the missing information.

2.1

11
23

2.2

chlorine
35,5

2.3

Ne

Question 3

Find the answers to the following questions in the Periodic Table (see p. 96).

3.1 Name another element with properties similar to sulphur.

3.2 Indicate the number of protons in the nucleus of:

3.2.1 a beryllium atom

3.2.2 a chlorine atom

3.2.3 a zinc atom

3.3 Name a semi-metal that is in the same period as beryllium.

3.4 Which element has an atomic number that is double that of nitrogen?

Question 4

Give the scientific name for the compounds below that contain these combinations of elements.

4.1 $NaC\ell$ 4.2 KBr

4.3 MgF_2 4.4 CuO

4.5 Li_2S

Question 5

Give the scientific name for the compounds below that contain these combinations of elements.

5.1 K_2SO_4 5.2 $Be(NO_3)_2$

5.3 $Fe(OH)_2$ 5.4 $Zn(C\ell O_4)_2$

5.5 $Ca_3(PO_4)_2$

Question 6

Complete the table by providing either the formula or the scientific name of the given compound.

Formula	Name
H_2O	6.1
CH_4	6.2
6.3	diphosphorus pentoxide
6.4	dinitrogen monoxide
CO	6.5
6.6	sulphur dioxide
OF_2	6.7
$HC\ell$	6.8
6.9	boron trichloride
6.10	sulphur trioxide

Question 7

Refer to the example given and complete the table below.

Compound		Elements present	Number of atoms of each element	Ratio in which elements bond
Name	**Formula**			
Example: sodium sulphate	Na_2SO_4	sodium, sulphur, oxygen	Na : 2; S : 1; O : 4	Na : S : O 2 : 1 : 4
(i)	$A\ell_2(PO_4)_3$			
(ii)				Fe : O 2 : 3
(iii)			K : 2; S : 1	
(iv) magnesium nitrate				Mg : N : O 1 : 2 : 6
(v) dihydrogen dioxide				

Question 8

Consider the following compounds: NH_4NO_2, Ba_3N_2, $Fe(NO_3)_3$

8.1 In this sequence, give the name ending of each compound.

8.2 Indicate the number of each of the mentioned particles that are present in the compounds by completing the table.

Number of:	Compounds		
	NH_4NO_2	Ba_3N_2	$Fe(NO_3)_3$
Atoms			
Oxygen atoms			
Metal atoms			
Nitrogen atoms			
*Nitrate ions			

***** *for enrichment*

Question 9

Give the chemical name and the common name for each of the following compounds:

$HC\ell$; H_2SO_4 ; HNO_3 ; NH_3 ; $NaC\ell$; $NaHCO_3$

TOPIC 2 CHEMICAL REACTIONS

Question 10

Write each of these descriptions of a reaction as a word equation:

10.1 Sodium reacts with sulphur to form sodium sulphide.

10.2 Calcium reacts with chlorine to form calcium chloride.

10.3 We get lithium oxide when lithium reacts with oxygen.

10.4 Potassium explodes in water and makes potassium hydroxide.

Question 11

Write each of these descriptions of a reaction as a balanced chemical equation:

11.1 Nitrogen reacts with hydrogen to form nitrogen trihydride.

11.2 Carbon reacts with chlorine to form carbon tetrachloride.

11.3 We get sulphur dioxide when sulphur burns in oxygen.

Question 12

Answer the following questions about the reaction:

$$2B + 3C\ell_2 \rightarrow 2BC\ell_3$$

12.1 Name the product.

12.2 How many atoms of boron are on the left hand side of the reaction equation?

12.3 How many atoms of chlorine are on the left hand side of the reaction equation?

12.4 Fill in the gaps:

There are _____ atoms of boron and _____ atoms of chlorine on the right hand side of the reaction equation.

12.5 Is the reaction balanced? Give a reason for your answer.

Question 13

Here is a reaction that turns a clear liquid milky. There are two products.

$$Ca(OH)_2 + CO_2 \rightarrow CaCO_3 + H_2O$$

13.1 Name the two reactants.

13.2 Name the two products.

13.3 Complete the table by counting the number of atoms of each element on both sides.

Element	Calcium	Oxygen	Hydrogen	Carbon
No. of atoms on left-hand side	13.3.1	13.3.3	13.3.5	13.3.7
No. of atoms on right-hand side	13.3.2	13.3.4	13.3.6	13.3.8

13.4 Is the reaction balanced?

Question 14

We can measure the wealth of a country by this chemical reaction:

$$SO_2 + O_2 \rightarrow SO_3$$

14.1 Copy the chemical equation and balance it.

14.2 Write the word equation for this reaction – you will have to name the reactants and products yourself.

14.3 Complete this sentence: Two _____ of SO_2 reacts with one _____ of O_2 to form _____ molecules of SO_3.

Question 15

Balance each of the following chemical equations. Then write a word equation for each equation:

15.1 $Zn + HC\ell \rightarrow ZnC\ell_2 + H_2$ 15.2 $P + O_2 \rightarrow P_2O_5$

15.3 $BaC\ell_2 + AgNO_3 \rightarrow Ba(NO_3)_2 + AgC\ell$

Note: *Ag = silver*

15.4 $CaCO_3 + HNO_3 \rightarrow Ca(NO_3)_2 + CO_2 + H_2O$

Question 16

Using the formulas below, together with the Periodic Table (see p. 96), write a balanced chemical equation for each of the following word equations:

H_2SO_4 ; KOH ; Na_2SO_4 ; NaOH ; HNO_3 ; $Fe(NO_3)_2$

16.1 potassium + water → potassium hydroxide + hydrogen gas

16.2 hydrogen sulphate (sulphuric acid) + sodium hydroxide → sodium sulphate + water

16.3 carbon + oxygen → carbon monoxide

16.4 iron + hydrogen nitrate (nitric acid) → iron nitrate + hydrogen gas

TOPIC 3

REACTIONS OF METALS WITH OXYGEN

Question 17

Select words from the list to complete the sentences below.

neon ; carbon ; aluminium ; reacts with ; to form ; and ; copper ; iron ; lithium ; oxygen ; nitrogen ; calcium

17.1 Lithium _____ oxygen to form _____ oxide.

17.2 _____ reacts with _____ to form aluminium oxide.

17.3 Calcium reacts with _____ to form _____ oxide.

17.4 _____ reacts with oxygen _____ copper oxide.

Question 18

Select symbols from the list to complete the chemical equations below.

O_2 ; → ; Mg ; Na_2O ; O_2 ; +

18.1 Na _____ O_2 → _____ 18.2 _____ + _____ → MgO

18.3 Zn + _____ _____ ZnO

Question 19

Balance the following reactions and name the products:

19.1 $K + O_2 \rightarrow K_2O$ 19.2 $Fe + O_2 \rightarrow FeO$

Question 20

Answer the following questions about the reaction of magnesium with oxygen:

20.1 Give the general word equation for the combustion reaction of a metal in oxygen.

20.2 Give the specific word equation for the above reaction.

20.3 Give a balanced chemical equation for the above reaction.

20.4 Is heat needed to start the reaction? What step in the method supports your answer?

20.5 Describe the appearance of the magnesium before the reaction takes place.

20.6 What is the colour of the magnesium oxide?

20.7 Other than colour, what physical property changes when magnesium burns?

20.8 Identify **two** dangers in this experiment and the safety precautions needed to mitigate the risk.

Question 21

Answer the following questions about the reaction of iron with oxygen:

21.1 Name the specific reactants that you will use and give a short description of the experimental procedure that you will follow for this reaction.

21.2 What is the colour of the flame with which the iron reactant start to glow/burn?

21.3 How will you afterwards know if a chemical reaction took place?

21.4 Compare the colour of the iron reactant to the colour of the iron oxide product.

21.5 We say that the product is brittle. What does *brittle* mean?

21.6 Which reaction happens faster – iron burning in air or iron burning in oxygen?

21.7 Give an observation that supports your answer to Question 21.6.

21.8 Consider the chemical equation for this reaction:

$$Fe + O_2 \rightarrow Fe_2O_3$$

21.8.1 Balance the above reaction.

21.8.2 Give a word equation for this reaction.

Question 22

Rusting is a world-wide problem leading to the loss of equipment worth billions of rands every year.

22.1 Which metal is involved in rusting?

22.2 Rusting is a form of corrosion. What is *corrosion*?

22.3 Balance this sequence of chemical equations involved in the formation of rust. Name the products formed in the second and third reactions.

$$FeO + O_2 \rightarrow Fe_2O_3$$
$$FeO + H_2O \rightarrow Fe(OH)_2$$
$$Fe_2O_3 + H_2O \rightarrow Fe(OH)_3$$

22.4 Identify, for each example below, whether it is an adequate method to prevent rusting of a steel object.

22.4.1 place in water
22.4.2 coat with oil
22.4.3 wipe with a dry cloth
22.4.4 wrap in paper
22.4.5 coat with varnish
22.4.6 attach a piece of copper

Question 23

For each example below, suggest the best way to prevent rusting:

23.1 steel supports for a bridge

23.2 corrugated iron roofing sheets
23.3 gear components on a bike
23.4 metal window frames
23.5 steel pipes underground

REACTIONS OF NON-METALS WITH OXYGEN

Question 24

24.1 Give the general word equation for a non-metal that burns in oxygen.

24.2 Give the formula of oxygen gas.

24.3 How can pure oxygen be obtained for a reaction with a non-metal?

24.4 For each of the following word equations, write the chemical equation using symbols, and then balance the equation:

24.4.1 nitrogen + oxygen → nitrogen dioxide

24.4.2 iodine + oxygen → iodine trioxide

24.4.3 phosphorus + oxygen → diphosphorus pentoxide

Question 25

When carbon burns in enough oxygen, it forms a gas. The gas is invisible and has no smell.

25.1 Which substance, as a source of carbon, can be used for the experiment?

25.2 Give the formula of carbon.

25.3 Name the invisible gas product.

25.4 What is the chemical formula of the product?

25.5 How can one test for the product to prove that this specific product was formed?

25.6 What is the colour of the flame when carbon burns?

25.7 List **five** fuels that contain carbon.

25.8 What environmental problem is likely caused by people burning too much fuel that contains carbon?

25.9 If there is too little oxygen during the combustion reaction of carbon, then the product is carbon monoxide. Write a balanced chemical equation for this reaction.

Question 26

The burning of sulphur is represented by the following chemical equation:

$$S + O_2 \rightarrow SO_2$$

26.1 Is this equation balanced? Provide two pieces of evidence to support your answer.

26.2 Name the product.

26.3 Describe the smell and appearance of the product.

26.4 What is the colour of the flame when sulphur burns?

26.5 Coal mined in South Africa has a high sulphur content. Explain how this increases the likelihood of acid rain.

TOPIC 5 ACIDS, BASES AND pH VALUE

Question 27

Complete the table to compare the properties of acids and bases.

	Taste	Feel between fingers	Effect on minerals	Soluble in water (yes/no)
Acids	27.1	27.3	27.5	27.7
Bases	27.2	27.4	27.6	27.8

Question 28

Classify each of the household substances below as a strong or weak acid or base. Say what colour a universal indicator will turn in the substance.

28.1 coffee

28.2 cola

28.3 rooibos tea

28.4 milk of magnesia

Question 29

29.1 What is an *indicator*?

29.2 Name **two** natural indicators.

29.3 Name **two** commercial indicators.

29.4 How does an universal indicator differ from the above mentioned indicators?

29.5 A few drops of universal indicator is added to an unknown solution in a test tube. The colour of the indicator changes to orange.

29.5.1 What is the nature of the solution in the test tube? Choose from **acidic**, **neutral** or **basic**.

29.5.2 What is the approximate pH range of the solution? Choose from **<7**, **=7** or **>7**.

29.6 A strong base is slowly added to the content of the test tube.

29.6.1 What colour change can be observed? Choose from **orange to red** or **orange to blue**.

29.6.2 What will happen to the pH of the solution? Choose from **increases**, **stays the same** or **decreases**.

29.7 A strong acid is now slowly added to the test tube.

29.7.1 What colour change can be observed?

29.7.2 What will happen to the pH of the solution?
Choose from **increases**, **stays the same** or **decreases**.

Question 30

Select a colour in the right hand column that matches the description in the left hand column.

	Description	Colour
30.1	The colour of phenolphthalein in an acid.	colourless
30.2	The colour of bromothymol blue in an acid.	red
30.3	The colour of red cabbage water when neutral.	pink
30.4	The colour of litmus in a base.	orange
30.5	The colour of universal indicator in a very strong base.	yellow
30.6	The colour of turmeric water in a base.	green
		blue
		indigo
		violet
		purple
		black

Question 31

Toothpaste has been mixed with some water.

31.1 What is the approximate pH of this mixture?

31.2 Why should toothpaste be this pH?

31.3 What colour will bromothymol blue turn in this mixture?

Question 32

Surprisingly, milk is slightly acidic. It is because of the lactic acid in the milk.

32.1 What element do you find in all acids?

32.2 What colour will litmus be in milk?

32.3 You dilute the milk with water. What colour is the litmus now?

Question 33

Here is an experimental procedure.

Step 1: Add a few drops of universal indicator to some dilute hydrochloric acid.

Step 2: Add sodium hydroxide drop by drop to the acid-indicator mixture until it turns green.

33.1 What is the colour of the indicator in the acid?

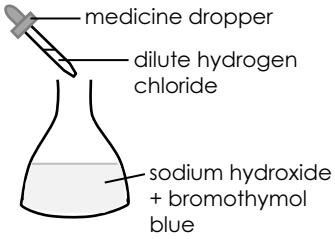
33.2 What is the pH of the mixture when the indictor turns green?

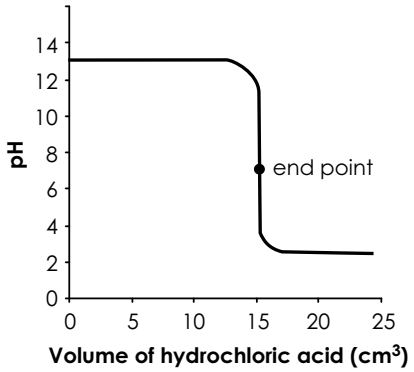
33.3 What do we call this type of reaction?

33.4 Explain the meaning of the term *end point* in the context of this experiment.

Question 34

The following graph represents the change in pH of a 25 cm^3 sodium hydroxide solution as dilute hydrogen chloride is being added to it. The indicator bromothymol blue was added beforehand to the sodium hydroxide solution.





34.1 Give the initial pH of the sodium hydroxide, before any hydrochloric acid has been added.

34.2 What is the initial colour of the bromothymol blue?

34.3 What volume of acid was added when the end point is being reached?

34.4 What is the pH of the content of the beaker at the end point?

34.5 What is the pH of the content of the beaker after 20 cm^3 of hydrochloric acid had been added?

34.6 What will the colour of the indicator be now?

TOPIC 6 REACTIONS OF ACIDS WITH BASES

Question 35

35.1 How can a metal oxide be formed in general?

35.2 Give an example of a metal oxide of a group 2 element.

35.3 How can a metal hydroxide be formed in general?

35.4 Give an example of a metal hydroxide of a group 1 element.

35.5 How can a non-metal oxide be formed in general?

35.6 Give an example of a non-metal oxide of a group 6 element.

Question 36

For solutions of the following substances:

(i) give the name of one example.

(ii) say if the solution will be acidic or basic.

(iii) say if it has a low or a high pH.

36.1 a metal oxide

36.2 a metal carbonate

36.3 a metal hydroxide

36.4 a non-metal oxide

Question 37

Give the general form of the following reactions as a word equation:

37.1 The reaction between an acid and a metal hydroxide.

37.2 The reaction between an acid and a metal oxide.

37.3 The reaction between an acid and a metal carbonate.

Question 38

Match the names of the substances in Column A with a chemical formula from Column B.

	Column A	Column B
38.1	potassium hydroxide	$CaC\ell_2$
38.2	sodium sulphate	NaOH
38.3	calcium hydroxide	KNO_3
38.4	magnesium nitrate	$Mg(OH)_2$
38.5	calcium chloride	$LiC\ell$
38.6	lithium hydroxide	Na_2SO_4
38.7	magnesium hydroxide	KOH
38.8	potassium nitrate	LiOH
38.9	sodium hydroxide	$Mg(NO_3)_2$
38.10	lithium chloride	$Ca(OH)_2$

Question 39

Use your answers in Question 38 to write a word equation and a balanced chemical equation for each of the following reactions:

39.1 nitric acid and potassium hydroxide

39.2 hydrochloric acid and calcium hydroxide

39.3 nitric acid and magnesium hydroxide

39.4 sulphuric acid and sodium hydroxide

39.5 hydrochloric acid and lithium hydroxide

Question 40

Match the names of the substances in Column A with a chemical formula from Column B.

	Column A	Column B
40.1	sodium oxide	$LiNO_3$
40.2	ammonium sulphate	$(NH_4)_2O$
40.3	lithium oxide	CaO
40.4	ammonium oxide	Na_2O
40.5	lithium nitrate	Li_2O
40.6	calcium oxide	MgO
40.7	magnesium oxide	$(NH_4)_2SO_4$
40.8	sodium chloride	$NaC\ell$

Question 41

Use your answers in Questions 38 and 40 to write a word equation and a balanced chemical equation for each of the following reactions:

41.1 hydrochloric acid and calcium oxide

41.2 nitric acid and magnesium oxide

41.3 hydrochloric acid and sodium oxide

41.4 sulphuric acid and ammonium oxide

41.5 nitric acid and lithium oxide

Question 42

Match the names of the substances in Column A with a chemical formula from Column B.

	Column A	Column B
42.1	lithium sulphate	$Ca(NO_3)_2$
42.2	ammonium carbonate	$MgCO_3$
42.3	calcium nitrate	$(NH_4)_2CO_3$
42.4	magnesium chloride	Li_2CO_3
42.5	lithium carbonate	Na_2CO_3
42.6	magnesium carbonate	Li_2SO_4
42.7	calcium carbonate	$MgC\ell_2$
42.8	sodium carbonate	$CaCO_3$

Question 43

Use your answers in Questions 38, 40 and 42 to write a word equation and a balanced chemical equation for each of the following reactions:

43.1 hydrochloric acid and magnesium carbonate

43.2 sulphuric acid and lithium carbonate

43.3 nitric acid and calcium carbonate

43.4 sulphuric acid and ammonium carbonate

43.5 hydrochloric acid and sodium carbonate

Question 44

Heartburn is a medical condition when too much acid is produced in the stomach.

44.1 Is stomach acid a strong or a weak acid?

44.2 Give the common name or the scientific name of stomach acid.

44.3 What is the approximate pH of stomach acid?

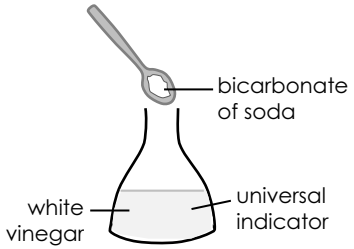
44.4 Name the group of medicines (e.g. milk of magnesia) that can be used to treat heartburn?

44.5 Milk of magnesia relieves the discomfort caused by stomach acid. We say it ____ the stomach acid.

44.6 What happens to the pH of the acid when it is treated with milk of magnesia? Choose between **increases**, **stays the same** or **decreases**.

Question 45

The science teacher wants to illustrate some important principles about acids and bases to his class. He pours about 125 mℓ white vinegar into a glass container and add a few drops universal indicator to it. He then adds a little bit of bicarbonate of soda (sodium bicarbonate) with a teaspoon and stirs the mixture continuously. Gas bubbles can be observed in the reaction mixture, which indicates that a reaction is taking place. After a while the reaction stops, but when a bit more bicarbonate of soda is added, the bubbles start forming again.



45.1 What is the colour of the indicator in the vinegar?

45.2 Which substance acts as an acid and which substance acts as a base?

45.3 Give the name or the formula of the gas that is being produced.

45.4 Can an unlimited amount of bicarbonate of soda be added to produce more and more gas? Explain.

45.5 What colour change can be observed as the bicarbonate of soda is being added?

45.6 This reaction is also known as a neutralisation reaction. Briefly explains what is meant by *neutralisation*.

45.7 At which stage/point is the neutralisation complete? (Refer to the amounts of acid and base in the mixture.)

45.8 What do we call the point mentioned in Question 45.7?

45.9 What is the colour of the reaction mixture at this point mentioned in Question 45.8?

TOPIC 7 REACTIONS OF ACIDS WITH METALS

Question 46

The general form of the reaction between an acid and a metal is:

acid + metal → salt + hydrogen

For each of the following reactions between an acid and a metal, write the word equation and the balanced chemical equation. You can find the formulae you need in the previous questions.

46.1 hydrochloric acid and calcium

46.2 nitric acid and lithium

46.3 sulphuric acid and sodium

Question 47

Dilute sulphurous acid (H_2SO_3) splashes onto a zinc roof sheeting. Where the acid lands the zinc turns from a silvery-grey to a dark grey colour.

47.1 What is the sulphurous acid dissolved in?

47.2 Give the everyday term for this solution.

47.3 What general term do we use to describe the chemical reaction between the acid and the zinc?

47.4 Write a balanced chemical equation for this reaction if one of the products is $ZnSO_3$.

47.5 Name the gas produced in this reaction.

47.6 Why do we collect the gas in an upside down test tube?

47.7 Name the product you expect to form when this gas burns in oxygen.

MODULE 3 ENERGY and CHANGE

ENERGY AND CHANGE

US 7507

Demonstrate an understanding of the concept of science

	SO1	SO2	SO3	SO4	SO5
TOPIC 3					X
TOPIC 4					X
TOPIC 5					X
TOPIC 6					X

US 7508

Conduct an investigation in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 1	X	X	X	X
TOPIC 2		X	X	
TOPIC 3	X	X	X	X
TOPIC 4	X	X	X	X

US 7509

Apply basic concepts and principles in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 1	X	X	X	X
TOPIC 2	X	X	X	X
TOPIC 3	X	X	X	X
TOPIC 4	X	X	X	X
TOPIC 5	X	X		X
TOPIC 6	X			
TOPIC 7	X	X		

US 7511

Analyse how scientific skills and knowledge contribute to sustainable use of resources

	SO1	SO2	SO3	SO4
TOPIC 3				X
TOPIC 5				X
TOPIC 6	X	X	X	

US 7513

Assess the impact of scientific innovation on quality of life

	SO1	SO2	SO3
TOPIC 3	X	X	
TOPIC 4	X		
TOPIC 5	X	X	
TOPIC 6	X	X	
TOPIC 7			X

TOPIC 1: FORCES

US 7508: SO 1 – AC 1-2; SO 2 – AC 1, 3, 4; SO 3 – AC 1, 3, 5; SO 4 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1-4

Lesson Outcomes

By the end of this topic, learners should be able to:

- Select and explain a problem/phenomenon to be investigated
- Devise and implement a procedure to investigate different forces
- Gather and interpret data
- Define concepts and principles relating to forces
- Demonstrate the effects of forces on materials
- Interpret scientific evidence and apply knowledge and skills regarding forces

Resources

- Class text & Study guide
- Practical equipment p. 134
- Practical equipment p. 135
- Practical equipment p. 136
- Practical equipment p. 142
- Practical equipment p. 143
- Practical equipment p. 144
- Practical equipment p. 145
- Practical equipment p. 147
- Practical equipment p. 148
- Practical equipment p. 150

TOPIC 2: ELECTRIC CELLS AND ENERGY SYSTEMS

US 7508: SO 2 – AC 1, 3, 4; SO 3 – AC 1, 3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 3; SO 4 – AC 1,4

Lesson Outcomes

By the end of this topic, learners should be able to:

- Devise and implement a procedure to investigate electric cells
- Gather and interpret data
- Define concepts and principles relating electric cells and energy systems
- Demonstrate how to make a cell using a lemon or zinc and copper
- Interpret scientific evidence and apply knowledge and skills regarding electric cells

Resources

- Class text & Study guide
- Practical equipment p. 154

TOPIC 3: RESISTANCE

US 7507: SO 5 – AC 1-2
US 7508: SO 1 – AC 1-3; SO 2 - AC 1, 3, 4; SO 3 – AC 1, 3, 5; SO 4 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-2; SO 4 – AC 1, 4
US 7511: SO 4 – AC 1
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of resistors in life
- Formulate a scientific hypothesis
- Devise and implement a procedure to investigate factors that affect resistance
- Gather and interpret data
- Define concepts and principles in electrical resistance
- Demonstrate how properties of conductors influence resistance
- Explain the principles and application of resistors in technology

Resources

- Class text & Study guide
- Practical equipment p. 158
- Practical equipment p. 159

TOPIC 4: SERIES AND PARALLEL CIRCUITS

US 7507: SO 5 – AC 1-2
US 7508: SO 1 – AC 1-2; SO 2 - AC 1, 3, 4; SO 3 – AC 1, 3, 5; SO 4 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-2; SO 4 – AC 1, 3, 4
US 7513: SO 1 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of series or parallel circuits in life
- Devise and implement a procedure to investigate electrical circuits
- Define concepts and principles relating to electrical circuits
- Devise and implement a procedure to investigate different circuits
- Gather and interpret data
- Demonstrate how to connect circuits in series or parallel
- Interpret scientific evidence and apply knowledge and skills in electrical circuits
- Explain the application of circuits in wiring and lighting of a house

Resources

- Class text & Study guide
- Ammeter
- Voltmeter
- Practical equipment p. 162
- Practical equipment p. 163
- Practical equipment p. 164
- Practical equipment p. 165
- Practical equipment p. 167

TOPIC 5: SAFETY WITH ELECTRICITY

US 7507: SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 2
US 7511: SO 4 – AC 1
US 7513: SO 1 – AC 1-4; SO 2 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of electricity safety
- Define concepts and principles relating electrical safety
- Demonstrate how to wire a three-pin plug safely
- Explain the application of electrical safety in wiring of plugs and houses

Resources

- Class text & Study guide
- Practical equipment p. 171

TOPIC 6: ENERGY AND THE NATIONAL ELECTRICITY GIRD

US 7507: SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3
US 7511: SO 1 – AC 1-3; SO 2 – AC 1-5; SO 3 – AC 1,2,3,5
US 7513: SO 1 – AC 1-4; SO 2 – AC 1-3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of electricity and energy sources in life
- Define concepts and principles relating to energy sources
- Classify and distinguish between renewable and non-renewable energy sources
- Explain how scientific knowledge and skills are applied to energy source development
- Describe the effect of the mismanagement of energy sources on the environment
- Explain the application of scientific principles in energy source development
- Determine the impact of energy sources on the quality of life

Resources

- Class text & Study guide

TOPIC 7: COST OF ELECTRICAL POWER

US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2 **US 7513:** SO 1 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to electrical costs
- Demonstrate how to calculate the cost of electricity

Resources

- Class text & Study guide
- Electricity bills

TOPIC 1 FORCES

US 7508: SO 1 – AC 1-2; SO 2 – AC 1, 3, 4; SO 3 – AC 1, 3, 5; SO 4 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-3; SO 4 – AC 1-4

Lesson Outcomes

By the end of this topic, learners should be able to:

- Select and explain a problem/phenomenon to be investigated
- Devise and implement a procedure to investigate different forces
- Gather and interpret data
- Define concepts and principles relating to forces
- Demonstrate the effects of forces on materials
- Interpret scientific evidence and apply knowledge and skills regarding forces

UNIT 1 TYPES OF FORCES

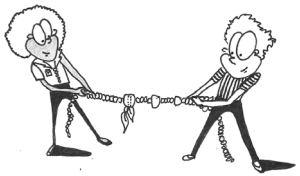
WHAT IS A FORCE?

The term 'force' is often associated with the size of a human's muscles. It is sometimes also confused with the energy or performance of a person, engine or machine.

In reality, forces are invisible — we can only see their effect.

- A force is a **push** or **pull** (or **twist**) exerted upon an object.
- When two objects interact, the one object can exert a force on the other.

The man pushes a vehicle



Two boys pull a rope

The boy screws the lid off a bottle

- There are different kinds of forces. The **type** of force (**name** of the force) depends on the origin of the force, i.e. how the force came into being.

MEASURING FORCE

- The unit in which force is measured is newton (N), named after the famous scientist Isaac Newton.
- A force has a **size** and a **direction**; we draw an arrow on paper to represent a force:

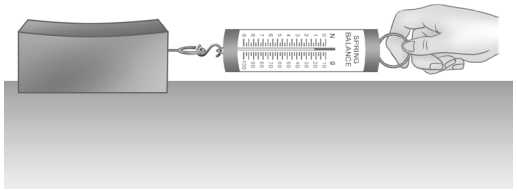
  length of arrow = size of force

  direction of arrow = direction of force

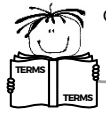
  e.g. a force of 40 N right can be represented as follows:

4 cm → scale: 1 cm : 10 N

- The symbol $\vec{F}$ is used to indicate a force.



A spring balance measuring the force needed to slide a block



spring balance: also called a spring scale, is used to measure force; contains a metal spring attached to a marker; the marker moves along a scale calibrated in newton, the unit of force

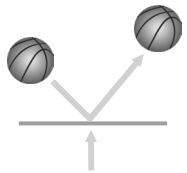
THE EFFECTS OF FORCES

Sometimes the force that is exerted on an object is too small to have a noticeable effect. In other cases, the effect is evident.

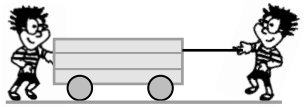
- A force can change the shape of an object.

- A force can change the movement of an object by:
  - putting a stationary object into motion

  - increasing or decreasing the speed of a moving object, or bringing it to a stop
  - changing the direction in which an object is moving



- Multiple forces can simultaneously be exerted on a single object. They then have a combined effect on the object.



A push force and a pull force are simultaneously exerted on a wagon

- If forces are exerted on an object but there is no visible effect, the forces balance one another. These forces are in **equilibrium**.

PRACTICAL INVESTIGATION 1A

The Effect of Push and Pull Forces on Objects and Materials

Aim

To investigate the effect of different forces on an object or a type of material.

Requirements

- ball of clay
- firm sponge

- tennis racket or similar
- inflated balloon
- strong elastic band
- tennis ball

Method

Perform the following actions:

1. Firmly squeeze the ball of clay in your hand. What happens to its shape when you do this?
2. Use your hands to lightly squeeze the sponge and then let it go. Now do this to the balloon. What happens to the shape of these objects?

3. Stretch the elastic band and release it. Compare its length before and after stretching.
4. Place the tennis ball on a horizontal surface, e.g. table top. Stretch the elastic band and release it so that it hits the side of the ball. What happens to the tennis ball?

5. Put the tennis ball on a smooth floor and exert a constant force sideways on it using either your hand or the racket. What happens to the speed of the ball?
6. Lightly roll the tennis ball over a carpet to the other side of the room. What happens to the speed of the ball?
7. Forcefully roll the tennis ball at the wall. Repeat this a couple of times, starting from different angles. What happens to the direction in which the ball is moving the moment the ball hits the wall?
8. Throw the ball to your friend by making it bounce off the floor once. Let them hit it back to you using a racket. What happens to the direction in which the ball is moving when it hits the floor and then again when it hits the racket?

Results and Conclusions

- When the clay is squeezed, a force is exerted on it and its shape changes. The clay keeps this new shape even after the force is removed. The clay is inelastic.
- When the sponge or balloon is squeezed, a force is exerted on it and its shape is changed. As soon as the force is removed, both objects return to their original shape. Both the sponge and balloon are elastic.

Results

- Your hand exerts a pulling force on the elastic band which stretches it out and changes its shape. It returns to its original form the moment it is released.
- When the elastic band hits the tennis ball, it exerts a force on the ball, causing it to roll away across the table top.
- When you exert a constant push force on the ball using your hand or the racket, the ball is set into motion and its speed increases.
- As the ball rolls forward across the carpet, the carpet exerts a frictional force backwards on the ball, causing the ball's speed to decrease.
- The moment the ball hits the wall, the wall exerts a force on it and changes the direction in which it is moving.
- The moment the ball hits the floor or racket, the floor or racket exerts a force on it and changes the direction in which it is moving.

FORCES WORK IN PAIRS

When two objects A and B interact, they each exert a force on the other. Forces thus always act **in pairs**.

- The force that object **A** exerts on object **B** is **equal** in **size** to the force that object **B** exerts on object **A**, but in the **opposite direction**.
- The forces are exerted on **different** objects so they cannot balance each other *(see Practical Investigation 1B)*.

PRACTICAL INVESTIGATION 1B

The Size and Direction of the Pair of Forces between Two Objects

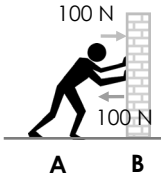
Aim

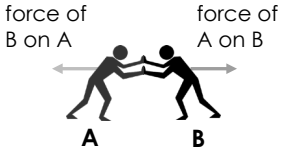
To investigate push and pull forces that objects exert on each other.

Method

Perform the following actions:

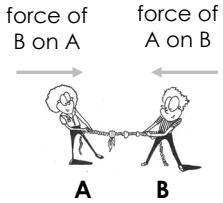
1. Use your hands to push against a wall, lightly at first and then harder.

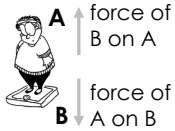




2. Stand opposite someone and push your hands against theirs; then both push with your hands.

3. Have two people at a small distance from each other each firmly grab hold of one end of a rope. First have one person pull hard on the rope, then have both people pull hard in opposite directions.

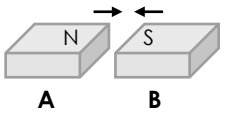


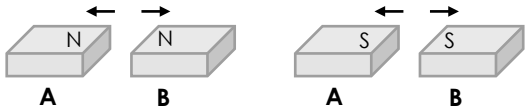


4. Stand on a bathroom scale.

5. Hold the N pole of one magnet near the S pole of another magnet.

   Turn one of the magnets around so that two S poles or two N poles face each other.





Results

Results and Conclusions

In all of the previous examples, there is a force pair at work:

- You exert a force on the wall and the wall exerts an equivalent force on you. The harder you push against the wall, the harder the wall pushes against you.
- You exert a push force on the other person and they, in turn, exert an equivalent push force on you. Regardless of whether one of you keep your hands still whilst the other pushes, or both of you push with your hands, an equal opposite push force is exerted on both persons' hands.
- You exert a pull force on the other person and they, in turn, exert an equivalent pull force on you. Regardless of whether one or both of you are pulling, an equal opposite force that pulls you closer together is exerted on you both.
- You exert a downward force (your weight) on the scale and the scale exerts an equal upward force on you.
- The N pole of the one magnet exerts an attracting force on the S pole (unlike pole) of the other. In the exact same way, the S pole exerts an equal attracting force on the N pole.
- Two like poles (N and N or S and S) of two different magnets exert equal repelling forces on each other.

The two forces in a **force pair**:

- are **equal in size** (regardless of the mass of the objects or the strength of the magnets)
- work in **opposite directions,**
- are **simultaneously** exerted on both objects, and
- do **not balance** each other.

NOTE

Forces always work in pairs, in other words they exist as two forces that simultaneously act on different objects; they never exist as single forces.

BALANCED AND UNBALANCED FORCES

If more than one force is exerted on an object, the forces combine to deliver a **net** or **resultant** force. The combined effect that they have on the object depends on the size and direction of each force *(see Practical Investigation 1C)*.

PRACTICAL INVESTIGATION 1C

The Combined Effect of Forces on an Object

Aim

To investigate the effect of (1) balanced and (2) unbalanced forces on an object.

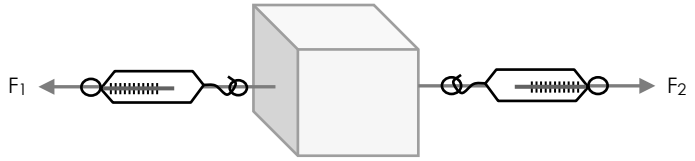
Requirements

- wooden block
- two hooks
- two spring balances

Method

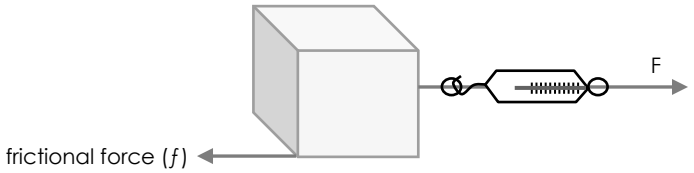
Screw two hooks into the exact same position on opposite sides of a large wooden block. Place the wooden block on a smooth surface. Now perform the following actions.

1. Hook a spring balance, calibrated in newton, to each hook on either side of the block. Check that the reading on each spring balance is zero.
   - Pull on the spring balances and extend them to the same length, thereby exerting equal forces in directly opposite directions on the wooden block. What do you observe?
   - Extend one spring balance further than the other, thereby exerting a larger force in one direction than in the other.



2. Now hook a spring balance to only one side of the block and place the block on a rough surface. Check that the reading on the spring balance is zero.

- Pull on the spring balance until the block starts to move. Allow the block to move at a constant speed. Take the scale reading to determine the size of the force required to:
  - set the block into motion, and
  - make the block move at a constant speed.
- Extend the spring balance further and, for a while, exert a larger constant force on the block. What happens to its speed?

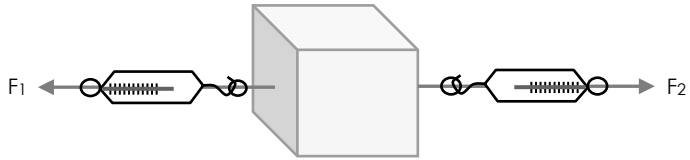


Results and Conclusions

Balanced forces

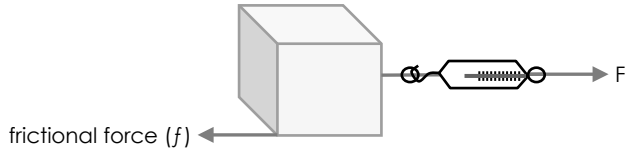
If equal forces are exerted on an object in opposite directions, the forces **balance** each other and have no effect on the object. The net/resultant force is **zero** ($F_{net} = 0$ **N**).

- The forces acting on the wooden block balance each other if:
  - two **equal** pull forces are exerted on the block, on a smooth (frictionless) surface, in directly **opposite** directions, or



$F_1 = F_2$

  - the **pull force** that is exerted on the block is equal to the **frictional force** (from the rough surface) exerted in the opposite direction.



$F = f$

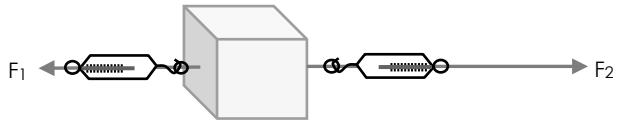
- The balanced forces (1) keep the block stationary, or (2) cause it to move in a straight line at a constant speed.
- Forces that balance each other have no combined effect on the speed, direction or shape of the object they act on.

frictional force: this is the contact force that opposes the movement of an object across a surface and that is parallel to the surface

Unbalanced forces

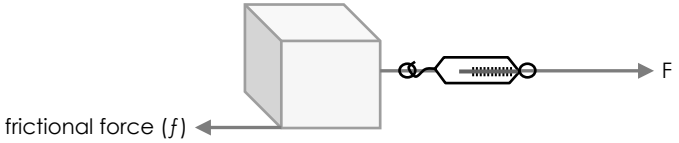
If unequal forces are exerted on an object in directly opposite directions, the forces do not balance each other, i.e. there is an **unbalanced** force acting on the object. The net/resultant force is **not zero** ($F_{net} \neq 0$ **N**).

- There is an unbalanced (net) force on the wooden block if:
  - **unequal** pull forces acting in directly **opposite** directions are exerted on the block on a smooth surface, or



$F_2 > F_1$

  - the **pull force** exerted on the block is **larger** than the **frictional force** (from the rough surface) exerted in the opposite direction.



$F > f$

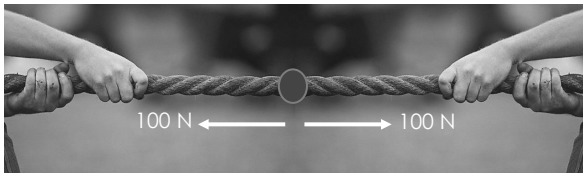
- The unbalanced force causes the block to change its speed. If it was at rest, it will start moving.
- Forces that do **not** balance each other do have a combined effect on the object they act on and can change its speed, direction or shape.

NOTE

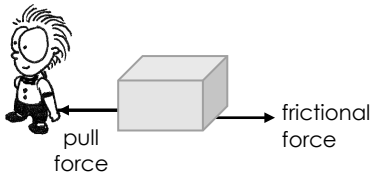
- *The block on the rough surface has both a pull force and a frictional force exerted on it.*
- *Take the reading on the spring balance just as the block starts moving. This shows the size of the pull force that is required to overcome the frictional force.*
- *The force that is required to set the block into motion is larger than the force that is required to keep it moving at a constant speed.*

Examples of Forces that are Balanced (in Equilibrium)

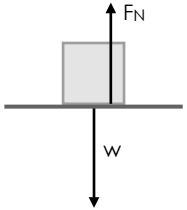
- Two tug-of-war teams exert equal pull forces on the rope so that the knot does not move.



- A boy pulls a crate across the floor with a pull force that is equal to the frictional force of the floor on the crate.



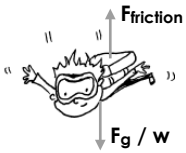
- The weight (w) of a wooden block that rests or moves on top of a floor (surface), is equal to the push force (F_N) of the floor on the block.



- If the forces exerted on an object balance each other, the object will
  - remain stationary; or
  - keep moving in a straight line at a constant speed; and
  - keep its shape

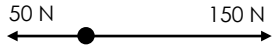
NOTE

*A skydiver falls downward through the air at a constant speed called **terminal velocity**. The downward gravitational force is balanced by the upward air resistance (on the open parachute and diver).*

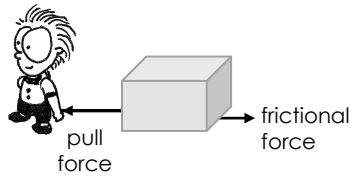


Examples of Forces that are Unbalanced (not in Equilibrium)

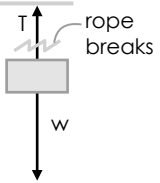
- One team in a tug-of-war competition exerts a larger pull force on the rope than the other.



- A boy pulls a crate across the floor with a pull force that is larger than the frictional force of the floor on the crate.



- The weight (w) of an object hanging from a rope a moment before the rope breaks is larger than the tension force (T) in the rope.



- An unbalanced force exerted on an object can change the object's:
  - speed
  - direction
  - shape

- *A falling stone accelerates downwards through the air. The downward gravitational force exceeds the upward air resistance and is not balanced by it.*
- *A cooldrink can is crushed if the compression force from outside the can exceeds the air pressure inside the can.*

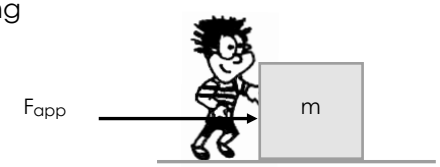
CONTACT FORCES AND FIELD FORCES

Forces are placed into two main groups, i.e. **contact forces** and **field forces** (non-contact forces):

- A contact force is the force that one object exerts on another when the objects are in contact with/touch each other.
- There are several different types of contact forces. The most important types are listed below:

Applied force (push and pull) (F_{app})

This includes any type of pushing or pulling on an object that causes a change in its position and speed, or that stretches or compresses it.

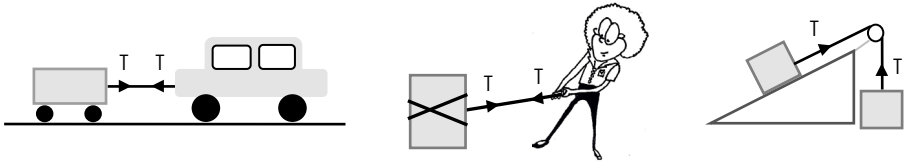


Compression force

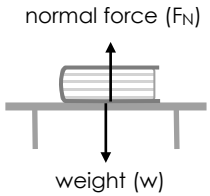
An object (e.g. a spring or balloon) that is compressed between one's hands is subject to compression force. A compressed object in turn exerts a compression force on the hands.

Tension force (T)

When objects are connected by means of a rope and the rope is pulled taut, the rope pulls on both objects. This force in a taut rope is called a tension force.



Normal force (N or F_N)



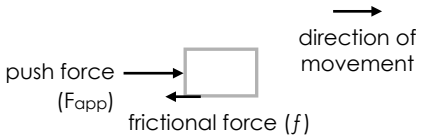
The force that a surface exerts on an object with which it is in contact and acts perpendicular to the surface on the object.

Frictional force (f)

This is the contact force that opposes the movement of an object across a surface. The direction of this force is parallel to the surface.

Properties of Frictional Force

- *Frictional force opposes movement and can prevent a stationary object from coming into motion, or it can decrease the speed of a moving object.*



- *Frictional force usually generates heat, e.g. when you rub your hands together or when a heavy crate is pushed across a rough surface.*

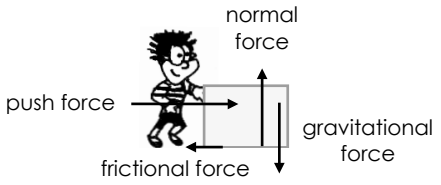
Indigenous people used to employ frictional force when they rubbed sticks together to start a fire.

Advantages and Disadvantages of Frictional Force

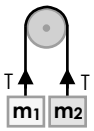
- ***Advantage:*** *It enables the soles of the feet to grip the ground and walk. Moving from one point to another would be impossible without frictional force. Note, however, that frictional force always opposes the direction of movement and will therefore decrease the speed of a moving object. This can be either an advantage or disadvantage.*
- ***Disadvantage:*** *Part of the energy provided by a person or engine is 'lost' due to friction.*

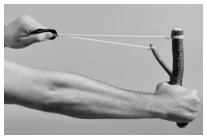
NOTE

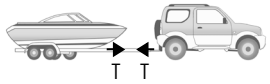
Different types of forces can simultaneously act on objects:

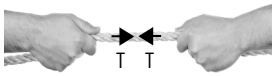


tension force (T)

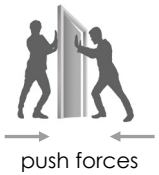


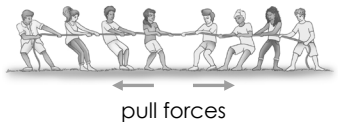






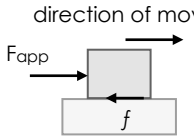
push and pull forces (F_{app})

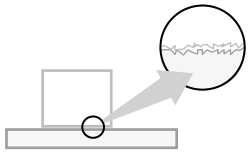




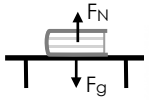
CONTACT FORCES

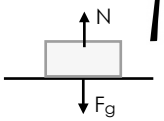
frictional force (f)

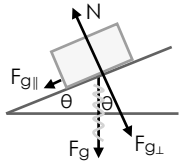




normal force (F_N/N)







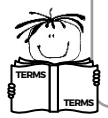
F_g = gravitational force (non-contact force); see next section

UNIT 2

FIELD FORCES: GRAVITATIONAL FORCE

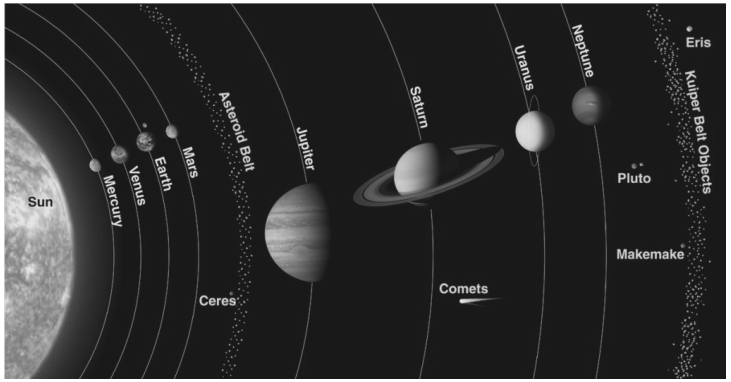
- A field force (non-contact force) is the force that one object exerts on another without the objects being in contact/touching. This is referred to as **action at a distance** force.
- If there is a 3D space around an object in which the effect of a certain type of force may be felt, this force space is called a **force field** and the force is called a **field force**.
- There are three main types of field forces introduced here: **gravitational force**, **magnetic force** and **electrostatic force**.

GRAVITATIONAL FORCE



Gravitational force or **gravity** is the force of attraction (pull) that any two objects exert on each other due to their masses.

- Around any object that has mass, there is a **gravitational field** in which another object with mass experiences a force. The force can act over a distance and is only **attractive**.
  - The gravitational force of attraction between the **sun** and **planets** is strong enough to keep the planets in their fixed orbits. There is also a weaker gravitational force of attraction between the individual planets.

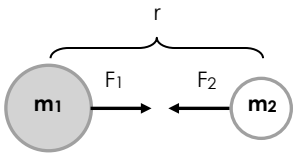


https://theplanets.org/solar-system/

Planets move in fixed orbits around the sun

- Similarly, the **earth** exerts a gravitational force of attraction on the **moon** (and vice versa)**.** This force pulls the moon towards the earth, so that it moves around the earth in an orbit.
- The **earth** exerts a gravitational force of attraction on any object on or near its surface (within its gravitational field)**.** This is called the **weight** of the object. The effect of this force is evident in the fact that objects in the air fall to the ground and remain there.
- The gravitational force of attraction between people or objects with relatively small masses is so small that its effect cannot be observed.

- The size of the gravitational force of attraction between two objects depends on:
  - their **masses**:
    the greater the masses of the objects, the greater the gravitational force of attraction between them



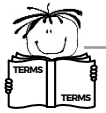
$F_1 = F_2$

  - the **distance** between their centres:
    the greater the distance between their centres, the smaller the gravitational force of attraction between them

- Gravitational force is measured in **newton (N)**.

NOTE

- *There are two factors that determine the gravitational force between objects, i.e. their masses and the distance between their centres.*
- *The gravitational force that the earth exerts on a person on the surface of the earth is much greater than the gravitational force that the moon exerts on that person on its surface. Put differently, the person's weight on the earth is much greater than their weight on the moon.*



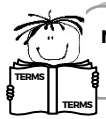
gravitational field: the force field around an object with mass in which another object with mass experiences an attractive force

- The **mass** and **weight** of an object:
  In everyday language, 'mass' and 'weight' are often used interchangeably, but in science they are two different terms with different meanings.

NOTE

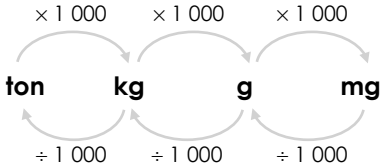
All scales make use of gravitational force and convert the effect of it on an object to the mass of the object or they compare the gravitational force of known and unknown masses.

MASS



mass: a measure of the amount of matter in an object

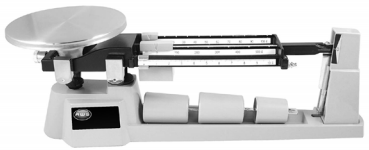
- The SI unit for mass is **kilogram (kg)**. Smaller masses are measured in gram (g) or milligram (mg).
- The different units are converted as follows:



NOTE

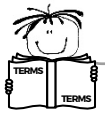
1 ton = 1 000 kg
1 kg = 1 000 g
1 g = 1 000 mg

- The mass of an object is **the same everywhere** in the universe.
- A **mass scale**, e.g. a triple beam balance, is used to determine the mass of an object.



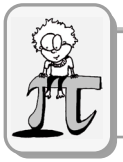
Mass scale

WEIGHT



weight: the gravitational force with which the earth (or other planet) attracts an object near the earth (or other planet)

- Weight is thus a force and is measured in the SI unit **newton (N)**.
- A newton **spring balance** is used to measure weight.
- If the mass of an object is known, its weight on earth (or on another planet) can be calculated as follows:



Weight = mass × gravitational acceleration

$$w = mg$$

Newton scale

- The gravitational acceleration **g** on or near the earth is **9,8 m s^{-2}**. This value indicates how an object accelerates towards the earth when only gravitational force acts on it (and thus how strongly it is attracted to the earth). The value of g is different in different places in the universe, e.g. on different planets.
- The weight of an object thus **differs** in different places in the universe, e.g. it is approximately six times greater on the earth than on the moon.

EXAMPLE

Take gravitational acceleration (g) as 9,8 m·s^{-2} on the earth and 1,63 m·s^{-2} on the moon. If a baby has a mass of 5 kg on the earth, then determine:

1.1 the weight of the baby on the earth,
1.2 the mass of the baby on the moon,
1.3 the weight of the baby on the moon.

Answer:

1.1 weight (w) = mass (m) × gravitational acceleration (g)
= 5 × 9,8
= 49 N

g = 9,8 m·s^{-2} on the earth

1.2 5 kg — *same as mass on earth*

1.3 w (on the moon) = mg = 5 × 1,63 = 8,15 N

PRACTICAL INVESTIGATION 2

The Effect of Gravity on a Falling Object

Aim

To demonstrate the effect of the earth's gravitational force of attraction on a falling object.

Requirements

- tennis balls
- machine to project balls
- camera

Method

1. Two learners each take a ball and go to a window on the first floor of the school building. The rest of the class stands outside on the ground below the window.
2. One learner drops a ball vertically to the ground from above.
3. The other learner throws/shoots a ball horizontally from the same height. (Use a machine that shoots tennis balls.)
4. The group on the ground tries to follow the course of the balls through the air. Consecutive photos taken at fractions of a second may be helpful.

5

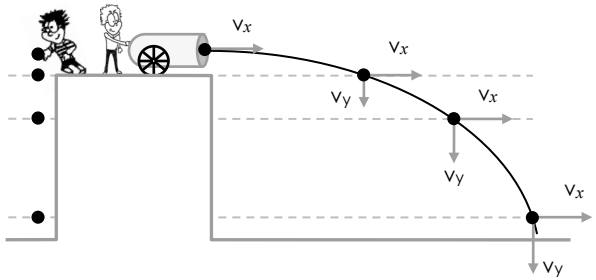
5 Repeat the investigation, but now let the learners drop one ball vertically and throw/shoot the other horizontally at exactly the same time.

NOTE

Repeat a couple of times with balls of the same and varying masses.

Results and Conclusions

- The ball that is dropped vertically and the one that is thrown/shot horizontally both fall towards the ground faster and faster, i.e. their downward speed increases. They thus **accelerate** towards the earth.
- A photo collage indicates how the vertical distance that the balls cover in each time interval increases.
- The earth (with its very large mass) exerts a **gravitational force of attraction** on both balls (with very small masses).
- The **direction** of the force is downwards towards the **centre** of the earth. An object that moves sideways whilst falling thus moves towards the earth along an arched course.



The gravitational force of attraction of the earth makes falling objects accelerate towards the earth

- The balls hit the ground **simultaneously**; they thus have the same acceleration. This acceleration, due to the gravitational force of attraction of the earth (or another planet), is known as gravitational acceleration.

NOTE

An object with a mass of 1 kg has a weight of 9,8 N. The earth thus exerts an attracting force of 9,8 N on a 1 kg mass and the gravitational acceleration (g) of a 1 kg mass towards the earth is 9,8 $m \cdot s^{-2}$.

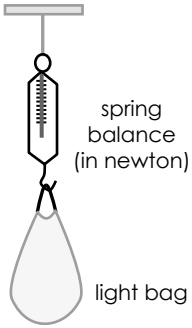
PRACTICAL INVESTIGATION 3

The Relationship between the Mass and Weight of an Object

Aim

To determine the relationship between mass and weight of different objects.

Method



1 Take objects with different masses (e.g. a shoe, apple and stone) and determine the mass of each in gram with the aid of a mass scale. Convert the masses to kilogram.

2 Now hang a light bag on a spring scale calibrated in newton. One by one, place the objects in the bag and determine the weight of each in newton.

3 Determine the mathematical relationship between the mass and weight of an object.

Results and Conclusions

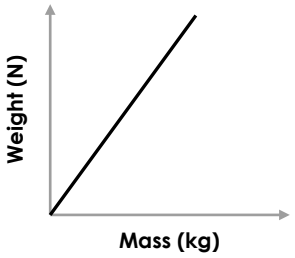
Object	Mass (g)	Mass (kg)	Weight (N)	$\frac{\text{Weight (N)}}{\text{Mass (kg)}}$
Shoe				
Apple				
Stone				

The **variables** in this investigation are:

- the **independent** variable: the mass of the object
- the **dependent** variable: the weight of the object
- the **fixed** variable: the same place in the universe

The relevant graph for the investigation is shown below:

The gradient of the graph gives the mathematical ratio/relationship between the mass and the weight of objects, i.e. the value of the gravitational acceleration (g).



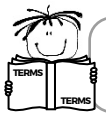
NOTE

The gradient of this graph is equal to the gravitational acceleration (g) at the place where the investigation was done.

UNIT 3

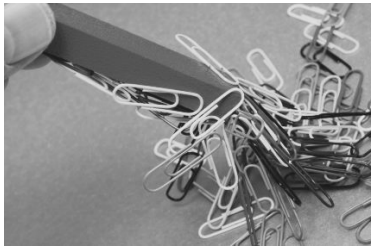
FIELD FORCES: MAGNETIC FORCE

MAGNETIC FORCE



magnetic force: the force that a magnet exerts on other magnets or magnetic materials

- Around all magnets, there is a magnetic field in which a magnetic force is exerted.
- Magnetic force acts over a distance and is thus a field (non-contact) force.
- The force can be **attractive** or **repulsive**.
- Magnetic force (magnetism) is used to distinguish between magnetic and non-magnetic substances:
  - substances that are attracted by a magnet are known as **magnetic** substances
  - substances that are not attracted by a magnet are **non-magnetic** substances *(see Practical Investigation 4)*



- A magnet can attract or repel other magnets or magnetic substances through a paper, wood or glass covering/screen. Magnetic force can thus be **transferred** by **non-magnetic** materials.
- Magnetic force is, however, **screened off** or **blocked** by **magnetic materials** such as iron, nickel and cobalt, as well as their alloys. Sometimes it is necessary to screen off the sensitive parts of a watch or other instrument from magnetic forces by encasing it in iron *(see Practical Investigation 5)*.

PRACTICAL INVESTIGATION 4

Distinguish between Magnetic and Non-magnetic Materials

Aim

To investigate which materials are attracted by a bar magnet and are thus magnetic.

Requirements

- bar magnets
- a collection of non-metal and metal objects, e.g. pieces of paper, wood, plastic, glass, iron (filings), copper, aluminium (foil) and nickel (a coin)

Method

Hold each of the above objects near a bar magnet (without touching it) and determine which of the substances is attracted by the magnet and are thus magnetic.

NOTE

A substance that is attracted by a magnet is a magnetic substance, otherwise it is non-magnetic.

Results

Results and Conclusions

Substance type	Magnetic/non-magnetic
Paper	non-magnetic
Wood	non-magnetic
Plastic	non-magnetic
Glass	non-magnetic
Iron (filings)	magnetic
Copper	non-magnetic
Aluminium	non-magnetic
Nickel	magnetic

The metals **iron** and **nickel** are the only magnetic substances in this investigation. The only other metal that is magnetic is **cobalt**.

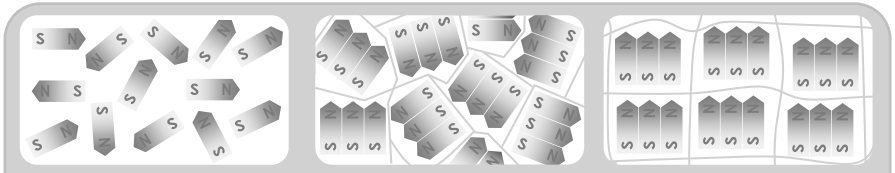
Non-metals are non-magnetic substances.

NOTE

The only substances that are magnetic are the metals iron, nickel and cobalt, as well as their alloys (mixtures).

FOR ENRICHMENT

Differences in the magnetic fields of atoms and groups of atoms determine magnetism in materials



PRACTICAL INVESTIGATION 5

Screening a Magnetic Field

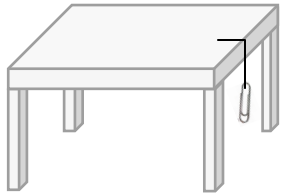
Aim

To investigate whether a magnetic force is blocked or transferred by magnetic and non-magnetic materials.

Requirements

- short length of thread
- strong bar magnet
- paper
- flat pieces of wood
- plastic/perspex
- Prestik
- paper clip
- aluminium foil
- small iron or steel plate
- glass

Method



1. Tie a short length of thread to a paper clip and use a small piece of Prestik to hang the thread from the edge of a table.
2. Hold the pole of a bar magnet about 2 cm from the paper clip. Observe.
3. Insert a piece of paper, a flat piece of wood, plastic, glass, aluminium foil, and different metal plates between the magnet and the paper clip one after the other. Notice if the magnetic force between the paper clip and the magnet decreases, causing the paper clip to fall off.

Results and Conclusions

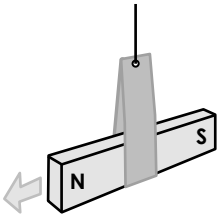
- Initially, there was an air gap between the paper clip and the magnet. The magnetic force was, however, transferred through the air to the paper clip, attracting it to the magnet.

Material	Magnetic force transferred (✓) or blocked (×)
Paper	✓
Wood	✓
Plastic	✓
Glass	✓
Aluminium	✓
Iron	×
Steel	×

- The paper clip remains attracted to the magnet despite a piece of paper, wood, plastic, glass or aluminium being placed between them. Magnetic forces can thus be transferred by all non-magnetic materials.
- The magnet loses its force of attraction on the paper clip and the paper clip falls off if a small iron or steel plate is placed between them. Any magnetic material (i.e. a material that contains iron, nickel or cobalt) will block magnetic forces.

MAGNETIC POLES

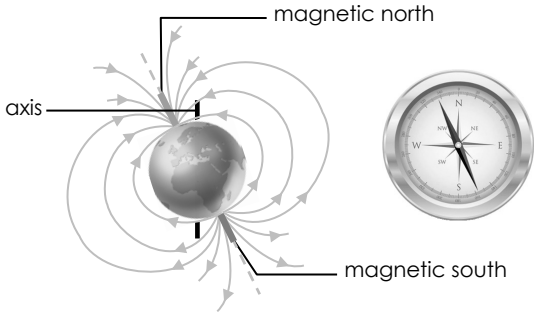
- If a bar magnet is tied to a piece of string and allowed to move freely, it comes to rest with the one end or pole pointing north. This pole is called the north-seeking pole or simply **north pole** (N pole).
- The opposite pole is called the **south pole** (S pole).
- All magnets have both a south and north pole.



NOTE

The poles of a magnet are the ends where the magnetic field is the strongest.

- The north poles of two magnets repel each other. Likewise, the south poles too repel each other.
- The north pole of one magnet and the south pole of another magnet attract each other.
- Summary:
  - **like** poles **repel** each other
  - **opposite** (unlike) poles **attract** each other
- A compass needle is in reality a north pole and points to the earth's magnetic north.
- Around the earth there is thus a magnetic field in which another magnet experiences a force.



NOTE

A compass is an instrument with a needle/pointer that indicates the magnetic north of the earth at a particular place/location.

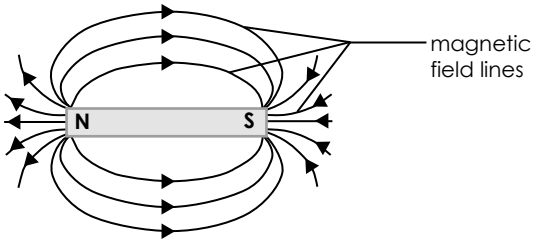
NOTE

*The magnetic pole close to the geographic north pole of the earth is known as the **magnetic north**. It is the direction in which the north pole of another free-moving magnet points. Likewise, the magnetic pole near the geographic south pole is called the **magnetic south** pole.*

MAGNETIC FIELDS

- A magnetic field is an invisible force field in which magnetic force is exerted.
- All magnets are surrounded by a magnetic field that stretches around in all directions. It is thus a 3-dimensional field.
- A magnetic field is invisible but can be detected by observing the pattern that the iron filings make around a magnet.

- The iron filings arrange themselves around the magnet along lines called **magnetic field lines**. We use magnetic field lines to represent a magnetic field 2-dimensionally on paper.
- The denser/closer the magnetic fields lines are to one another, the stronger the magnetic field is. It is the **strongest** at the **poles**.
- Magnetic field lines **never cross** one another.
- The **direction** of the field lines is from **north** to **south**. This is the direction in which a compass needle (N pole) that is placed in the field, will point.



Magnetic field pattern around a bar magnet

magnetic field: the force field around a magnet in which another magnet or magnetic substance experiences a force

magnetic field lines: the imaginary lines used to represent the 3-dimensional force field around a magnet on 2-dimensional paper

- If a free-moving magnet is placed in another magnetic field (usually stronger than the earth's magnetic field), it will experience a force *(see Practical Investigation 6)*.

SUMMARY

- *Magnetic field lines begin and end at the edges of the magnet.*
- *Magnetic field lines are denser where the magnetic field is stronger (i.e. near the poles).*
- *Magnetic field lines never touch or cross one another.*
- *The direction of a magnetic field is from north to south and is indicated by means of arrows on the magnetic field lines.*

PRACTICAL INVESTIGATION 6

Magnetic Forces

Aim

To investigate the magnetic forces of attraction and repulsion between two bar magnets.

Requirements

- two bar magnets

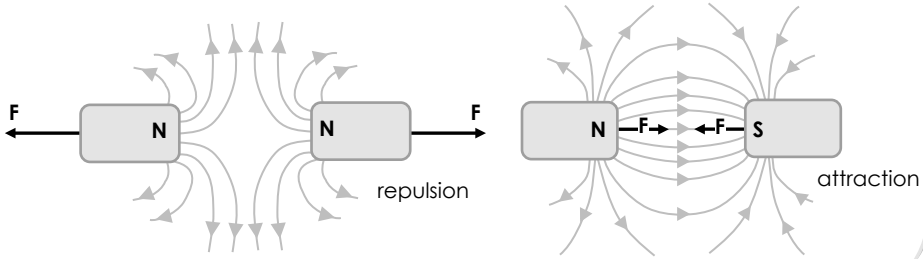
Method

1. Take two bar magnets and place them on a table with the two north poles near each other. Observe.
2. Now place the two south poles near each other. Observe.
3. Turn one of the magnets around, placing the north pole of the one magnet near the south pole of the other. Observe.

Results and Conclusions

- The two north poles repel each other, as well as the two south poles.
- The north pole of the one magnet is attracted to the south pole of the other magnet.
- Around each bar magnet there is thus a magnetic field in which the other magnet experiences a magnetic force: the like poles repel each other and the unlike poles attract each other.

Magnetic force as a result of the interaction between the magnetic fields around magnet poles



PRACTICAL INVESTIGATION 7

Magnetic Fields

Aim

To observe magnetic field patterns (the arrangement of iron filings) around a magnet.

Requirements

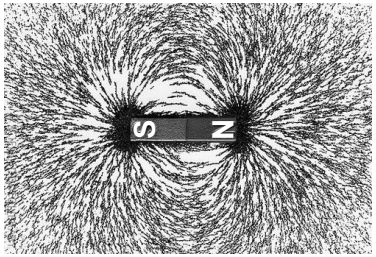
- pencil and paper
- 2 bar magnets
- iron filings

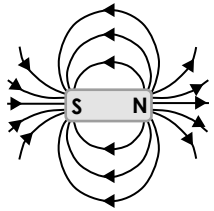
Method

1. Place a bar magnet flat on a table.
2. Place a sheet of paper over the magnet.
3. Evenly sprinkle iron filings on the sheet of paper; lightly tap the paper with a pencil.
4. Draw the pattern of the iron filings, i.e. of the magnetic field lines with a pencil, on a separate sheet of paper.
5. Now move the magnet around under the sheet of paper. Observe.
6. Firmly hold the sheet of paper with both hands and lift it up to about 30 cm above the magnet. At the same time, ask a friend to move the magnet around on the table. Observe.
7. Place a second bar magnet under the sheet of paper with (1) both north poles or both south poles near each other, and (2) a north pole and a south pole near each other. Draw the pattern of the iron filings in each case on a piece of paper.

Results and Conclusions

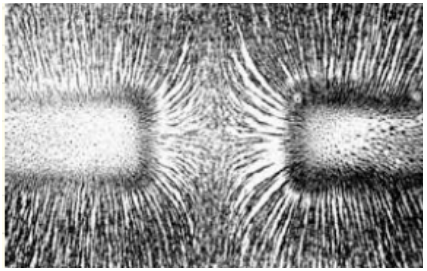
- The iron filings experience a magnetic force in the area around the magnet and arrange themselves in a pattern on the sheet of paper above the magnet as shown below.



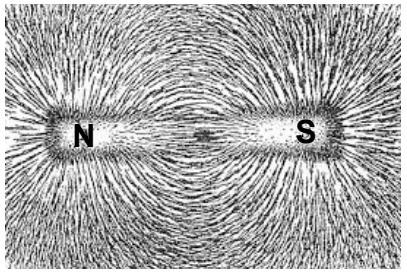


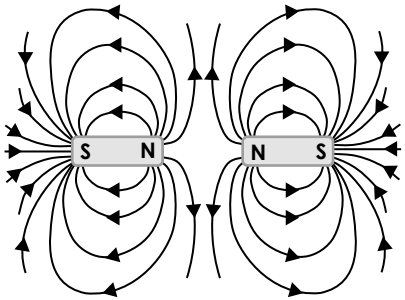
- The magnetic field around the bar magnet is strongest at the poles (where the iron filings are arranged more densely) and weakest at the centre of the magnet (where the iron filings are arranged less densely).
- The iron filings move with the moving magnet (and its magnetic field) in the direction of the force that it experiences within the magnetic field.
- If the sheet of paper is lifted up and moved away from the magnet, it eventually reaches an area outside the magnet's magnetic field. Here, the iron filings no longer experience any force so the arrangement becomes random.
- The magnetic field patterns for two magnets look like this:

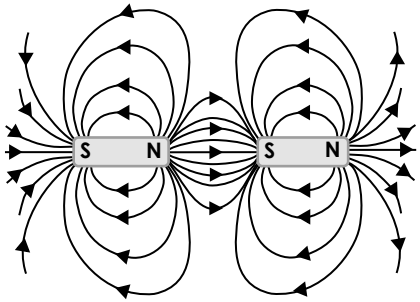
Like poles near each other



Unlike poles near each other





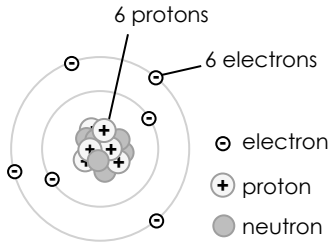


Magnetic field pattern and direction around (and between) 2 bar magnets aligned with their poles close to each other

FIELD FORCES: ELECTROSTATIC FORCE

POSITIVE AND NEGATIVE CHARGES

- All matter is made up of small particles, called **atoms**.
- The nucleus or centre of an atom contains **protons** (positively-charged particles) and **neutrons** (neutral particles).
- A cloud of **electrons** (negatively-charged particles) surrounds the nucleus of an atom.

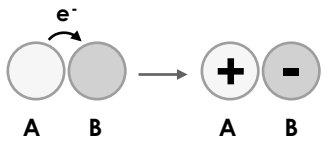


Neutral C atom

- In a neutral atom, there is an equal number of protons and electrons.
- A neutral object consists of neutral atoms.
- An object that has an **excess of electrons** on its surface is **negatively charged**.
- An object that has a **shortage of electrons** on its surface is **positively charged**.

THE CHARGING OF OBJECTS BY FRICTION

- When non-conductors (insulators) are rubbed together, electrons from the surface of one substance/material can be transferred to the surface of the other. These materials can collect and retain electric charge; we refer to them as having static electricity.



NOTE

A non-conductor builds up static electricity by accumulating charge on its surface, usually through friction. A negative or positive charge is thus obtained and can be retained.

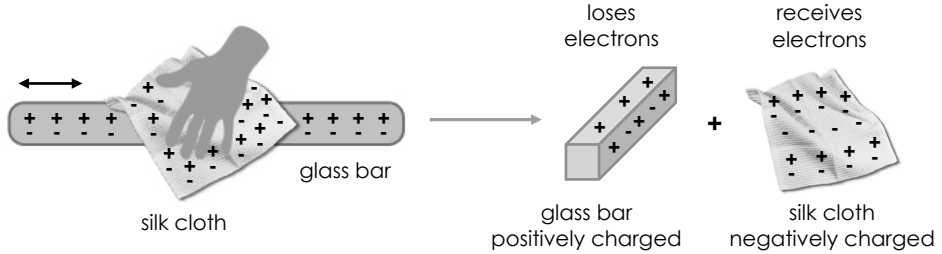
- If electrons are transferred from A to B:
  - A becomes positively charged (has a shortage of electrons), and
  - B becomes negatively charged (has an excess of electrons).
- When a charged object is touched, a quick discharge can take place in the form of a spark or electric shock.

NOTE

- *Only electrons can be removed from an atom. Protons and neutrons are bound very tightly in the nucleus and cannot be removed.*
- *Electrical conductors (e.g. metals) are substances that electrons can pass through; they are thus able to conduct an electrical current.*
- *Insulators or non-conductors (e.g. plastic, rubber, paper and glass) are substances through which electrons cannot pass, but which can accumulate charges (electrons).*

Positively Charge a Glass Bar through Friction

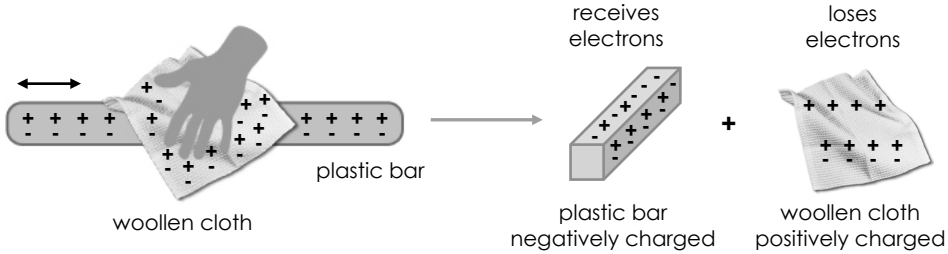
If a **glass** bar is rubbed with a **silk cloth**, electrons are transferred from the bar to the cloth and the bar acquires a **positive** charge and the cloth a negative charge.



Neutral glass bar and silk cloth

Negatively Charge a Plastic Bar through Friction

If a **plastic** bar is rubbed with a **woollen cloth**, electrons are transferred from the cloth to the bar and the bar thereby acquires a **negative** charge and the cloth a positive charge.

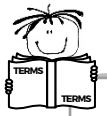


Neutral plastic bar and woollen cloth

NOTE

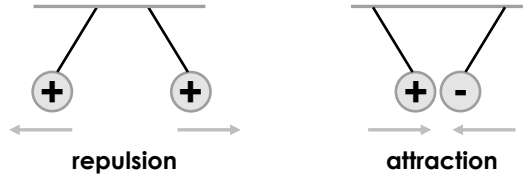
If two materials are rubbed together, one of them will be more inclined to receive electrons and thereby acquire a negative charge, and the other more inclined to lose electrons and thereby acquire a positive charge.

ELECTROSTATIC FORCE



electrostatic force: the force between charges or charged objects

- Charges (charged objects) that are placed near one another have **electric potential energy** and exert a force on one another.
- Electrostatic force is another example of a non-contact (field) force.
- The energy comes from the work done by the friction process.
- Electrostatic force is the attracting or repelling force between electric charges near one another.
  - **like** charges (**+** and **+** or **-** and **-**) **repel** each other
  - **unlike** (opposite) charges (**+** and **-**) **attract** each other



NOTE

There are no attracting or repelling forces between two uncharged objects.

(see Practical Investigation 8)

PRACTICAL INVESTIGATION 8

Electrostatic Forces

Aim

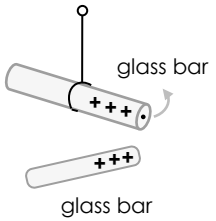
To investigate how objects made of different materials can be charged by friction. Note the electrostatic forces of attraction and repulsion.

Requirements

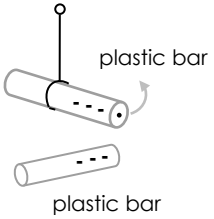
- 2 plastic bars (rulers/perspex bars)
- 2 glass bars
- inflated balloons
- silk cloth, woollen cloth and bits of other textiles
- plastic bags
- pieces of paper

Method

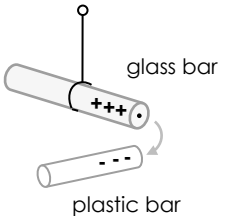
1. Take two similar bars, e.g. two glass bars, and mark the one end of each with a dot. Rub these ends with the same cloth, e.g. a silk cloth, so that they acquire a positive charge. Hang the one bar from a piece of string and hold the charged end of the other bar close to it. Observe.



2. Repeat this investigation, this time using two plastic bars. Rub the marked end of each bar with a woollen cloth so that it acquires a negative charge. Observe.



3. Repeat the investigation yet again, but now use two different bars and charge them as before (i.e. rub the glass bar with a silk cloth and the plastic bar with a woollen cloth). Now hold the charged end of the plastic bar near the charged end of the glass bar that is hanging from a string. Observe.



4

4. Charge the glass bar again as before. Use two or three different textiles to rub the plastic bar. Determine for each textile if the plastic bar is (1) attracted to or (2) repelled by the positively-charged glass bar. This will confirm the type of charge obtained by the bar and the specific textile.

5. Hold each bar near pieces of paper, plastic bags or inflated balloons. Observe.

Results and Conclusions

- The like positive charges of the two glass bars repel each other.
- The like negative charges of the two plastic bars repel each other.
- The opposite (unlike) charges of the positively-charged glass bar and the negatively-charged plastic bar attract each other.
- Different textiles can charge the plastic bar differently. It depends on which of the two (bar and textile) attracts electrons more strongly. This object will become negatively charged.
- Each charged bar will attract the pieces of paper, plastic bags or inflated balloons by polarising charge on them.

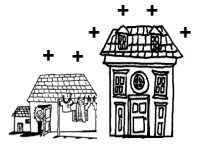
NOTE

In rainy weather or humid conditions, water molecules in the air allow electric charge to 'leak' away from charged objects, causing them to lose their static electricity. This investigation therefore does not work well under such conditions.

THE CHARGING OF THUNDER CLOUDS: LIGHTNING

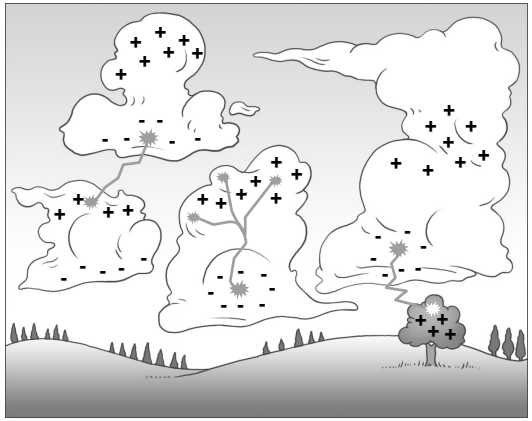
- During a thunder storm, the particles in the clouds (e.g. air molecules and rain drops) acquire positive and negative charges through friction caused by wind and the movement of the particles past one another.
- Inside the clouds, the positive and negative charges are separated in such a way that the positive charges collect at the top of the clouds and the negative charges at the bottom.

- This separation of charges then induces (creates) positive charges in high towers, trees and buildings. There is now a large difference in the potential energy (potential difference) between the positive and negative charges.



Lightning Bolt; Release of Charge

- When the potential difference becomes too big, a quick discharge occurs when a charge stream (including electrons) moves across the air gap from cloud to cloud or from the clouds to the ground. This is visible as lightning flashes or bolts.
- The fast flow of charge also heats the air and causes sound shock waves. This is heard as thunder.



Charges separate and negative charges collect at the bottom of clouds during a thunderstorm

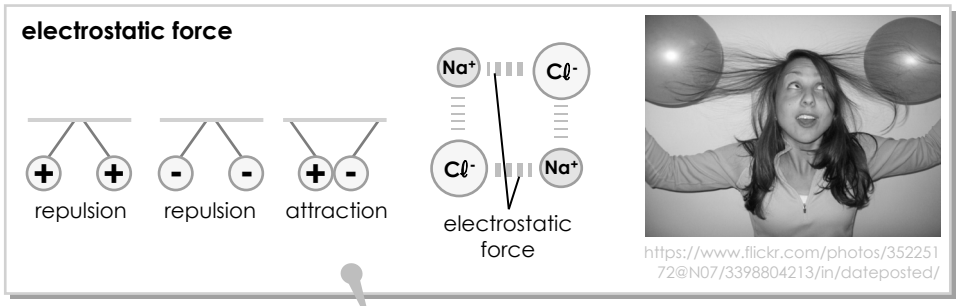
Safety Precautions against Lightning

- The safest place during a thunder storm is inside a car or building.
- Stay away from windows.
- Stay away from high places. Never seek shelter under a tree or roof overhang.
- Crouch in the smallest lowest possible position with your feet together.
- Avoid water, e.g. a dam or river.
- Avoid using telephones and electrical appliances.

NOTE

On a dry day, one's body is inclined to build up static electricity through friction, e.g. when you rub your hand across your hair or jersey. The moment you touch another object, charge quickly flows to this object and an electric spark can be seen and heard. This is a small-scale form of lightning.

In rainy weather or humid conditions, electric charge easily 'leaks' away from charged objects, therefore they do not build up static electricity.



TOPIC 2 ELECTRIC CELLS AS ENERGY SYSTEMS

US 7508: SO 2 – AC 1, 3, 4; SO 3 – AC 1, 3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 3; SO 4 – AC 1,4

Lesson Outcomes

By the end of this topic, learners should be able to:

- Devise and implement a procedure to investigate electric cells
- Gather and interpret data
- Define concepts and principles relating electric cells and energy systems
- Demonstrate how to make a cell using a lemon or zinc and copper
- Interpret scientific evidence and apply knowledge and skills regarding electric cells

UNIT 1 ELECTRIC CELLS

Electric cells and batteries are a source of energy and are used to power electrical appliances, e.g. light bulbs, radios, remotes, cell phones, etc.

A CELL IS A CHEMICAL SYSTEM

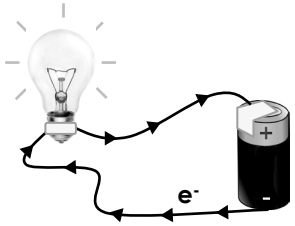
- An electric cell consists of two terminals (**electrodes**) made of different elements (usually metals) and a conducting fluid or paste (**electrolyte**) through which the charges can move once the cell has been connected to a circuit.
- The moment a conducting wire connects the electrodes to each other, a chemical reaction takes place. The one electrode acts as the **positive** electrode and the other as the **negative** electrode.

The electrodes of a cell as circuit symbols

- The circuit is completed by the movement of charges (ions) through the electrolyte and the movement of electrons through the external circuit.
- An **electric cell** is thus a **system** in which certain chemical reactions cause the flow of electricity by means of an external circuit.

A CELL IS A SOURCE OF ELECTRICITY

- Inside a cell there are thus certain chemicals (different electrodes and electrolytes). The moment the cell is connected to a circuit, a spontaneous chemical reaction takes place by which electrons collect at the one terminal (negative electrode) of the cell. Electrons are then withdrawn from the other terminal (positive electrode). **Chemical** energy is converted to **electrical** energy.
- The difference in potential energy between the terminals – also known as the **emf** or **terminal potential difference** or **voltage** – causes the electrons to move as an electric current through the external circuit, from the negative to the positive electrode. The electric current thus leaves and enters the cell again via the electrodes.



- The **emf** indicates **how much energy** is stored in the cell and transferred to the charges (electrons) as they leave the cell. The emf is measured in **volts (V)**. The charges can move through the external circuit and transfer energy to electrical appliances to provide power.
- As the cell continues to be used, the chemicals are depleted and the cell eventually goes flat.

NOTE

*The **emf** of a cell indicates how much energy each coulomb of charge could get from the cell.*

*The terminal **potential difference** between the ends of a closed external circuit is somewhat less than the emf of the cell, because a small amount of energy is lost inside the cell due to friction.*

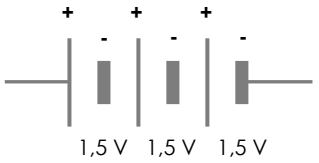
*The term **emf** is an abbreviation for electromotive force, a term that is no longer used.*

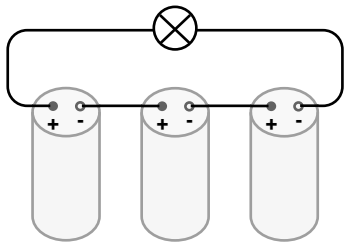
A BATTERY IS A GROUP OF CELLS

- When two or more cells are connected to one another, they form a **battery**.
- Cells may be connected to one another in different ways in order to form a battery.

- **Cells in series:**
  - a positive pole of one cell is connected to a negative pole of another cell
  - the total emf of the battery = the sum of the emf of individual cells
  - a battery of two or more cells supplies more energy to the charges moving through the circuit and generates a stronger current than a single cell

  Emf (battery) = 1,5 × 3 = 4,5 V

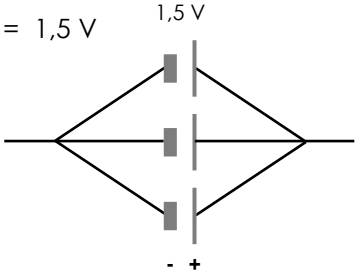


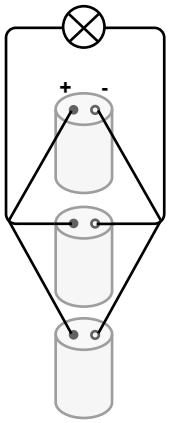


Three cells in series

- **Cells in parallel:**
  - a positive pole is connected to another positive pole and a negative pole to another negative pole
  - each cell should have the same emf
  - the total emf of the battery = the emf of one cell
  - a battery with two cells in parallel generates the same total current as a battery with a single cell; every cell generates half of the total current, but lasts twice as long as a single cell
  - any number of cells in parallel generate the same total current; the more cells are in parallel, the smaller the fraction of the total current each cell generates and the longer they last

  Emf (battery) = 1,5 V





Three cells in parallel

PRACTICAL INVESTIGATION 9A

Electric Cells

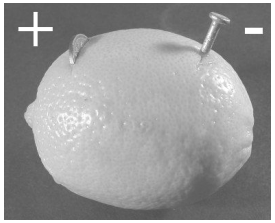
Aim

To make a lemon cell.

Requirements

- three or four lemons
- galvanised nail(s) (iron nails coated in a layer of zinc)
- piece of copper, e.g. a 20c coin, a piece of copper wire or copper strip
- crocodile clips
- electric conducting wire
- voltmeter or LED bulb

Method



1. Squeeze the lemon from all sides so as to release the juice on the inside.
2. Press the nail and the piece of copper (coin, wire or strip) into the lemon at a short distance (about 4 cm) from each other. They should not touch each other, and a little part of each should be visible above the lemon's peel.
3. The nail (coated in zinc (Zn)) forms the negative electrode and the piece of copper (Cu) forms the positive electrode of the lemon cell.
4. Fasten a crocodile clip to each electrode and use conducting wire to connect them to the terminals of a voltmeter as follows: connect the negative electrode (Zn) of the lemon to the negative (black) terminal of the voltmeter and the positive electrode (Cu) of the lemon to the positive (red) terminal of the voltmeter. The reading on the voltmeter indicates the emf of the cell.
5. Replace the voltmeter with an LED bulb. Check whether it lights up. If it does not, include another one, two or three lemon cells in series in the circuit.

Results and Conclusions

- The moment the circuit is completed, the voltmeter gives a reading. The juice of the lemon acts as electrolyte, whilst the piece of copper and the zinc-coated nail act as electrodes. Together, they form an electric cell.
- The emf of this cell is probably too low to light up an LED bulb. With more lemon cells, i.e. with a lemon battery, the total emf is higher. An LED bulb will light up if enough cells are connected to generate the required emf.

PRACTICAL INVESTIGATION 9B

Electric Cells (continued)

Aim

To make a Zn-Cu electric cell.

Requirements

- 2 glass beakers
- zinc (Zn) plate
- zinc sulphate solution
- copper (Cu) plate
- copper sulphate solution
- salt bridge (a strip of cloth or paper towel)
- crocodile clips
- electric conducting wire
- LED bulb
- voltmeter

Method

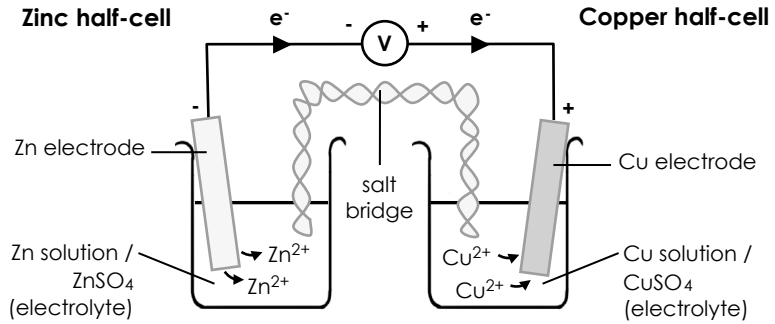
1. Prepare the zinc sulphate and copper sulphate solutions beforehand *(see instructions that follow)*.
2. Place the Zn plate in the beaker with the $ZnSO_4$ solution and the Cu plate in the beaker with the $CuSO_4$ solution.
3. Use electric conducting wire and crocodile clips to connect each plate to the correct terminal of a voltmeter (i.e. connect the Zn plate to the negative terminal and the Cu plate to the positive terminal).

4

NOTE

Prepare the zinc sulphate and copper sulphate solutions with a concentration of about 1 mol·dm^{-3} by dissolving 40 g of the salt in 250 mℓ (one cup) water. Calculating the concentration of solutions is not required at Grade 9 level.

4. Twist a piece of paper towel like a rope and dip it in one of the solutions, thereby making a salt bridge.
5. Complete the circuit by placing the two ends of the salt bridge in the two respective beakers (**half-cell**). This provides a pathway for charges to flow from one beaker to the other.
6. Look at the voltmeter and note its reading. Replace the voltmeter with an LED bulb and see whether it lights up.



A Zn-Cu cell produces electrical energy; electrons move from the Zn to the Cu plate through the conductor

Results and Conclusions

- A chemical reaction takes place in each of the two beakers:

  In the beaker with the Zn plate, electrons are released during the reaction, causing the Zn plate to have an excess of electrons. The Zn plate forms the negative electrode.

  In the beaker with the Cu plate, electrons are absorbed during the reaction, causing the Cu plate to have a shortage of electrons. The Cu plate forms the positive electrode.

  Electrons move from the Zn plate to the Cu plate via the connecting wires, i.e. through the external circuit.

- The moment the circuit is completed, the voltmeter gives a reading. The concentration of each solution influences this reading. This cell should have a reading of about 1,1 V. A normal flashlight battery has an emf of 1,5 V. Most light bulbs and other appliances require 3 V or more, therefore the LED bulb will not light up if it is connected to a single cell.

TOPIC 3 RESISTANCE

US 7507: SO 5 – AC 1-2
US 7508: SO 1 – AC 1-3; SO 2 - AC 1, 3, 4; SO 3 – AC 1, 3, 5; SO 4 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-2; SO 4 – AC 1, 4
US 7511: SO 4 – AC 1
US 7513: SO 1 – AC 1-2; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of resistors in life
- Formulate a scientific hypothesis
- Devise and implement a procedure to investigate factors that affect resistance
- Gather and interpret data
- Define concepts and principles in electrical resistance
- Demonstrate how properties of conductors influence resistance
- Explain the principles and application of resistors in technology

UNIT 1 USES OF RESISTORS

CONDUCTORS OF ELECTRICITY

- Some materials such as metals are good **conductors** of electricity. Non-metals, except carbon in the form of graphite, are insulators or **non-conductors** of electricity.
- All matter is made up of atoms. An atom consists of a positive nucleus surrounded by negative electrons moving in energy levels. These energy levels are like layers of electrons.
- In metals, the **electron(s)** in the outer energy level of an atom become **free** or delocalised and the remaining part of the atom (a metal ion) becomes positively charged. These outer electrons move between the positive ions of the metal atoms.

- A metal thus consists of an arrangement of **positive metal ions** and **delocalised electrons** (Fig. 1).
- If a metal conducting wire is connected to a battery, the electrons move through the wire in the same direction between the metal ions, i.e. towards the positive terminal of the battery (Fig. 2). This generates an **electric current**.

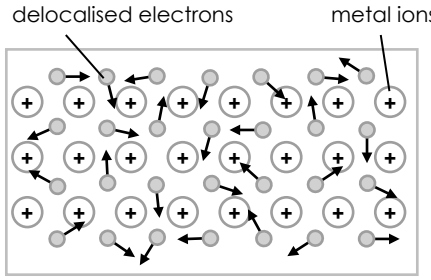


Figure 1

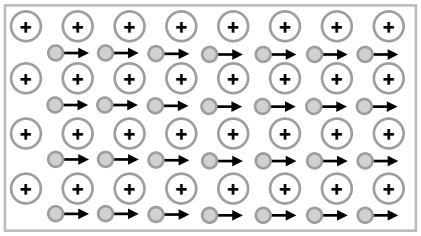
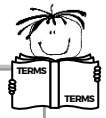


Figure 2

Charges (electrons) in a metal conductor move in the same direction as soon as the conductor is connected to a battery (Fig. 2)

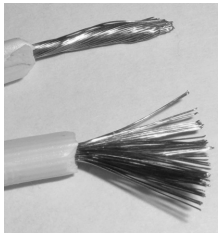
- In all conductors there are **collisions** between the electrons and the metal ions that cause a degree of resistance against the flow of the electric current.
- In insulators or **non-conductors,** the outer electrons are bound tightly to the atom nuclei and **cannot move freely**. There is thus **no** electric **current** if an insulator is connected to a battery.



electrical conductor: a substance through which charge can move
electric non-conductor: a substance through which charge cannot move

RESISTANCE

- No conductor allows charges, e.g. electrons to move through it completely unhindered. All conductors thus have a degree of **resistance** that causes them to **heat up**.
- Copper wire is most commonly used as the electric connecting wire in circuits due to the outer electrons in copper atoms being 'free' to easily move through the circuit.



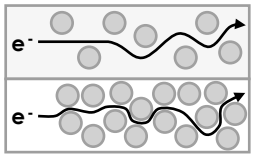
Copper wire

- **Copper** wire thus has a **low** resistance and little energy is lost in the form of heat when an electric current flows through it.
- Other metals such as **tungsten** used as filament in older types of light bulbs have a **high** resistance and do not allow charge to easily flow through them. These metals allow only a very small electric current to pass through and they become very hot when connected in a circuit. They do, however, have important applications, i.e. in the provision of heat and light.

NOTE

*The electrical **resistance** of a substance is the opposition against the movement of charge through the substance and is measured in ohm (Ω).*

The easier electrons (charge) move through a conductor, i.e. the less they collide with the metal ions, the lower the resistance is.



good conductor

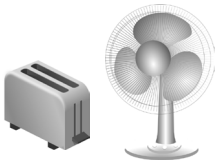
poor conductor

A good conductor of electricity allows electric charges to easily pass through it. So it offers little resistance against the flow of the electric current.

- The resistance of an electrical component is determined by its physical properties and indicated on the component as a value in ohm (Ω).

Resistors

- Conductors with a very high resistance are called **resistors** and are used to **regulate** the **strength** of the **current** in a circuit. If the current that flows through an appliance is too strong, it may damage the appliance or cause it to burn out.
- Appliances such as toasters, heaters and kettles contain an element that heats up. A resistor made of nichrome wire (an alloy of nickel and chrome with a **high resistance**) is normally used in the element to convert **electrical** energy to **thermal** energy so that it may perform a certain function.



- In contrast, electric motors in appliances such as fans, beaters, washing machines and tumble dryers contain a coil with **low resistance** wire in which **electrical** energy is converted into **mechanical** (kinetic) energy. Here, the movement of certain parts or components of the appliance serves a useful function.

- The resistance of materials can be both **useful** and also **detrimental**. It is very useful in controlling the strength of a current and in appliances where heat or light is employed functionally. On the other hand, in electrical power lines, resistance hampers the transfer of electrical energy from one point to another due to much energy lost in the form of heat.

- An adjustable resistor is called a **rheostat**.

NOTE

*A **rheostat** is often used in the volume controls on sound appliances and in dimmer switches. An LDR (light-dependent resistor) contains a light sensor. Its resistance depends on the brightness or intensity of the light falling in on it. It has a higher resistance in the dark and can cause lights outside your house to switch on automatically once it gets dark.*

UNIT 2 FACTORS THAT AFFECT RESISTANCE IN A CIRCUIT

The resistance of a conductor depends on different factors, i.e.:

- the type of material of the conductor
- the length of the conductor
- the thickness of the conductor
- the temperature of the conductor

THE TYPE OF CONDUCTOR

- We have already seen that certain metals are better conductors of electricity than others, e.g. pure **silver**, **copper**, **gold** and **aluminium** are the best conductors of electricity (in decreasing order).
- In contrast, **wolfram/tungsten** and **nichrome wire** are poor conductors of electricity.
- Half-metals are poor conductors and non-metals (except graphite) are non-conductors of electricity.

THE LENGTH OF THE CONDUCTOR

- The longer the conductor, the higher its resistance and the lower its conducting ability.

THE THICKNESS OF THE CONDUCTOR

- The thinner the conductor, the higher its resistance and the lower its conducting ability.

NOTE

Think of a water pipe; the thicker the pipe, the easier the water flows through it.

THE TEMPERATURE OF THE CONDUCTOR

- The higher the temperature of a metal conductor, the higher its resistance and the lower its conducting ability.

NOTE

In metal conductors, the speed and kinetic energy of the atomic particles increase when the temperature increases. Moving charges collide with one another and with the metal ions more frequently. The charges have more difficulty moving through the conductor, thus the conductor has a higher resistance at a higher temperature.

PRACTICAL INVESTIGATION 10

The Factors that Influence the Resistance of a Metal Conductor

Aim

To investigate the relationship between any factor (i.e. type or length or thickness of a conductor) and the resistance of the specific conductor.

NOTE

Keep all the other factors constant when testing each factor.

PRACTICAL INVESTIGATION 10A

Investigate the Relationship Between the Type of Conductor and the Resistance of the Conductor

Aim

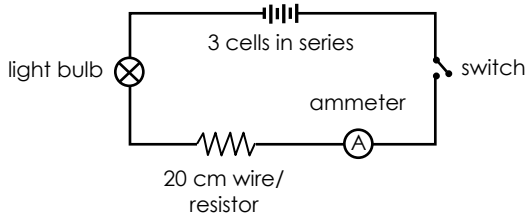
To investigate the relationship between the type of conductor and the resistance of the conductor (as indicated by its electrical conductivity).

Requirements

- 3 flashlight batteries
- 2 crocodile clips
- ammeter
- electric conducting wire
- light bulb
- switch
- 20 cm pieces of copper, aluminium, steel and nichrome wire of the same thickness

Method

1. Start with the 20 cm piece of copper wire and connect it in a circuit with the other components as indicated in the diagram below.



2. Close the switch and note the reading on the ammeter.

NOTE

An ammeter measures the strength of the current flowing through a circuit in ***amperes (A)*** *(see p. 161).*

3. Open the switch for a couple of seconds so that the conducting wires may cool.
4. Replace the 20 cm piece of copper wire with another type of wire and repeat Steps 1 to 3 with each wire type.
5. Write a hypothesis for the investigation.
6. Identify the dependent, independent and controlled variables.
7. Note the results in a table and then plot the dependent variable against the independent variable in a graph.
8. Draw a conclusion.

Hypothesis

Copper wire has the lowest resistance, followed by aluminium, steel and then nichrome wire. The better the conductivity (i.e. the higher the ammeter reading), the lower the resistance.

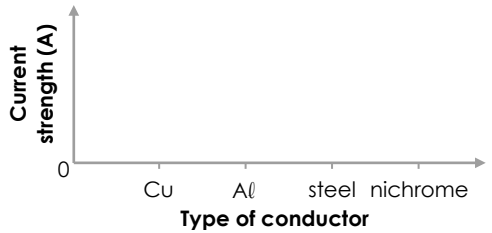
Variables

- dependent: the resistance of the conductor (as deduced from the conductivity/ammeter reading)
- independent: the type of conductor
- controlled: the length, thickness and temperature of the conductor

Results

Type of conductor	Ammeter reading (A)
Copper wire	
Aluminium wire	
Steel wire	
Nichrome wire	

The graph showing current strength (A) against type of wire.



Conclusion

From copper wire to nichrome wire, the resistance increases and the conductivity decreases (the length, thickness and temperature of the wires being kept constant). The hypothesis was thus correct.

PRACTICAL INVESTIGATION 10B

Investigate the Relationship Between the Length of the Conductor and the Resistance of the Conductor

Aim

To investigate the relationship between the length of a conductor and its resistance (as indicated by its electrical conductivity).

Requirements and Method

Repeat Steps 1 to 8 of Investigation 10A, but use different lengths of nichrome wire, i.e. 20 cm, 40 cm, 60 cm and 80 cm, all of the same thickness. Connect the wires in the circuit one after the other.

Hypothesis

The shorter the wire, the lower the resistance and therefore the better the conductivity (i.e. the higher the ammeter reading).

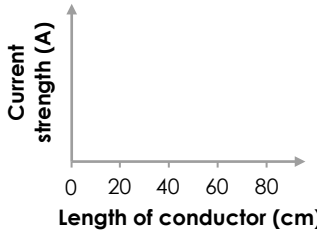
Variables

- dependent: the resistance of the conductor (as deduced from the conductivity/ammeter reading)
- independent: the length of the conductor
- controlled: the type, thickness and temperature of the conductor

Results

Length of conductor (cm)	Ammeter reading (A)
20	
40	
60	
80	

The graph showing current strength (A) against length (cm) of wire.



Conclusion

As the length of the wire increases, the resistance increases and the conductivity decreases (the type, thickness and temperature of the wire being kept constant). The hypothesis was thus correct.

PRACTICAL INVESTIGATION 10C

Investigate the Relationship Between the Thickness of the Conductor and the Resistance of the Conductor

Aim

To investigate the relationship between the thickness of a conductor and its resistance (as indicated by its electrical conductivity).

Requirements and Method

Repeat Steps 1 to 8 of Investigations 10A and 10B, but use two 20 cm pieces of nichrome wire with different thicknesses, i.e. 0,2 mm and 0,3 mm. First connect the one wire in the circuit, then the other.

Hypothesis

The thicker the wire, the lower the resistance and therefore the better the conductivity (i.e. the higher the ammeter reading).

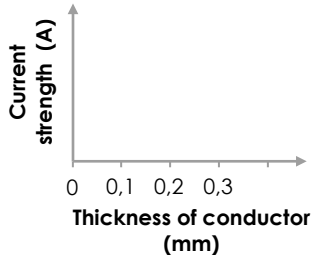
Variables

- dependent: the resistance of the conductor (as deduced from the conductivity/ammeter reading)
- independent: the thickness of the conductor
- controlled: the type, length and temperature of the conductor

Results

Thickness of conductor (mm)	Ammeter reading (A)
0,2	
0,3	

The graph showing current strength (A) against thickness (mm) of wire.



Conclusion

As the thickness of the wire increases, the resistance decreases and the conductivity increases (the type, length and temperature of the wire being kept constant). The hypothesis was thus correct.

TOPIC 4 SERIES AND PARALLEL CIRCUITS

US 7507: SO 5 – AC 1-2
US 7508: SO 1 – AC 1-2; SO 2 - AC 1, 3, 4; SO 3 – AC 1, 3, 5; SO 4 – AC 1-3
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 3 – AC 1-2; SO 4 – AC 1, 3, 4
US 7513: SO 1 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of series or parallel circuits in life
- Devise and implement a procedure to investigate electrical circuits
- Define concepts and principles relating to electrical circuits
- Devise and implement a procedure to investigate different circuits
- Gather and interpret data
- Demonstrate how to connect circuits in series or parallel
- Interpret scientific evidence and apply knowledge and skills in electrical circuits
- Explain the application of circuits in wiring and lighting of a house

IMPORTANT CIRCUIT CONCEPTS

The discussion on cells, batteries, resistors and other components may be summarised as follows:

- A **cell** or a **battery** (consisting of more than one cell) is an **energy source** that transfers electrical energy to the charges in the conducting wire in a circuit.

Electric Current

- Electric current is the **flow of electric charges** through a circuit.
- In metal conductors, these charges are composed of free-moving **electrons** that move through the conductor (external circuit) from the negative to the positive terminal of the battery (*see p. 156*).
- This flow of electrons is known as the **electron current**.
- Scientists were previously under the impression that electric current is the flow of **positive** charges from the positive to the negative pole of a battery. This is known as **conventional current**.
- When we refer to the **direction of the current**, it is accepted as the direction of **conventional** current, i.e. from the positive to the negative pole of the battery.

- The symbol for current strength is **I** and the SI unit for current strength is **amperes (A)**.
- Current strength is measured with an **ammeter**.
- For current strength to be measured, the entire current must flow through the ammeter. An ammeter thus has a **low resistance**.
- An ammeter is always connected in **series** in a circuit.

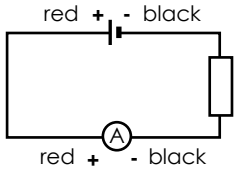
Potential difference

- **Potential difference** or **voltage** is the difference in electric potential energy per unit of charge between two points in a circuit.
  - it is the **energy** that the **charges transfer** to a component, e.g. a resistor, and which they '**lose**' when they move through it, **OR**
  - it is the **energy** that the **charges receive** from a component, e.g. a battery. The terminal potential difference is the potential difference measured on either side of the battery.
- The symbol for potential difference is **V** and the SI unit is **volt (V)**.
- Potential difference is measured with a **voltmeter**.
- A voltmeter is always connected in **parallel** with the component in the circuit. A voltmeter has a **high resistance** and the current does not flow through it.

NOTE

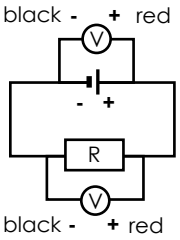
Ammeter: *An ammeter is connected in series with the rest of the circuit, with the negative (black) terminal of the ammeter on the side that is connected to the negative pole (terminal) of the battery and the positive (red) terminal of the ammeter on the side that is connected to the positive pole (terminal) of the battery.*

Symbol: (A)



NOTE

Voltmeter: *A voltmeter is always connected in parallel with the circuit component you are measuring with the negative (black) terminal of the voltmeter on the side closest to the negative pole (terminal) of the battery and the positive (red) terminal of the voltmeter on the side closest to the positive pole (terminal) of the battery.*



Symbol: (V)

Resistance

- The term **'resistance'** is used to refer to the resistance a conductor offers **to the flow** of electric **current** through it.
- A **resistor** is an electrical component with a high resistance. It is specially manufactured and connected in a circuit to **control** the **current** in the circuit.
- Resistors can be connected in **series** or in **parallel** in a circuit.
- The symbol for resistance is **R** and the SI unit is **ohm (Ω)**.

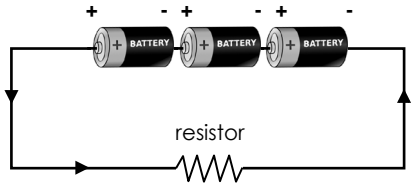
UNIT 1

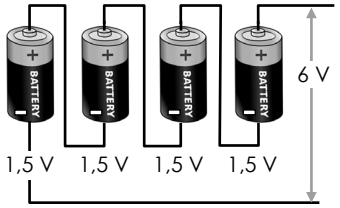
SERIES CIRCUITS

In a series circuit, all the components except the voltmeters are connected in series (in line) so that there is only one path for the current to flow through. Consider how cells and resistors respectively can be connected in series:

CELLS IN SERIES

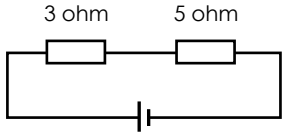
Connect one or more cells in series in a circuit by connecting the negative terminal (pole) of one cell to the positive terminal of a second cell and then connecting this cell's negative terminal to the positive terminal of a third cell, etc.





RESISTORS IN SERIES

Connect one, two or more resistors in series in a circuit so that the electric current must flow through all the resistors.



PRACTICAL INVESTIGATION 11A

Cells in Series

Aim

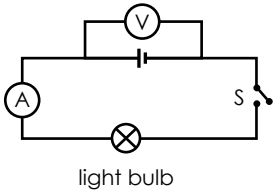
To investigate the effect of connecting more cells in series in a circuit. Observe the brightness of a light bulb.

Requirements

- 3 cells or flashlight batteries (1,5 V each)
- voltmeter
- ammeter
- small light bulb or LED
- switch
- connecting wires

Method

1. Complete a circuit by connecting one cell or flashlight battery in series with an ammeter, light bulb and switch. Connect a voltmeter in parallel across the ends of the cell *(see the diagram)*.



2. Close the switch. Immediately note the ammeter and voltmeter readings. Also note the brightness of the light bulb.
3. Open the switch and allow some time for cooling.
4. Now connect a second cell (flashlight battery) in series with the first. Connect the voltmeter in parallel across both cells.
5. Take the ammeter and voltmeter readings and note it down. Also note the brightness of the light bulb.
6. Connect a third cell in series with the other two. Repeat the steps.

Results

Number of cells	Ammeter reading	Voltmeter reading	Brightness of light bulb
1			
2			
3			

Conclusions

- The total voltage over the cells in series is the sum of the voltages of the individual cells, i.e. the total voltage of the three 1,5 V cells is:

$$V_{total} = 1,5 + 1,5 + 1,5 = 4,5 \text{ V}$$

- The more cells connected in series, the greater the total current strength and the brighter the light bulb burns.

PRACTICAL INVESTIGATION 11B

Resistors in Series

Aim

- To measure the total voltage/potential difference across the battery (whole circuit) and the voltages across individual resistors connected in series.
- To investigate how connecting more resistors in series affects the current strength of the circuit.
- To measure the current strength at different points in a series circuit.

Requirements

Use the same items as for Practical Investigation 11A, as well as:

- extra voltmeters and ammeters, and
- 3 resistors (or light bulbs) with different resistance values.

Method

1. Connect any one of the resistors (R_1) in series with the components of the circuit. Connect a voltmeter (V) in parallel across the battery and another voltmeter (V_1) in parallel across the resistor (Fig. 1).
2. Close the switch, take the ammeter (A_1) and voltmeter readings and note them down. (Both V and V_1 are now reading the potential difference across the external circuit which contains only the one resistor, R_1.)
3. Connect a second resistor (R_2) in series with the first. Connect a voltmeter (V_2) across the resistor (Fig. 2).
4. Close the switch, take the ammeter and voltmeter readings and note them down. Change the position of the ammeter or connect an extra ammeter (A_2) as indicated. Take the readings and note them down.
5. Connect a third resistor (R_3) in series with the first two. Connect a voltmeter (V_3) across this resistor (Fig. 3).
6. Close the switch, take the ammeter and voltmeter readings and note them down. Change the position of the ammeter or connect extra ammeters (A_2 and A_3) as indicated. Take the readings and note them down.

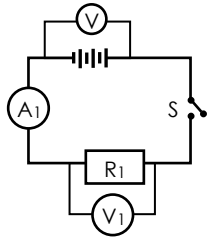


Figure 1

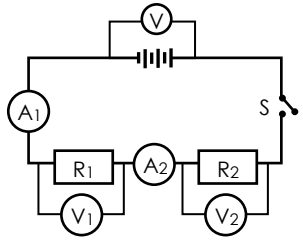


Figure 2

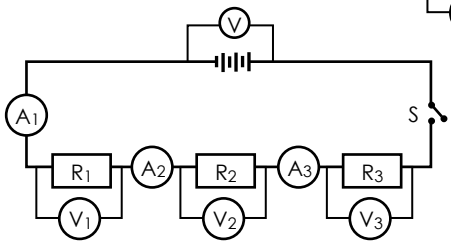


Figure 3

Results

Resistors	Ammeter readings (A)			Voltmeter readings (V)			
	A_1	A_2	A_3	V	V_1	V_2	V_3
Resistor 1		–	–			–	–
Resistor 1 and 2			–				–
Resistor 1, 2 and 3							

Conclusions

- The resistor with the highest resistance has the largest V reading (voltage/potential difference) across its ends.

  The resistor with the lowest resistance has the smallest V reading (voltage/potential difference) across its ends.
- The V reading (voltage) across the battery = the sum of the V readings (voltages) across the resistors, i.e. $V_{total} = V_1 + V_2 + V_3$.

Resistors in series thus share the total voltage/potential difference and serve as **potential dividers**.

- The current strength decreases as the number of resistors in series increases and therefore the total resistance increases.

  The more light bulbs connected in series, the dimmer they glow.

- The current strength is the same throughout the circuit.
  $A_1 = A_2 = A_3$

- If one resistor (light bulb) connected in series breaks (fuses), the main current is interrupted (I = 0 A) and the rest of the resistors (light bulbs) won't work.

NOTE

The voltmeter reading across the battery indicates how much energy the battery can offer a unit of charge (see page 153 & 161). The voltmeter across the ends of a resistor measures the voltage/ potential difference between the two points and indicates the energy per unit of charge* that is transferred to the resistor.*

**A unit of charge is 1 Coulomb.*

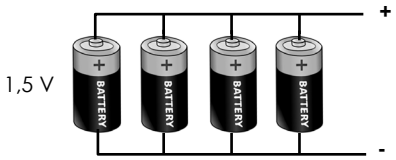
UNIT 2

PARALLEL CIRCUITS

In a parallel circuit, all the components (except the ammeters) are connected in parallel. An ammeter is always connected in series.

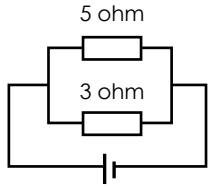
CELLS IN PARALLEL

Connect one, two or more cells in parallel in a circuit by connecting all the negative and all the positive terminals to one another.



RESISTORS IN PARALLEL

Connect two or more resistors in parallel in a circuit by placing them next to one another and then connecting them in such a way that there is more than one path for the current to flow through.



PRACTICAL INVESTIGATION 12A

Cells in Parallel

Aim

To investigate the effect of connecting more cells in parallel in a circuit. Observe the brightness of a light bulb.

Requirements

- 3 cells or flashlight batteries (1,5 V each)
- voltmeter
- ammeter
- small light bulb or LED
- switch
- connecting wires

Method

1. Complete a circuit by connecting one cell or flashlight battery in series with an ammeter, light bulb and switch as in Fig. 1 below. Connect the voltmeter in parallel across the ends of the cell.

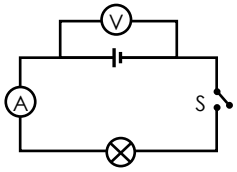


Figure 1

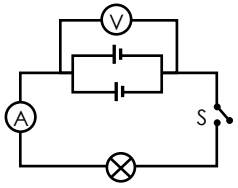


Figure 2

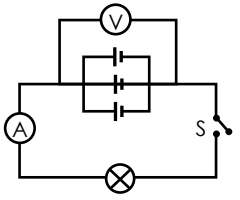


Figure 3

2. Close the switch. Immediately note the ammeter and voltmeter readings. Also note the brightness of the light bulb.

3

3. Open the switch and allow some time for cooling.
4. Now connect a second cell (flashlight battery) in parallel with the first cell. Connect the voltmeter in parallel across both cells (Fig. 2).
5. Note the ammeter and voltmeter readings. Also note the brightness of the light bulb.
6. Connect a third cell (flashlight battery) in parallel with the other two. Repeat the steps (Fig. 3).

Results

Number of cells	Ammeter reading	Voltmeter reading	Brightness of light bulb
1			
2			
3			

Conclusions

- The total voltage across two or three cells in parallel is the same as that for one cell.
- The total current strength thus stays the same, as does the brightness level of the light bulb.

PRACTICAL INVESTIGATION 12B

Resistors in Parallel

Aim

- To measure the voltages/potential difference across individual resistors connected in parallel, and the total voltage/potential difference across the resistors connected in parallel.
- To investigate how connecting more resistors in parallel affects the current strength of the circuit.
- To measure and compare the current strength in the different parallel branches and the main circuit.

Requirements

Use the same items as for Practical Investigation 12A, as well as:

- extra voltmeters and ammeters and
- 3 resistors (or light bulbs) with different resistance values

Method

1. Connect any one of the resistors (R_1) in series with the components of the circuit. Connect a voltmeter (V) in parallel across the battery and another voltmeter (V_1) in parallel across the resistor (Fig. 1). Close the switch, take the ammeter (A) and voltmeter readings and note them down. (Both V and V_1 are now reading the potential difference across the resistor and across the external circuit, which contains only the one resistor, R_1.)

2. Connect a second resistor (R_2) in parallel with the first. Connect a voltmeter (V_2) across this resistor and an ammeter (A_1 and A_2) in each of the branches (Fig. 2). Close the switch, take the ammeter and voltmeter readings and note them down.

3. Connect a third resistor (R_3) in parallel with the first two. Connect a voltmeter (V_3) across this resistor and an ammeter (A_1, A_2 and A_3) in each of the branches (Fig. 3). Close the switch, take the ammeter and voltmeter readings and note them down.

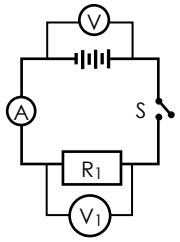


Figure 1

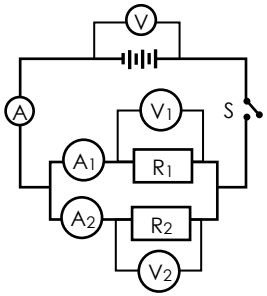


Figure 2

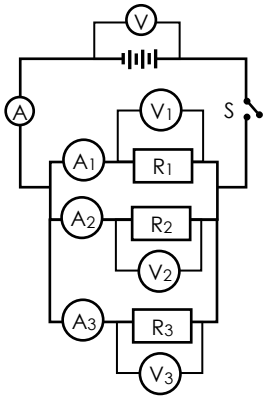


Figure 3

Results

Results

Resistors	Ammeter readings (A)				Voltmeter readings (V)			
	A	A_1	A_2	A_3	V	V_1	V_2	V_3
Resistor 1			–	–			–	–
Resistor 1 and 2				–				–
Resistor 1, 2 and 3								

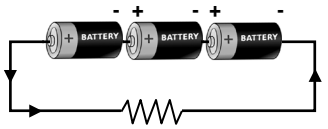
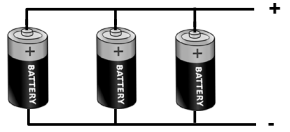
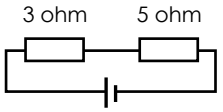
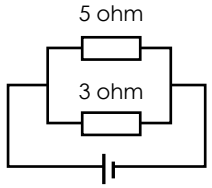
Conclusions

- The voltage across all the resistors connected in parallel equals the voltage across each individual resistor ($V_{total} = V_1 = V_2 = V_3$).

> **NOTE**
> *There are no other resistors in the circuit, therefore the voltmeter across the battery reads the voltage across the entire parallel connection.*

As more or fewer light bulbs are connected in parallel, their brightness remains the same.

- The A reading of the main current = the sum of the A readings (current strength) in each of the parallel branches, i.e.
  $A = A_1 + A_2 + A_3$.
  Resistors in parallel thus share the total current strength and act as **current dividers**.
- The resistor with the highest resistance has the smallest A reading, thus the weakest current flows through it.
  The resistor with the lowest resistance has the largest A reading, thus the strongest current flows through it.
- As the number of resistors in parallel increases, the total resistance lowers and the current strength increases.
- If one resistor (light bulb) connected in parallel breaks (fuses), the main current is not interrupted; there is still current flowing through the other resistors and the other light bulbs keep burning. The total resistance has increased and the total current strength decreased.

CELLS IN SERIES	CELLS IN PARALLEL
Total voltage Total voltage (potential difference) is equal to the sum of the voltages across each individual cell connected in **series** (*see Practical Investigation 11A*). *Each cell adds to the voltage available to the charges.*  **V_{total} = 1,5 + 1,5 + 1,5 = 4,5 V**	**Total voltage** Total voltage (potential difference) across cells connected in **parallel** is the same as the voltage of an individual cell (*see Practical Investigation 12A*). *Each charge gains voltage from a single cell only.*  **V_{total} = 1,5 V**
RESISTORS IN SERIES	**RESISTORS IN PARALLEL**
Resistors or light bulbs connected in **series** in a circuit:  **Potential dividers** ▪ The total voltage across the battery is equal to the sum of the voltages across each of the individual resistors. **$V_{total} = V_1 + V_2$** **Relationship between resistance and voltage** ▪ The resistor with a higher resistance has a larger voltage across it. ▪ The resistor with a lower resistance has a smaller voltage across it.	Resistors or light bulbs connected in **parallel** in a circuit:  **Current dividers** ▪ The total **current** from the battery splits into smaller currents. ▪ The **current strength** provided by the battery is equal to the sum of the current strengths through each component/resistor. **$I_{total} = I_1 + I_2$** **Relationship between resistance and current** ▪ The parallel branch with the highest resistance draws the weakest current. ▪ The parallel branch with the lowest resistance has the strongest current.

The same current
- The current strength is the same throughout a series circuit.
- Components connected in series create a single pathway for the charges.
- The current strength going through each component is equal to the current strength of the whole circuit.

$I_{total} = I_1 = I_2 = I_3$

Total resistance and main current
- The total resistance increases with every addition of a resistor in series and the main current strength decreases accordingly (*see Practical Investigation 11B*).

The same voltage
- The voltage across each parallel branch is the same.
- Components connected in parallel create multiple pathways for the charges.
- Each component has the same voltage across it which is equal to the voltage across the battery.

$V_{total} = V_1 = V_2 = V_3$

Total resistance and main current
- The total resistance decreases with every addition of a resistor in parallel and the main current strength increases accordingly (*see Practical Investigation 12B*).

Quantity	Symbol	SI unit
Current	**I**	Ohm (Ω)
Voltage	**V**	Volt (V)
Resistance	**R**	Ampere (A)

Summary of physical quantities and their symbols used in electrical circuits

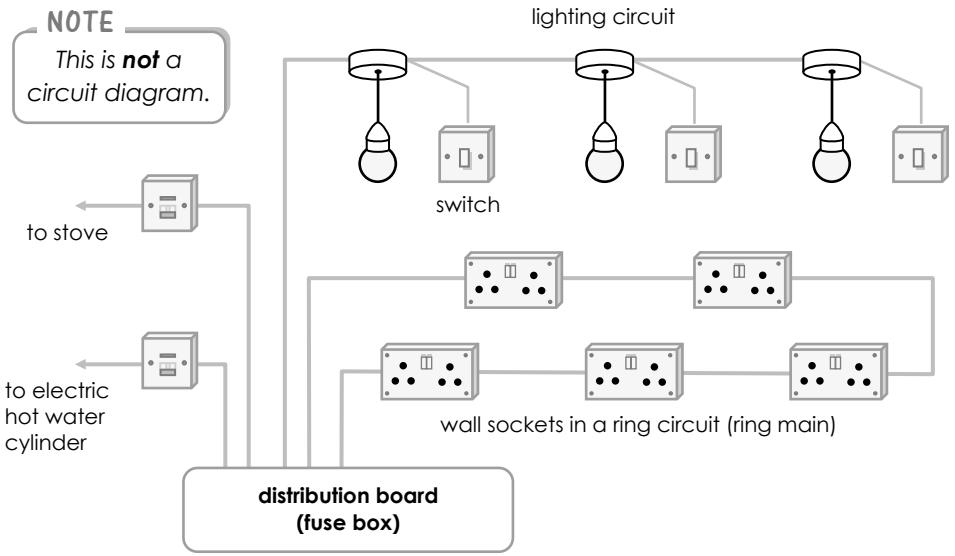
LIGHTING SYSTEMS IN OUR HOMES

Electrical energy is supplied to towns, cities and every house by the national electricity grid. The electricity supply to our homes is approximately 220 V. It is used to power lights and other electrical appliances.

Parallel Connection

- The lighting systems in our homes are generally connected in **parallel** (*see p. 169: Wiring in houses*). Parallel connections have the following advantages:
  - The light bulbs are each connected to the main circuit in their own parallel circuit. If one bulb fuses (i.e. if its filament breaks), only the one parallel branch is eliminated. The rest of the lights will remain on.
  - If more lights are switched on, the voltage across all the bulbs remains the same and the brightness of the bulbs does not change as the lights are switched on and off.

A simplified representation of the lighting system in houses



NOTE

The brightness of a light bulb depends on its power rating, i.e. the rate at which energy is transferred to it. This in turn depends on the voltage. In light bulbs connected in parallel, the voltage across all the bulbs remains constant, regardless of whether bulbs are switched on or off. The power and the brightness remain constant.

PRACTICAL INVESTIGATION 13

Lighting Systems in Our Homes

Aim

- To identify series and parallel circuits in electrical wiring in houses, cars and toys.
- To draw series and parallel circuit diagrams.

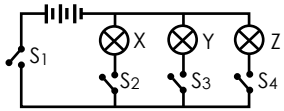
Requirements

- a battery consisting of 2 or 3 cells
- 3 small light bulbs
- connecting wires
- 4 switches

Method

Method

1. Connect the battery, light bulbs and switches in a circuit so that:



   - one switch (S_1) can switch the electricity supply on and off to all the light bulbs, similar to the main switch in the electrical wiring of a house.
   - the separate switches (S_2, S_3 and S_4) can switch the light bulb on and off in each parallel branch (*see the circuit diagram*).

2. First close the main switch and then switch any light bulb or combination of light bulbs on or off.

3. Note which light bulb(s) burn(s) and compare the brightness of the bulbs in each case. Complete the table below.

Results and Conclusions

	Position of switch (open/closed)	Bulbs burning	Brightness (very bright/ bright/dim)
1	S_1 closed; S_2, S_3, S_4 open	none	-
2	S_1, S_2 closed; S_3, S_4 open	X	bright
	(Also consider other combinations, e.g. S_1 and S_4 closed and S_2 and S_3 open, etc.)		
3	S_1, S_2 and S_3 closed; S_4 open	X, Y	bright
	(Also consider other combinations, e.g. S_1, S_2 and S_4 closed and S_3 open, etc.)		
4	S_1, S_2, S_3, S_4 closed	X, Y, Z	bright

Switch S_1, as well as the switch in the specific parallel branch (e.g. S_2), must be closed for a certain light bulb (e.g. X) to burn. One or more light bulbs can be bypassed whilst the others burn. The brightness of the bulbs remains the same regardless of whether more or fewer bulbs are connected in parallel.

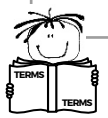
RESISTORS MANUFACTURED WITH AN ACCURATE RESISTANCE

- Resistors are manufactured to have an accurate resistance. Different colour codes are assigned to the different resistance values.
- Resistors are connected in a circuit to control the current strength so that an overly strong current does not cause the electrical components to burn out.

RELATIONSHIP BETWEEN VOLTAGE (V), CURRENT STRENGTH (I) AND RESISTANCE (R)

- In two circuits with **the same** total **voltage**, the current strength will:
  - be larger in the circuit with lower resistance, and
  - smaller in the circuit with higher resistance.
- For the same total voltage, the current strength through a resistor is therefore inversely proportional to the size of its resistance, i.e. if the resistance doubles, the current strength halves.
- Also, for **the same resistance** at the same temperature, the current strength through the resistor increases/decreases proportionally to the voltage across it, i.e. if the voltage doubles, the current strength also doubles. This is summarised in Ohm's law.

Ohm's law: the current strength through a resistor is directly proportional to the voltage across the resistor at a constant temperature



NOTE

Ohm's law is discussed in more detail in Grade 10.

WIRING IN HOUSES

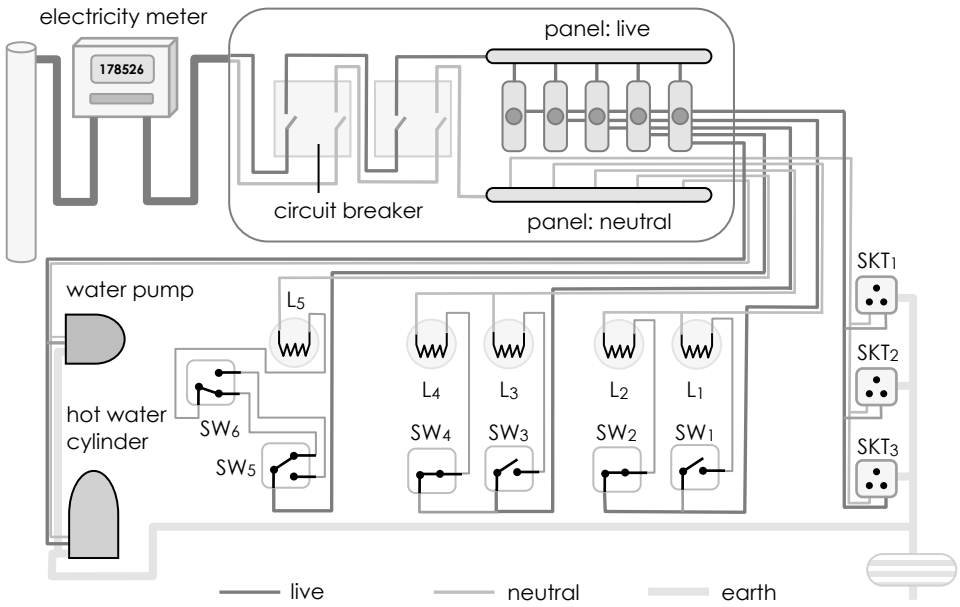
- The main electricity supply in South Africa is provided by Eskom and brought to the electricity boxes outside houses by overhead or underground cables.
- Two wires, i.e. a **live wire** (L) and a **neutral wire** (N), are connected to the electricity box and run to each house:
  - the live wire (L) carries a high-voltage electric current to the electrical appliances in the house.
  - the neutral wire (N) carries a low-voltage electric current from the electrical appliances back to the source.
- The two wires connect the electricity box to a distribution board in the house via a **main switch**. The main switch controls the electricity supply to the house and will trip if the current becomes too strong.
- At the **distribution board (fuse box)**, the current branches into different circuits, e.g. the circuits for the **lights**, the **stove**, the **hot water cylinder** and the **wall sockets** (ring main). Each of these circuits has circuit breakers or trip switches in case the current is too strong.
- The metal part of an electrical appliance is connected to an **earth wire** that is connected to a three-pin plug along with the live and neutral wires.
- The earth wire itself does not usually conduct current. It is installed as a safety measure to carry extra dangerous current away to the ground.
- A **three-pin plug** is plugged into a wall socket to power the electrical appliance. The wall socket is connected to the earth cable in the ground. In this way, the fuse box and electrical appliances are all connected to the ground. In many cases, the ground cable is connected to a metal water pipe or rod that offers good conduction to the ground.

NOTE

Normally, the fuse box is connected to:

- *the main switch via a 60 A circuit breaker,*
- *the light switches via a 5 A circuit breaker,*
- *the stove circuit via a 25 A circuit breaker, and*
- *a group of wall sockets via a 15 A circuit breaker.*

Simple representation of electrical wiring and circuits in a house



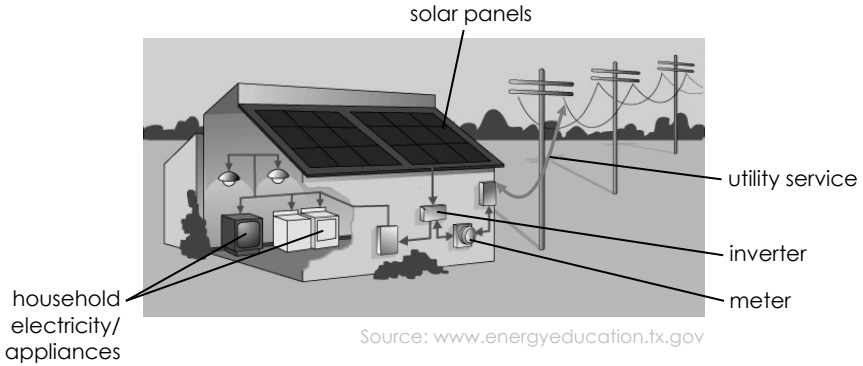
SW_1 - SW_4 = normal switches SW_5 - SW_6 = two-way switches

L_1 - L_4 = lights SKT_1 - SKT_3 = plug sockets

FOR ENRICHMENT

Self-provision of electricity via solar panels and batteries

The erratic supply of electricity by Eskom has forced people to consider their own sources of electricity by means of solar heating panels and large rechargeable batteries.



Source: www.energyeducation.tx.gov

Household grid connected to a photovoltaic system

TOPIC 5 SAFETY WITH ELECTRICITY

US 7507: SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 2
US 7511: SO 4 – AC 1
US 7513: SO 1 – AC 1-4; SO 2 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of electricity safety
- Define concepts and principles relating electrical safety
- Demonstrate how to wire a three-pin plug safely
- Explain the application of electrical safety in wiring of plugs and houses

UNIT 1 SAFETY PRACTICES

OVERLOAD

- The **more resistors** there are connected in **parallel**, the lower the total resistance and the stronger the current.
- If many electrical appliances are connected to a **multiplug** at a single power point, or various light bulbs in a **parallel** network are switched on, the total resistance lowers significantly and the total **current strength** may increase dangerously.

- **Overload** may occur on the main circuit if too many resistors are connected in parallel.
- For safety purposes, the main circuit includes a fuse or circuit breaker that will interrupt the current when it reaches a specific strength.

FUSES, CIRCUIT BREAKERS AND EARTH LEAKAGE SYSTEMS

Fuses

- A fuse is a very thin, short piece of wire with a **low melting point**.
- It is connected in **series** in a circuit so that the full current must flow through it.
- If the current is too strong, the wire will get too hot and **melt**. This causes an interruption in the circuit which, in turn, stops the flow of the current.
- A fuse needs to be replaced the moment it has melted.
- The wiring in **older** houses often have fuses as a safety mechanism.

Circuit breakers

- A circuit breaker is a magnetic switch that automatically switches off if overload or a short circuit occurs.
- It consists of a coil around a soft iron core. An **electromagnet** is formed the moment a current flows through the coil.
- The **strength** of the magnet **increases** along with the current strength and will move two **contact points** in the circuit **away from each other**. This interrupts the circuit once the current reaches a certain strength.
- Circuit breakers are often connected to individual **switches** that control the stove, lights or plugs, etc. The switch can be switched on again once the problem has been solved.

Earth leakage circuit breakers

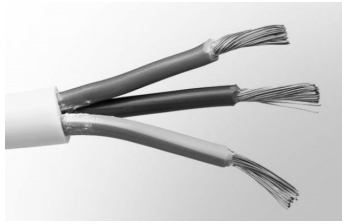
- This type of circuit breaker **protects** humans against **electric shock**.
- If the current that enters an appliance via the live wire is different to the current that leaves it via the neutral wire, then there is **current** flowing along a **wrong path**.
- For example, when an electric current of 30 mA or more flows to the ground through a **body**, due to damaged wiring or a short circuit.
- An earth leakage circuit breaker is then very quickly **activated** so that the electricity supply to the circuits in the house is interrupted. This can prevent fatal electric shock or serious burn wounds.

NOTE

A current that is not strong enough to activate a normal circuit breaker can still cause injury or death.

THREE-PIN PLUGS

- Many appliances have a three-pin plug as a **safety precaution** for the connection to the main circuit.
- The three-pin plug has a live wire (brown), a neutral wire (blue) and an earth wire (green-and-yellow).



The Earth Wire

The earth wire is connected to the **metal casing** of the appliance (e.g. kettle) and is connected to an earth cable in the **ground** via the wall plug.

The Earth Cable

The earth cable has almost zero resistance. Thus, if the metal casing of the appliance becomes charged due to a fault, the **charge** is safely discharged to the **ground**.

PRACTICAL INVESTIGATION 14

Three-pin Plug of an Electrical Appliance

Aim

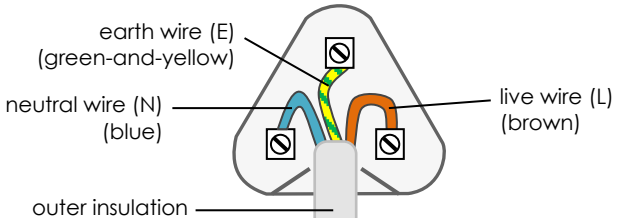
How to connect the wiring in a three-pin plug.

Equipment

- 20 cm of three core electrical cable
- three-pin plug
- pliers
- screwdriver
- sharp knife

Method

1. Remove the back cover of the plug.
2. Use a screwdriver to partially loosen the screws in the plug so that the wires can fit underneath them.
3. Use the knife and pliers to remove the outer insulation on the ends of the wires that must fit underneath the screws.
4. Use the colour codes or other instructions on the plug and connect the brown wire at L (live), the green-and-yellow wire at E (earth), and the blue wire at N (neutral).
5. Firmly tighten the screws so that the wires don't pull loose.
6. Check that the wires are correctly connected according to their colours, that they are connected firmly enough to prevent wires pulling loose, and that there are no uncovered wires on the outside of the plug.



Wiring of a three-pin plug

Useful Safety tips

Plugs, cables, wiring

Only use SABS-approved plugs, extension leads and multi-plugs

Never connect too many appliances to a single plug point

Always check the state of your electrical cables to make sure they are not damaged (check that electrical wires are properly insulated with no 'bare' sections of electrical cord showing anywhere)

Preferably use three-pin plugs for electrical appliances such as stoves, fridges and heaters

Extensions and connections

If you have a need for an extension cord, don't run it under carpets, rather run it over the carpet and secure with tape

Don't run extensions through doors and windows and to other buildings

Don't allow neighbours to connect their electricity through your personal meter

Do not carry long objects such as pipes, ladders and scaffolding under power lines and accidentally touch them

Switch off electricity

Switch off and disconnect electrical appliances after use or when they are being repaired

Switch electricity off at the wall socket before pulling the plug out (never pull a plug out by the cord as it can damage it or expose wires)

Educate users

If there is a baby in the house, ensure that wall sockets are covered with a safety cap

Educate children about the dangers of electricity

Do not stick fingers into plug sockets

Never put electrical wires directly into a wall plug socket as this can shock you

Do not touch a switch with wet hands and do not use electrical appliances in a bathroom

Keep cords away from hot stoves and other hot surfaces

Repair and maintenance

Switch off the main switch when electrical wiring is being repaired or an electrical fire breaks out

Always get a qualified electrician to do any electrical repairs or to install new plug points

ILLEGAL ELECTRICAL CONNECTIONS

Illegal connections to the Eskom mains supply can be dangerous and are regarded as **power/energy theft**.

In poorer neighbourhoods and informal settlements, electricity is often illegally siphoned off Eskom's main electricity grid by means of illegal electrical connections to power lines.

These connections are very **dangerous**. Often:

- the wiring is done incorrectly
- wires are not properly insulated
- the voltage in the wires is much higher than what is needed in houses
- people may receive a fatal electric shock when making new connections
- short circuits arise that can set the insulation alight, causing houses and settlements to burn down

Besides the danger associated with illegally siphoned electricity, it is not paid for, so using it is a crime. It is regarded as power/energy theft.

NOTE

Connections to the main electricity grid before the electricity meter box are not only very dangerous, but also illegal and therefore punishable by law.

TOPIC 6 ENERGY AND THE NATIONAL ELECTRICITY GRID

US 7507: SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3
US 7511: SO 1 – AC 1-3; SO 2 – AC 1-5; SO 3 – AC 1,2,3,5
US 7513: SO 1 – AC 1-4; SO 2 – AC 1-3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of electricity and energy sources in life
- Define concepts and principles relating to energy sources
- Classify and distinguish between renewable and non-renewable energy sources
- Explain how scientific knowledge and skills are applied to energy source development
- Describe the effect of the mismanagement of energy sources on the environment
- Explain the application of scientific principles in energy source development
- Determine the impact of energy sources on the quality of life

UNIT 1 ELECTRICITY GENERATION

COAL AND OTHER TYPES OF POWER STATIONS

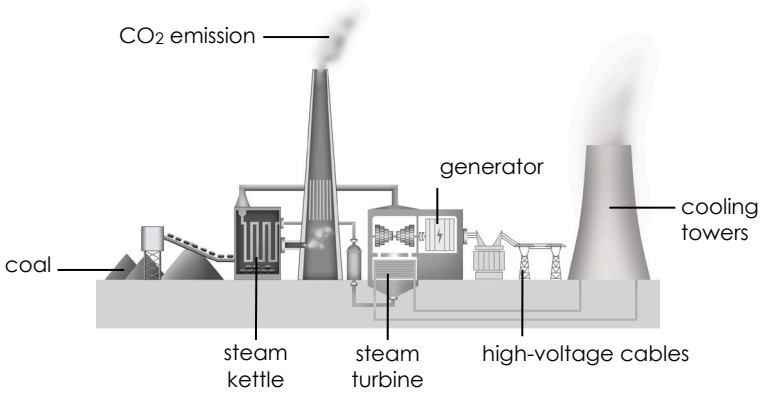
- At a power station (also called a 'power plant'), a generator is used to generate electricity.
- Most power stations in South Africa use fossil fuels (coal, oil and natural gas) to supply houses and factories with electricity.

- Radioactive fuel is used for electricity generation at nuclear power stations, e.g. Koeberg.

THE FUNCTIONING OF A POWER STATION

The **functioning** of a power station is based on the following procedures:

- the fuel, e.g. coal, is burned and steam is produced in a steam boiler or kettle
- the high-pressure, high-temperature steam moves across the blades of a turbine
- the energy of the steam spins the turbine
- the turbine spins a generator
- the generator generates electricity (mechanical (kinetic) energy → electrical (potential) energy)
- electricity is distributed by high-voltage cables and thereby supplied to houses and factories
- the steam is condensed back to water in cooling towers
- the process is repeated



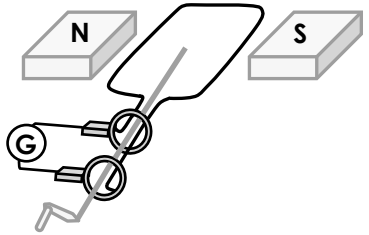
Functioning of a coal power station

*A turbine consists of a wheel with blades, and an axle in the middle. The steam that is released hits the blades, causing the wheel to spin. The kinetic energy of the steam is thus converted into mechanical energy in the wheel. This mechanical energy is transferred to the generator via the axle, so that it rotates. Inside the generator, the **mechanical energy** is converted into **electrical energy** within a magnetic field.*

FOR ENRICHMENT

THE FUNCTIONING OF A GENERATOR

- *The functioning of a generator is based on the rotation or spinning of a coil of insulated copper wire in a permanent magnetic field, or on the spinning of a magnetic field relative to a coil.*
- *A typical turbine causes electromagnets to spin around big coils of insulated copper wire inside a generator.*
- *This relative movement between the coil and the magnetic field creates or induces an electric current in the coil.*
- *The electromagnets perform 50 rotations per second and generate electricity at a voltage of approximately 20 000 volts.*



Simplified alternating current generator

DISADVANTAGES OF FOSSIL FUELS

Approximately 90% of South Africa's electricity is currently generated through the burning of coal. Coal is reasonably abundant in South Africa and is the cheapest energy source. However, there are numerous disadvantages associated with the burning of coal, i.e.:

- low-grade coal is used and pulverised to a powder before it is burned
- the fine dust particles from the large quantities of coal stored near the power station cause environmental and air pollution
- large quantities of coal ash are produced during combustion and stored in ash heaps that deface the environment
- coal consists primarily of the element carbon, but also contains impurities such as sulphur; during a combustion reaction with oxygen, gases such as carbon dioxide (CO_2), sulphur dioxide (SO_2) and nitrogen dioxide (NO_2) are formed; these oxide gases dissolve in rain water and in moisture in the air to form acid rain
- carbon dioxide gas (CO_2) is a greenhouse gas that is released into the atmosphere in large quantities and causes global warming
- coal is a non-renewable energy source that is rapidly being depleted

ALTERNATIVE SOURCES OF ENERGY

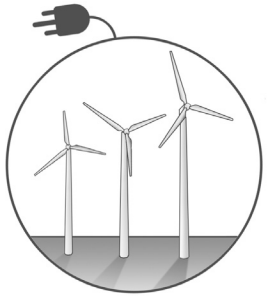
Besides coal, there are alternative sources of energy that can be used to drive turbines and generators, including:

- wind
- ocean waves
- nuclear fission
- falling water
- the sun

Wind power

Functioning and advantages

- In wind-driven electricity generators, a strong wind spins the rotor blades of the turbine.
- Rotor blades are up to 50 m long and spin slowly. Gears are therefore used to spin the turbines fast enough to generate electricity.
- The turbine in turn spins a generator to generate electricity.
- No fuel is required and no pollution occurs.
- Wind power is a renewable energy source.



Disadvantages

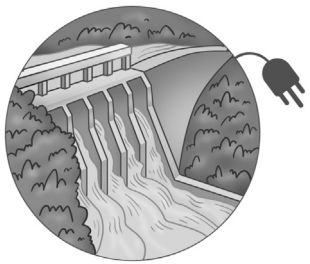
- Wind turbines/windmills are huge and expensive.
- Massive areas of land are required for the erection of wind farms.
- No electricity can be generated on windless days.

- About 1 000 wind turbines are needed to generate the same amount of energy as a modern power plant running on coal or other fuel.

> **NOTE**
> *Areas such as the coastal regions in the Western and Southern Cape generally get lots of wind and are ideally suited to the erection of wind farms.*

Hydroelectric power

Functioning and advantages



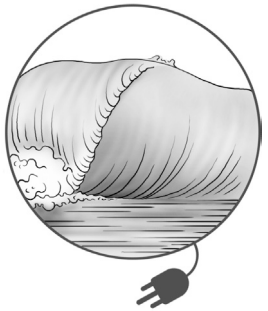
- The functioning of a hydroelectric power station is based on falling water causing a turbine to spin.
- The turbine in turn spins a generator in order to generate electricity.
- No fuel is required to spin the turbine and no pollution occurs.
- Hydroelectric power is a renewable energy source.

Disadvantages

- South Africa is unfortunately a dry country without many rivers and high-lying water sources for the generation of hydroelectric power.
- Dams are expensive to build. They also have a significant impact on the environment and on local communities.

Tidal and wave power

Functioning and advantages



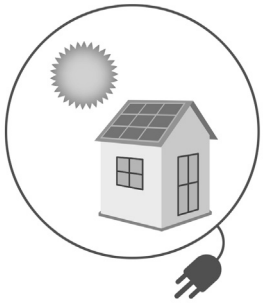
- The ocean tides, i.e. high tide and low tide, are a result of the gravitational pull of the sun and the moon.
- There is an average difference of approximately 8 m between high and low tide. To harness tidal power, a special dam wall is built over a river mouth. This wall lets the ocean water through and dams it up as the tide rises.
- When the tide recedes, the water flows back over a number of turbines causing them to spin.
- The turbines in turn spin a generator to generate electricity.
- The movement of waves can also be used to move large floating turbines (rafts) and thereby generate electricity.
- No fuel is required and no pollution occurs.
- Wave power is a clean, renewable energy source with no waste products.

Disadvantages

- During low tide, there are large areas of exposed mud that are the habitats of many small animals that form a vital part of the food chain. Building a dam disrupts these mudflats and damages the ecosystem.
- The river mouths are no longer available for maritime use.
- The natural environment along the coast is defaced.
- A very large number of rafts is needed to generate a reasonable amount of electricity.

Solar power

Functioning and advantages



- **Sun-heated steam**
  - There are different ways to focus the heat of the sun in order to heat water and produce steam. One method involves using thousands of mirrors.
  - Mirrors are set up to focus the heat of the sun on a tower in which steam is produced.
  - The steam can be used to spin a turbine that, in turn, spins a generator in order to generate electricity.
  - No fuel is required and no pollution occurs.
  - Solar power is a clean, renewable energy source.

NOTE

Some of the largest solar power plants in the world are located in the Northern Cape in South Africa.

- **Solar panels and solar cells**
  - Solar power can also be generated by using large solar panels to convert the sun's radiant energy into an electric current.
  - A solar panel consists of many solar cells.
  - Solar panels are joined together to form large solar plates.
  - Sunlight consists of small 'packages' of energy called photons.
  - When these photons in sunlight hit a solar cell, electrons are released from the atoms in the cell.
  - Conducting wires are connected to complete a circuit in which the electrons move. In this way, electricity is generated.
  - Solar panels have no moving parts.
  - They are reasonably simple to design and are low-maintenance.
  - No waste products are formed and no air pollution occurs.
  - Solar power is a clean, renewable energy source.

Disadvantages

- The materials used to construct solar panels are dangerous pollutants.
- Continuous sunshine is needed; solar power cannot be generated in cloudy or rainy weather conditions.
- Solar power cannot be effectively generated in all parts of the world, nor can it be generated at night.
- Batteries must be charged for the provision of electricity when the sun is not shining.
- The manufacturing and use of these large batteries is not very environmentally friendly.
- The equipment needed for generating solar power is very expensive.

UNIT 2

NUCLEAR POWER IN SOUTH AFRICA

RADIOACTIVE FUEL

South Africa has one nuclear power station, i.e. Koeberg in the Western Cape. It is the only nuclear power station in Africa.

- A nuclear power station uses radioactive elements, e.g. radioactive uranium (U), as fuel.
- A nuclear reactor is used to split uranium atoms, thereby forming smaller atoms of two different elements. This process is known as **nuclear fission**.
- Two or three neutrons of a uranium atom are released during this process and they can, in turn, split the nuclei of other uranium atoms, thereby freeing more neutrons.
- A controlled chain reaction takes place in which the nuclear fission process is repeated.
- A very small quantity of uranium can eventually release large quantities of thermal energy.

FOR ENRICHMENT

RADIOACTIVE ELEMENTS

A radioactive element releases energy through radiation, i.e. the spontaneous emission of particles, e.g. alpha particles (helium nuclei), beta particles (fast-moving electrons) or gamma rays. This causes the spontaneous decay of atom nuclei.

- *Uranium, a very heavy metal, is abundant on the earth's surface and may serve as a long-term source of concentrated energy.*
- *Natural uranium is found in the earth's crust and in seawater as a mixture of two isotopes, i.e. U-238 (99,3%) and U-235 (0,7%). U-238 is only slightly radioactive and decays very slowly. This slow decay still releases enough heat to sufficiently warm the earth's interior.*

- *U-235 is, however, very radioactive. The nucleus of a U-235 atom consists of 92 protons and 143 neutrons (92 + 143 = 235). When a neutron collides with the nucleus of a uranium atom, nuclear fission takes place (i.e. the atom splits in two) and energy is released in the form of heat.*

- *The type of element formed depends on the number of protons that end up in each new atom.*

OPERATION OF A NUCLEAR POWER STATION

- The radioactivity of uranium leads to nuclear fission. This is accompanied by the release of large amounts of heat/thermal energy.
- The heat is transferred to a cooling medium (e.g. water) that flows through the reactor. Seawater is used to cool radioactive steam.
- The heating of the water produces steam.
- The steam is used to drive a turbine, as in the case of coal power stations.
- The turbine spins the axle of a generator, thereby generating electricity. The electricity that is generated by nuclear energy is called **nuclear power**.

RADIOACTIVITY AND NUCLEAR WASTE

- The radiation produced during radioactive decay is very dangerous and can cause cancer. The nuclear reactor needs to be surrounded by very thick concrete walls and lead plates to seal off the radiation and prevent it from being transferred to the environment.
- The spent nuclear fuel (nuclear waste) remains radioactive for hundreds of years and therefore needs to be stored safely. It is usually disposed of in special containers deep under the earth's surface.

UNIT 3

NATIONAL ELECTRICITY GRID

INTERACTIVE SYSTEM

All the power stations in South Africa, including hydroelectric and nuclear power stations, form part of the **national electricity grid** that supplies the entire country with electricity. The grid is a system of **interactive parts** and a change in one part of the network/grid affects other parts of the network/grid.

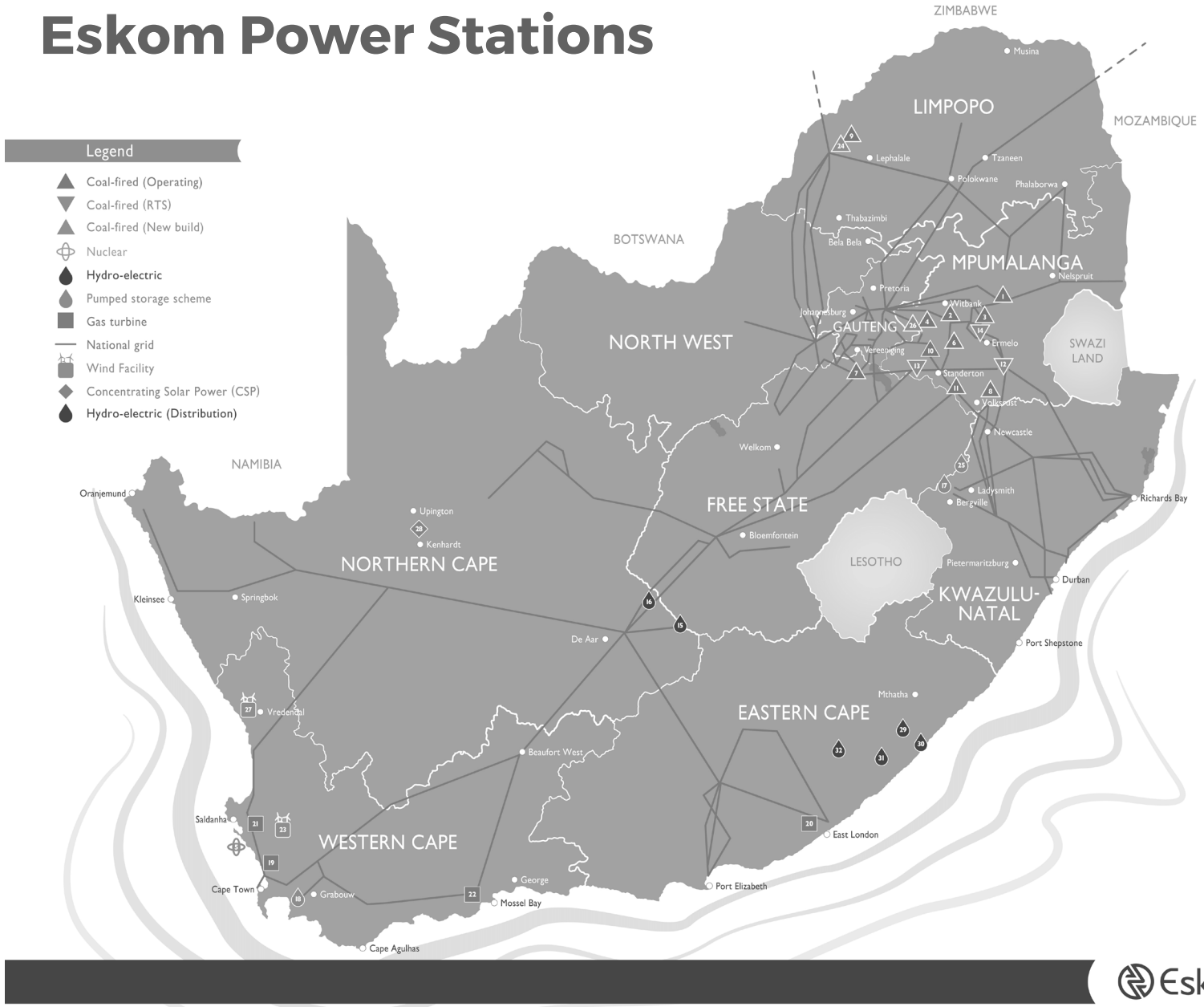
Power stations

- The electricity that is generated by the various power stations must be supplied to the grid at exactly the right voltage.
- If more electricity than needed is available, it is used for purposes such as pumping water to high-lying dams. If less electricity is available than needed, load shedding may be initiated.
- Power stations are usually located near coal mines, away from towns and cities.

Power lines

- High-voltage cables or transmission lines are used to safely transport electricity from the power station to towns or cities.
- The resistance in the cables causes much energy (about 15%) to be lost in the form of thermal energy. The stronger the current, the greater the energy loss.

Eskom Power Stations



Base load stations

1 Arnot	2 352 MW		7 Lethabo	3 708 MW
2 Duvha	3 600 MW		8 Majuba	4 110 MW
3 Hendrina	2 000 MW	Coal	9 Matimba	3 990 MW
4 Kendal	4 116 MW		10 Matla	3 600 MW
6 Kriel	3 000 MW		11 Tutuka	3 654 MW

Nuclear

5 Koeberg 1 940 MW

Return-to-service stations

Coal

12 Camden 1 510 MW
13 Grootvlei 1 200 MW
14 Komati 940 MW

The return-to-service (RTS) stations were mothballed in 1990 and are in the process of being recommissioned due to the growing demand for electricity. The return-to-service project for Camden power station ended on 31 March 2010 with the entire station fully commercial.

Peak demand stations

Hydro-electric	15 Gariep	360 MW
	16 Vanderkloof	240 MW
Pumped storage scheme	17 Drakensberg	1 000 MW
	18 Palmiet	400 MW
Gas turbine	19 Acacia	171 MW
	20 Port Rex	171 MW
	21 Ankerlig	1 338 MW
	22 Gourikwa	746 MW

The peaking stations can generate electricity within a few minutes of start-up, making them ideally suited to supply power during peak periods. They also assist in regulating the system voltage and frequency to ensure stability of the national transmission network.

Renewable energy

Wind Facility

23 Klipheuwel Wind Facility 3 MW

New build

Coal	24 Medupi	4 788 MW
	26 Kusile	4 800 MW
Pumped storage scheme	25 Ingula	1 332 MW
Wind Facility	27 Sere Wind Facility	100 MW
Solar	28 Concentrating Solar Power (CSP)	100 MW

Distribution

Hydro-electric	29 First Falls	6 MW
	30 Second Falls	11 MW
	31 Colley Wobbles	42 MW
	32 Ncora	2 MW

These hydro-electric power stations fall within the Distribution Division in the Eastern Cape operating unit and are used to stabilise the distribution network in that area.

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http://www.eskom.co.za/Whatweredoing/ElectricityGeneration/PowerStations/Pages/Map_Of_Eskom_Power_Stations.aspx

Transformers

- Due to energy loss at higher current strengths, step-up transformers are used at the power station to increase the voltage to as high as 750 000 V. An increase in voltage results in a decrease in current strength. (There is an inverse relationship between voltage and current strength.) This, in turn, decreases the amount of electrical energy that is converted into thermal energy in the cables.
- In the cities and towns, the voltage is decreased by a step-down transformer and the current strength increased.
- Electricity is supplied to houses at a voltage of 220 – 240 V.

POWER SURGES AND GRID OVERLOAD

Eskom needs to control the electricity supply and avoid grid overload.

- A **power surge** occurs when the voltage suddenly spikes, e.g. when lightning strikes or when power is reconnected after load shedding.

  Other causes of power surges include short circuits or circuit breaks in wiring systems, or the switching on and off of electrical appliances that use a lot of electricity, e.g. hot water cylinders.

  Power surges can damage sensitive electronic devices, e.g. computers.

- A **grid overload** occurs when there is a big demand for electricity, but not enough available in the grid.

  In such cases, power cuts or outages occur, sometimes without warning. This is not only inconvenient, but can also be dangerous, e.g. when life-supporting equipment suddenly stops functioning.

High-voltage cables (transmission lines)

TOPIC 7 COST OF ELECTRICAL POWER

US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2
US 7513: SO 1 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating electric costs
- Demonstrate how to calculate the cost of electricity

UNIT 1 THE COST OF POWER CONSUMPTION

ELECTRICAL POWER

- **Electrical power** refers to the **rate** of **electrical energy** supply.
- The electric current (charge) that flows through a circuit transfers electrical energy (E) to the electrical appliances in a circuit in order to power them. The energy transferred is equal to the amount of work (W) done by the charges. The amount of energy that is transferred or the work that is done is measured in joules (J).
- The rate at which energy is transferred or at which work is done is known as **power**. 'Rate of' = 'per unit of time' or 'divided by unit of time', thus power = energy transferred per unit of time.

$$\text{Power (W)} = \frac{\text{energy transferred (J)}}{\text{unit of time (s)}}$$

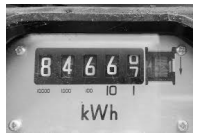
POWER RATINGS (ENERGY CONSUMPTION)

- The SI unit used to measure electrical power is **watt** (W). One watt is equal to one joule of energy transferred or work done per second ($1\ W = 1\ J{\cdot}s^{-1}$)
- 1 kilowatt (kW) = 1 000 watt (W)
- Different appliances need different amounts of electrical power to function, e.g. a hairdryer that is marked 2 000 W uses 2 000 J energy per second, whereas a light bulb of only 15 W uses only 15 J energy per second. The wattage needed to power an appliance is also called its **power rating**.

CONSUMER COST

Quantity of Electrical Power

- It costs Eskom a huge amount of money to generate electricity and supply it to houses and factories. Eskom recovers these costs from municipalities that, in turn, recover it from consumers in two ways:
  - Eskom reads the **electricity meters** at houses and factories on a specific day each month to determine how many units of electricity were used by the consumer during that month. This reading is indicated on the municipal bill for payment by the consumer.



Electricity meter outside houses

  - A **prepaid** electricity meter, equipped with an electricity card, is installed at houses. The consumer can buy a certain number of **units** of electricity online or directly from the municipality or from most supermarkets. The receipt gives token numbers that the consumer must punch into the meter to load the new credits.

Prepaid electricity meter

- These units are fixed quantities of electrical power.
- The **quantity of power** consumed by the consumer and the payable amount is calculated as follows:
  - the quantity of power used is measured in **kilowatt hours (kWh)**
  - number of kWh = power (kW) × number of hours (h)

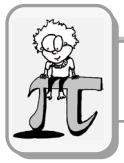
NOTE

1 kWh is used when a 1 kW (1 000 W) appliance is used for 1 hour

Cost of Electrical Power Consumption

The cost to the consumer is calculated as follows:

Cost = power rating of appliance × number of hours it was used (kWh) × unit price of electricity (tariff)



Cost = number of kWh × tariff per kWh

EXAMPLE

An electric hairdryer is labelled as: 240 V, 2 000 W. Assume the electricity tariff at the start of the year was R1,53 per kWh. How much would it cost you at the end of January if you used the hairdryer every morning for 15 minutes?

Solution:

Power rating = *2 000 W*
= *2 kW*

Time (number of hours) = *31 × 0,25*
= *7,75 hours*

Cost = *power rating × time × tariff*
= *2 kWh × 7,75 h × R1,53*
= *R23,72*

- *15 minutes* = $\frac{1}{4}$ *hour*
  = *0,25 hours*
- *January has 31 days*

SAVING ELECTRICITY

We all have a responsibility to save electricity, to minimise costs and limit the pollution caused by the generation of electricity and its impact on the environment. Examples of measures that may be taken include:

- switching off lights and electrical appliances when they are not in use
- using only energy-saving light bulbs
- using solar power and solar heating panels for the hot water cylinder

TOPIC 1 FORCES

Question 1

1.1 Define a *force*.

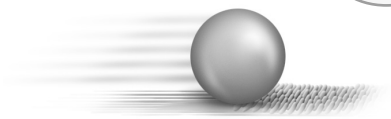
1.2 Provide the symbol for force.

1.3 Provide the unit in which force is measured.

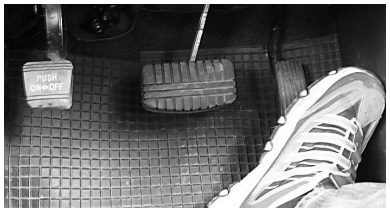
1.4 A boy plays with a rugby ball. If he exerts a force on the ball with his hand or foot, name **four** different effects such a force can have on the ball.

1.5 Name the effect that the specific force (in bold) has on each of the objects below:

1.5.1 a child sits with his entire **weight** on a big gym ball



1.5.2 a ball rolls on a thick carpet experiencing a **friction** force from the carpet



1.5.3 you keep your foot on your car's accelerator for the **engine** to exert constant **force** on the car

1.5.4 the boy swings a ball attached to a **rope** round and round

Question 2

Consider the following situations and determine what types of forces are exerted on the specific object (in brackets):

2.1 a boy stands with his schoolbag in his hand (schoolbag)

2.2 a book lies on the table (book)

2.3 a man pushes a crate over a rough floor (crate)

2.4 a stone falls through the air (stone)

Question 3

Complete the following sentence:

There are always ... 3.1 ... objects involved when a force is exerted. Forces therefore always act in ... 3.2 ....

3.3 Explain what is meant by a *force pair*. Refer to the object(s) experiencing the forces as well as the size and direction of the forces in a force pair.

3.4 Can the forces in a force pair balance (and thus cancel) each other? Give a reason for your answer.

3.5 Identify the force pairs in the next examples:

3.5.1 a boy sits on his bicycle's saddle

https://victoriafalls24.com/blog/2015/11/23/i-love-namibia/children-donkey-cart-namibia/

3.5.2 donkey(s) pulling a donkey cart

3.5.3 the moon orbits the earth

3.5.4 a man pushes a crate

Question 4

Explain what is meant by the following and provide an example of each:

4.1 balanced forces

4.2 unbalanced forces

Question 5

Bryan and Samuel stand on the floor and pull on either side of a rope.

5.1 Name the forces exerted on the rope (excluding the weight of the rope) and state when these forces will be:

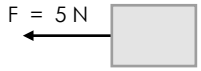
5.1.1 balanced 5.1.2 unbalanced

5.2 Name the forces being exerted on Bryan (excluding his weight and the normal force of the floor) and state when these forces will be:

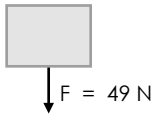
5.2.1 balanced 5.2.2 unbalanced

Question 6

6.1 One or more forces are exerted on a crate as indicated in the examples below. In each case determine the size and direction of the force X that is required to balance these force(s):

6.1.1 

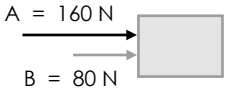
6.1.2 

6.1.3 

6.2 Two learners, A and B, push a piano that is in rest over a smooth tile surface, as shown in the examples below. (Friction force can thus be ignored.) For each example:

(i) Determine if the piano will move and if so, in which direction and

(ii) also determine the size and direction of the force a third learner, C, will have to exert to prevent the piano from moving.

6.2.1 

6.2.2 

Question 7

Indicate the forces exerted on the object(s) in brackets in the following situations:

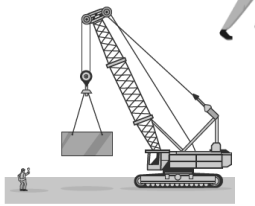
7.1 Two teams engage in a tug-of-war. The team members hold each other in position and the knot does not move. (front members of each team)

7.2 You pull your friend on roller skates by the hand. (friend)

7.3 Susan sits on a chair. (Susan)

7.4 Paul pushes a crate at a constant speed across the floor. (crate)

7.5 A concrete block is attached to a crane with a cable and hoisted up. (concrete block)



Question 8

8.1 What is meant by *gravitational force* or *gravity*?

8.2 Is gravitational force attractive or repulsive or both?

8.3 Forces are placed into two main groups, i.e. contact forces and field forces (non-contact forces). In which category does gravitational force fall?

8.4 What unit is used to indicate gravitational force?

8.5 Which **two** factors determine the gravitational force between objects?

8.6 Why will the gravitational force between two apples on a table not cause them to move closer to each other?

Question 9

9.1 What does the mass of an object indicate?

9.2 Which SI unit is used to indicate the mass of an object or person?

9.3 Convert the following masses to kilogram:

9.3.1 350 g 9.3.2 5 g

9.3.3 60 g 9.3.4 2 500 g

9.4 What is meant by the *weight* of an object?

9.5 What is the SI unit for weight?

9.6 How can the weight of an object on earth or another planet be calculated?

9.7 Is the weight of an object the same everywhere in the universe? Explain.

9.8 Is the mass of an object the same everywhere in the universe? Explain.

9.9 Use the words **smaller/greater/same** to describe how:

9.9.1 your weight on the moon and on the earth differ.

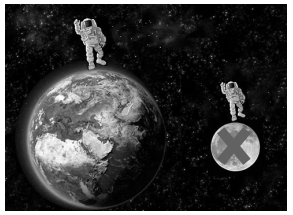
9.9.2 your mass on the moon and on the earth differ.

Question 10

Peter stands on a scale and measures his mass. He also uses a kitchen scale to measure the mass of an apple, bread and a bag of flour. Complete the following table and determine the weight of each object.

	Object	Mass (g or kg)	Weight (N)
10.1	Peter	65 kg	
10.2	apple	20 g	
10.3	bread	800 g	
10.4	flour	2,3 kg	

Question 11



Yolo and Bonga's weight on earth is 490 N and 588 N respectively.

11.1 Calculate both their masses on earth.

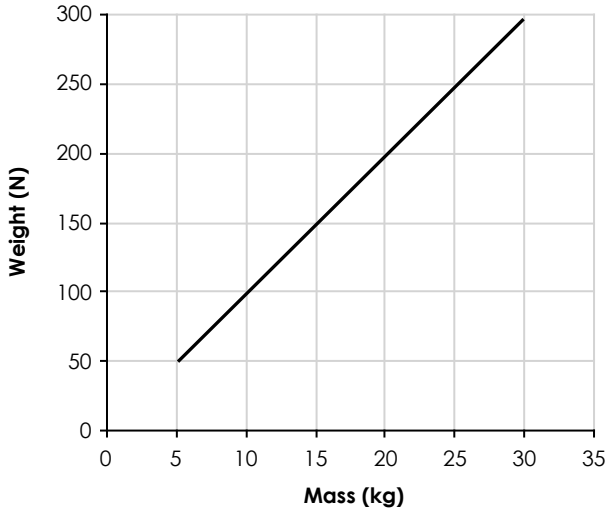
11.2 Calculate the weight of both on a planet X where the gravitational acceleration equals 5 $m \cdot s^{-2}$.

11.3 Calculate both their masses on planet X.

11.4 On planet Y, Yolo's weight is 225 N. What is the gravitational acceleration on planet Y?

Question 12

Consider the graph below which Hanu compiled by hanging various mass pieces, ranging from 5 kg to 30 kg, on a newton scale and measuring the weight of each.



12.1 What is the weight of a 15 kg object?

12.2 What is the mass of an object with a weight of 250 N?

12.3 What mathematical relationship can you observe between the weight (N) and the mass (kg) of an object? What value of the graph shows this relationship?

12.4 What is the weight of:

12.4.1 a 7 kg object

12.4.2 a 60 kg object

12.5 What are the

12.5.1 independent variable

12.5.2 dependent variable

12.5.3 and fixed variable(s)

in the above experiment?

Question 13

13.1 What is meant by *magnetic force*?

13.2 Is magnetic force attractive or repulsive or both?

13.3 Forces are classified into two main groups, namely contact forces and field forces (non-contact forces). In which category does magnetic force fall?

13.4 What is meant by *magnetic substances*?

13.5 Name the **three** metals that are magnetic substances.

13.6 Consider the following materials and classify them as magnetic or non-magnetic:

13.6.1 copper

13.6.2 steel

13.6.3 aluminium

13.6.4 lead

13.6.5 carbon

13.6.6 cobalt

Question 14

14.1 Explain what is meant by

14.1.1 a magnetic field

14.1.2 magnetic field lines

14.2 Explain the terms

14.2.1 magnetic poles

14.2.2 magnetic north

14.2.3 compass

Question 15

15.1 Draw the magnetic field pattern around a bar magnet. Clearly indicate the magnetic poles and the direction of the magnetic field around the magnet.

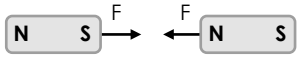
15.2 Draw the magnetic field pattern between the poles of two bar magnets placed next to each other (as shown in the diagrams below).

15.2.1 

15.2.2 

15.2.3 

15.3 (15.3.1 - 15.3.3) Redraw the above diagrams and use arrows to indicate the force (F) experienced by each magnet. See the example below:

Example: 

15.4 Complete by choosing the right words:

15.4.1 Figure 15.3.1 above shows that like/opposite poles attract/repel each other.

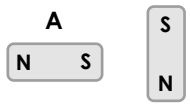
15.4.2 Figure 15.3.2 above shows that like/opposite poles attract/repel each other.

15.4.3 Figure 15.3.3 above shows that like/opposite poles attract/repel each other.

15.5 Use arrows to indicate the force experienced by object A in each of the following cases:

15.5.1 

15.5.2 

15.5.3 

Question 16

16.1 The board eraser with a built-in magnet sticks to the one white board in the classroom but falls off a second board that is seemingly identical. What difference should there be in the composition of the two boards?

16.2 Fridge magnets stick firmly to a fridge but are not attracted by a wardrobe door.

16.2.1 Refer to the type of material that the fridge and the wardrobe door may be composed of to explain this fact.

16.2.2 If a small piece of wood is slid in between the fridge and the magnet, will the magnet still be attracted by the fridge or not? Give a reason for your answer.

Question 17

You are provided with three metals X, Y and Z, as well as a few nails and a permanent magnet.

17.1 Briefly describe how to determine whether any of the three metals is made of a magnetic material.

17.2 Briefly describe how to determine whether any of the three metals is a magnet itself.

17.3 X is made of a magnetic material, Y from a non-magnetic material and Z is a magnet itself. Complete the following table.

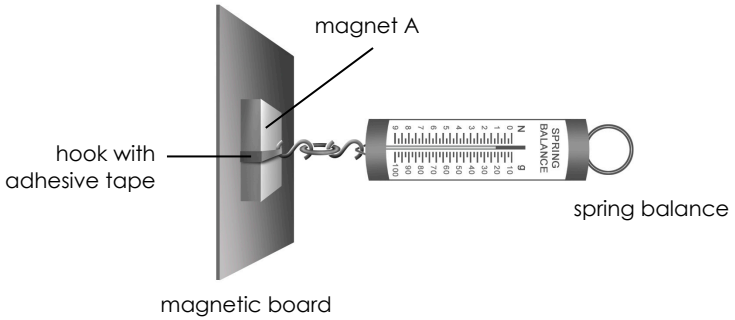
	Metals	Attract nails (yes/no)	Attracted by a magnet (yes/no)	Repelled by a magnet (yes/no)
17.3.1	X	(i)	(ii)	(iii)
17.3.2	Y	(i)	(ii)	(iii)
17.3.3	Z	(i)	(ii)	(iii)

17.4 Name **one** element X may contain.

Question 18

18.1 The strength of 4 different magnets, A, B, C and D is being investigated by determining the magnitude of the force required to remove each magnet from a magnetic board. The following steps are performed:

- Firmly stick a metal hook to the first magnet, A, with adhesive tape.
- Hook a spring balance on it and pull the spring balance until the magnet just comes loose from the board.
- Take the reading (in newton) on the spring balance and record it in a table.
- Repeat the steps for magnets B, C and D.



18.1.1 Consider the completed table at the end of Question 18 on p. 186 and answer the questions that follow:

(i) Which magnet is the strongest?

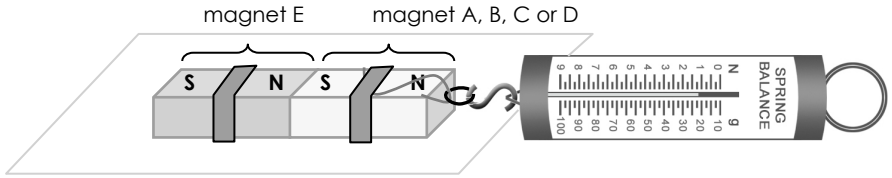
(ii) Which magnet is the weakest?

(iii) Which magnets have equal strength?

18.2 A similar experiment is conducted to determine the magnetic force between each of the above-mentioned magnets and another bar magnet (E). Once again make use of a spring balance to determine the magnitude of the force required to pull the magnets away from each other. Perform the following steps:

- Firmly attach the bar magnet (E) with adhesive tape to the table.
- Firmly stick a metal hook to the first magnet (A), pointing in the direction of the magnet's north pole.
- Hold the south pole of this magnet (A) against the north pole of the bar magnet (E), causing them to attract each other.

- Hook a spring balance onto the metal hook and pull it until magnet (A) is just removed from the bar magnet (E).
- Take the reading (in newton) on the spring balance and record it in a table.
- Repeat the steps for each magnet.



18.2.1 Consider the completed table at the end of Question 18 and answer the questions that follow:

(i) Which magnet has the strongest attraction to E?

(ii) Which magnet has the weakest attraction to E?

(iii) Which magnet(s) are equally attracted to E?

18.3 A sensitive mass scale is used to determine each magnet's mass (see the completed table at the end of Question 18).

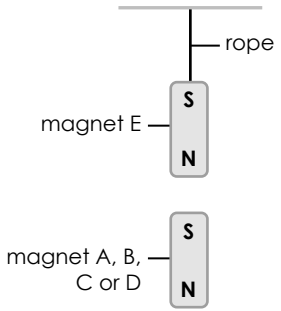
18.3.1 Calculate the weight of each magnet (A, B, C and D) and complete the missing values ((i) to (iv)).

Hold the bar magnet (E) vertically in the air or hang it on a piece of rope. Hold each of the magnets A, B, C and D in turn below E with opposite poles to each other. Let go of the bottom magnet.

18.3.2 Name **two** forces exerted on the bar magnet (E) when hanging vertically from a rope.

18.3.3 Name the **two** forces that are exerted on each of the magnets A, B, C and D.

18.3.4 Compare the sizes of the two forces mentioned in Question 18.3.3, for each of the magnets A, B, C and D (see completed table) and predict whether they will be attracted to E and keep hanging in the air or whether they will fall down.



Magnet	Force of board on magnet (18.1)	Force between magnet and bar magnet (E) (18.2)	Mass of magnet (kg)	Weight of magnet (18.3)
A	2 N	3 N	0,31	(i)
B	1,5 N	2,2 N	0,31	(ii)
C	3 N	4,5 N	0,41	(iii)
D	2 N	3 N	0,41	(iv)

Question 19

19.1 What is meant by *static electricity*?

19.2.1 How can an object obtain static electricity?

19.2.2 What types of materials can be charged with static electricity?

19.3.1 Name the **three** subatomic particles of an atom and state the relative charge of each.

19.3.2 Which charged particles are transferred to or from the surface of a balloon or a plastic bar when rubbed with a cloth?

19.4.1 How can an object acquire a positive charge?

19.4.2 How can an object acquire a negative charge?

19.5 Complete: Charges with the same sign are known as ... 19.5.1 ... charges and charges with opposite signs as ... 19.5.2 ... charges.

19.6 Indicate whether there is an electrostatic attracting or repelling force between:

19.6.1 like charged objects

19.6.2 opposite (unlike) charged objects

19.6.3 a charged and uncharged object

Question 20

A glass bar is rubbed with a silk cloth and electrons are transferred from the bar to the cloth.

20.1 Choose the correct option: The bar has an/a 20.1.1 excess/ shortage of electrons and thus has a net 20.1.2 positive/negative charge.

20.2 Choose the correct option: The cloth has an/a 20.2.1 excess/ shortage of electrons and thus has a net 20.2.2 positive/ negative charge.

20.3 What effect does the cloth and the bar have on each other?

20.4 Draw a sketch of the cloth and the bar before and after friction was applied and indicate the net charge on each in both instances.

Question 21

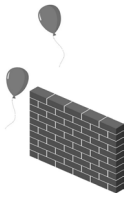
Liam rubs two balloons with a cloth giving them a negative charge.

21.1 Complete:

Electrons were transferred through friction from the... 21.1.1 ... to the ... 21.1.2 ....

21.2 The charged balloons are hung next to each other by two thin strings. Draw a picture of the balloons and indicate the direction of the force they exert on each other.

21.3 Liam takes one of the balloons, holds it next to a wall and lets it go.



21.3.1 What happens to the balloon?

21.3.2 Give a reason for your answer.

21.4 Liam takes one of the balloons and holds it next to a fridge.

21.4.1 What happens to the balloon?

21.4.2 Give a reason for your answer.

Question 22

You drive in your car on a dry day and you get charged with static electricity as a result of friction between your clothes and the car seat. You stop and touch the metal door handle to open it.

22.1 What do you observe (see, hear and feel) when you open the door?

22.2 Explain your observation.

22.3 What is the similarity between your observation and a lightning bolt in the sky during a thunderstorm?

Question 23

23.1 Briefly describe how lightning is formed.

23.2 Name **four** safety precautions one can take during a thunderstorm.

Question 24

Sandy combs her hair with a plastic comb on a dry sunny day. Both the comb and her hair are electrostatically charged through friction.

24.1 Complete: The comb acquires electrons and thus has a ..... charge.

24.2 What charge does her hair obtain?

24.3 She then holds the comb above a few pieces of tissue paper. The paper pieces lift up and cling to the comb. Give a reason for this observation.

24.4 Give a reason why the comb will not readily pick up the paper pieces in humid air, for example on a rainy day?

24.5 Now she combs her hair with a metal comb. Give a reason why the metal comb will not pick up the paper pieces.

TOPIC 2

ELECTRIC CELLS AS ENERGY SYSTEMS

Question 25

25.1 What are electric cells or batteries used for?

25.2 What is the difference between an *electric cell* and a *battery*?

25.3 Name any **two** components of an electric cell necessary for proper functioning.

25.4 What energy conversion takes place in an electric cell?

25.5 What is an *electrolyte*?

25.6 Electrons gather at one electrode; therefore this is the ... 25.6.1 ... electrode. At the other electrode, electrons are extracted, so this is the... 25.6.2 ... electrode.

25.7 What is the role of the electrodes in an electric cell?

25.8 When is an electric cell flat?

Question 26

Jacques makes an electric cell by placing a copper plate in a glass beaker with a copper sulphate solution and a zinc plate in a beaker with a zinc sulphate solution. He connects the two plates with electric conducting wire and a voltmeter. He completes the circuit by placing the two ends of the salt bridge in the two respective beakers.

26.1 Make a complete drawing with captions of the electric cell.

26.2 What are the Zn and Cu plates called?

26.3 Which substances in the cell act as an electrolyte?

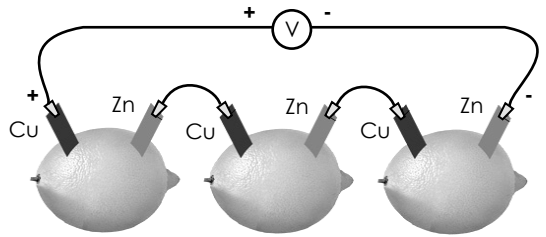
26.4 Initially the voltmeter reading is 1,1 V, but it decreases gradually to below 1 V, then below 0,5 V until the reading is 0 V. What is happening to the cell? Why is this happening?

Question 27

Emma makes an electric cell with the following equipment:

- 3 lemons
- 3 metal plates from each of the metals copper, iron, zinc, aluminium and magnesium
- electric conducting wire
- crocodile clips
- voltmeter

She starts by pressing a copper and zinc plate 4 cm from each other into each lemon and connects the plates with conducting wire and crocodile clips to each other and to a voltmeter in an external circuit (see the drawing below). She then replaces one type of plate with another until she has tried all possible combinations. With each new combination she takes the voltmeter reading. Her goal is to determine which cell has the greater potential difference.



Her results are as follows:

Potential difference (V) across each pair of metals

		Negative electrode				
		Mg	**Al**	**Zn**	**Fe**	**Cu**
Positive electrode	Cu	2,2	1,63	0,9	0,6	0
	Fe	1,6	1	0,3	0	—
	Zn	1,3	0,7	0	—	—
	Al	0,6	0	—	—	—
	Mg	0	—	—	—	—

27.1 What acts as an electrolyte in this cell?

27.2.1 What combination of metals has the highest voltmeter reading?

27.2.2 In this case (Question 27.2.1), which metal is the positive electrode, and which is the negative electrode?

27.2.3 What happens to the voltmeter reading if the electrodes are swopped?

27.3 Compare the Mg-Aℓ cell with the Aℓ-Zn cell with reference to the polarity of the electrodes and the size of the voltmeter reading.

TOPIC 3 RESISTANCE

Question 28

Describe the following terms:

28.1 electrical conductor

28.2 electrical insulator

28.3 electrical resistance

28.4 resistor

Question 29

29.1 What types of materials are normally good conductors of electricity? How is electricity conducted in these materials?

29.2 What types of materials are normally insulators or non-conductors of electricity? What is the reason for this?

29.3 What is the purpose of resistors in circuits?

29.4 What is the use of conductors with a high resistance?

29.5 What is the disadvantage of resistance in conductors?

Question 30

30.1 Name the **four** factors that influence the resistance of a conductor.

30.2 Consider the following table, where two pieces of wire, A and B with certain specifications, are alternately connected to a circuit.

For each of the investigations (30.2.1 - 30.2.4):

(i) Name the factor under investigation that has an influence on the conductor's resistance.

(ii) Compare wire A and B with regards to:

(1) the resistance

(2) the electrical current passing through them (ammeter reading)

(3) the conductivity

(iii) Make a general conclusion about the factor's influence on the resistance of a conductor.

		Type of wire	Length	Thickness	Temperature
30.2.1	A	copper	20 cm	0,2 mm	25°C
	B	nichrome	20 cm	0,2 mm	25°C
30.2.2	A	copper	20 cm	0,2 mm	25°C
	B	copper	40 cm	0,2 mm	25°C
30.2.3	A	copper	20 cm	0,2 mm	25°C
	B	copper	20 cm	0,3 mm	25°C
30.2.4	A	copper	20 cm	0,2 mm	25°C
	B	copper	20 cm	0,2 mm	40°C

TOPIC 4

SERIES AND PARALLEL CIRCUITS

Question 31

What is the function of the following components in a circuit:

31.1 battery

31.2 ammeter

31.3 voltmeter

31.4 resistor

Question 32

32.1 Answer the following questions about electric current:

32.1.1 What is meant by *electric current*?

32.1.2 Complete: Electron current involves the flow of _____ from the _____ terminal to the _____ terminal of the battery in an external circuit.

32.1.3 Complete: Generally, the 'direction of the current', refers to the direction of the conventional current, i.e. the flow of _____ charges from the _____ terminal to the _____ terminal of the battery in the external circuit.

32.1.4 What instrument is used to measure current strength?

32.1.5 How should the instrument in Question 32.1.4 be connected in a circuit? Briefly explain your answer.

32.1.6 What is the symbol for current strength?

32.1.7 What SI unit is used to measure and indicate current strength?

32.2 Answer the following questions regarding potential difference:

32.2.1 What is meant by *potential difference* or *voltage*?

32.2.2 What instrument is used to measure potential difference/voltage?

32.2.3 How should the instrument in Question 32.2.2 be connected in a circuit? Briefly explain your answer.

32.2.4 What is the symbol for potential difference/voltage?

32.2.5 What SI unit is used to measure and indicate potential difference/voltage?

32.3 Answer the following questions about resistance:

32.3.1 What is meant by *electrical resistance*?

32.3.2 How do you conclude that a conductor has resistance when connected to a circuit?

32.3.3 What is the purpose of the resistance in a conductor?

32.3.4 What is the symbol for resistance?

32.3.5 What SI unit is used to measure and indicate resistance?

Question 33

33.1 A battery consists of 3 cells of 1,5 V each, connected in series.

33.1.1 Describe how the cells are connected to each other.

33.1.2 Make a representation of 3 cells connected in series, as shown in a circuit diagram.

33.1.3 What is the total potential difference of the three cells?

33.1.4 What is the (a) advantage and (b) disadvantage of connecting cells in series?

33.2 A battery consists of 3 cells of 1,5 V each, connected in parallel.

33.2.1 Describe how the cells are connected to each other.

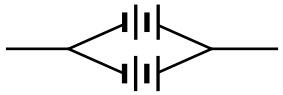
33.2.2 Make a representation of 3 cells connected in parallel, as shown in a circuit diagram.

33.2.3 What is the total potential difference of the three cells?

33.2.4 What is the (a) advantage and (b) disadvantage of connecting cells in parallel?

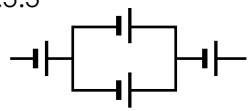
33.3 Consider the representations of different series-parallel connections of 1 V cells. Calculate the total potential difference in each instance.

33.3.1



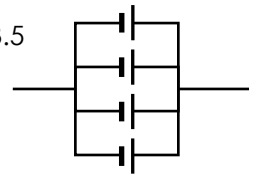
33.3.2

33.3.3



33.3.4

33.3.5



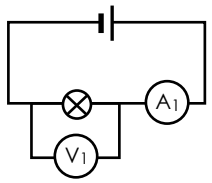
Question 34

34.1 Consider the following circuits and rank

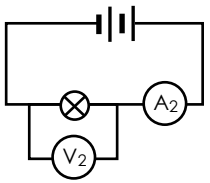
34.1.1 the ammeter readings and

34.1.2 voltmeter readings from high to low.

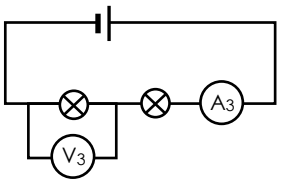
(a)



(b)

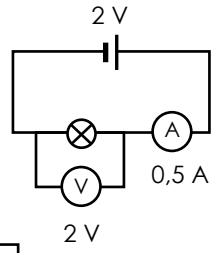


(c)

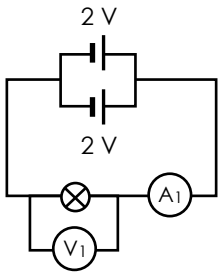


34.2 Consider the following circuit diagrams. Use the A reading and V reading as shown in diagram (a) and complete table 34.2.1 below by filling in the missing values for diagrams (b) and (c).

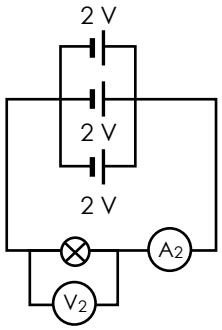
(a)



(b)



(c)



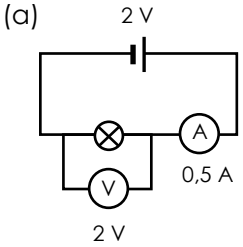
34.2.1

Circuit	Voltmeter reading (V)	Ammeter reading (A)
(a)	V = 2 V	A = 0,5 A
(b)	V_1 =	A_1 =
(c)	V_2 =	A_2 =

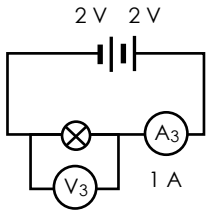
34.2.2 Draw a conclusion from the V readings and A readings in the table with reference to the number of cells and how they are connected.

34.3 Consider the following circuit diagrams. Use the A reading and V reading as shown in diagram (a) and complete table 34.3.1 below by filling in the missing values for diagrams (b) and (c).

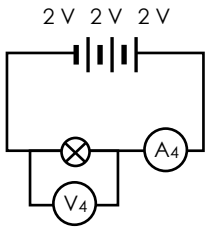
(a)



(b)



(c)



34.3.1

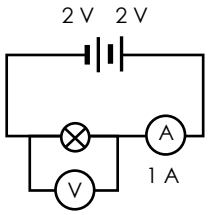
Circuit	Voltmeter reading (V)	Ammeter reading (A)
(a)	V = 2 V	A = 0,5 A
(b)	V_3 =	A_3 = 1 A
(c)	V_4 =	A_4 =

34.3.2 Draw a conclusion from the V readings and A readings in the table with reference to the number of cells and how they are connected.

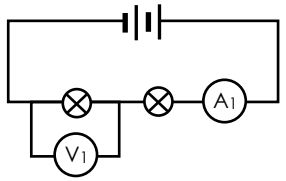
Question 35

35.1 Consider the following circuit diagrams. Use the A reading and V reading as shown in diagram (a) and complete table 35.1.1 on the next page by filling in the missing values for diagrams (b) and (c). (All the light bulbs have the same resistance.)

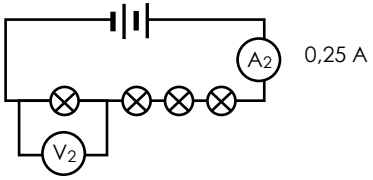
(a)



(b)



(c)



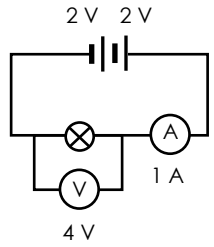
35.1.1

Circuit	Voltmeter reading (V)	Ammeter reading (A)
(a)	V = 4 V	A = 1 A
(b)	V_1 =	A_1 =
(c)	V_2 =	A_2 = 0,25 A

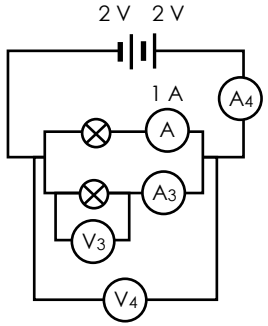
35.1.2 Draw a conclusion from the V readings and A readings in the table with reference to the number of resistors and how they are connected.

35.2 Consider the following circuit diagrams. Use the A reading and V reading as shown in diagram (a) and complete table 35.2.1 by filling in the missing values for diagrams (b) and (c). (All the light bulbs have the same resistance.)

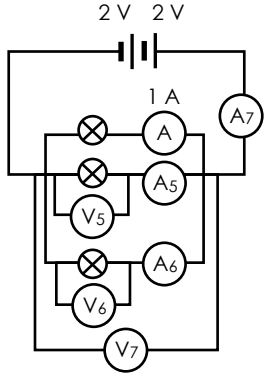
(a)



(b)



(c)



35.2.1

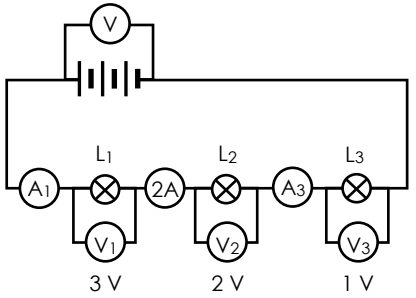
Circuit	Voltmeter reading (V)	Ammeter reading (A)
(a)	V = 4 V	A = 1 A
(b)	V_3 = V_4 =	A_3 = A_4 =
(c)	V_5 = V_6 = V_7 =	A_5 = A_6 = A_7 =

35.2.2 Draw a conclusion from the V readings and A readings in the table with reference to the number of resistors and how they are connected.

Question 36

Consider the following circuit diagrams. Provide the missing ammeter and voltmeter readings in each case and answer the questions that follow. (The light bulbs do not necessarily have the same resistance.)

36.1

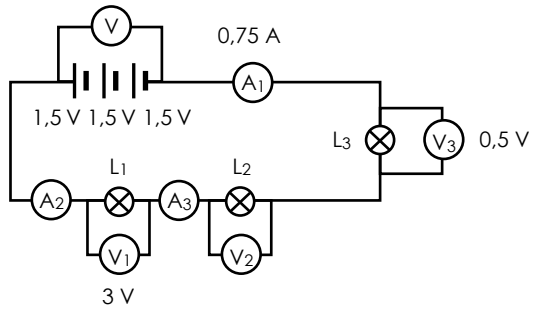


36.1.1 A_1 = A_3 = V =

36.1.2 Which of L_1, L_2 or L_3 has the highest resistance?

36.1.3 What is the change in (i) the total resistance and (ii) the total current if another bulb L_4 is connected in series to the other three? In each case only state: **greater, smaller** or **stays the same**.

36.2

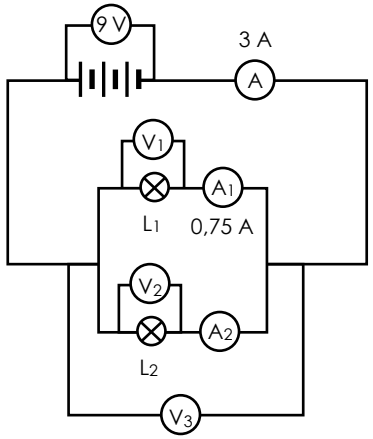


36.2.1 A_2 = A_3 = V = V_2 =

36.2.2 Which of L_1 or L_2 burns the brightest?

36.2.3 What happens to L_1 and L_2 if L_3 fuses?

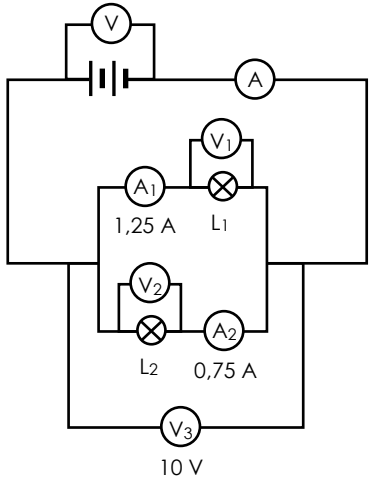
36.3



36.3.1 A_2 = V_1 = V_2 = V_3 =

36.3.2 Which of L_1 or L_2 has the highest resistance?

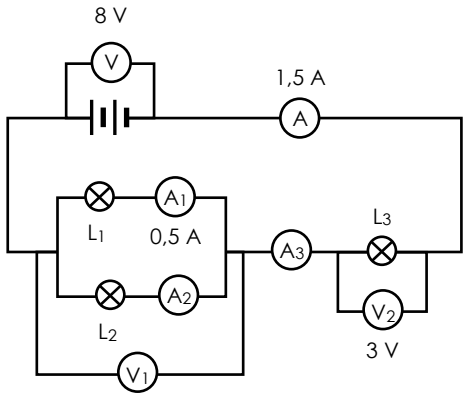
36.4



36.4.1 A = V_1 = V_2 = V =

36.4.2 What happens to light bulb L_1 if L_2 fuses?

36.5



36.5.1 A_2 = A_3 = V_1 =

36.5.2 Which of the light bulbs L_1 or L_2 burns the brightest?

36.5.3 What is the change in L_1's brightness if (i) L_2 fuses and (ii) another light bulb L_3 is connected in parallel with L_1 and L_2? (Use **brighter / the same brightness / dimmer**)

TOPIC 5 SAFETY WITH ELECTRICITY

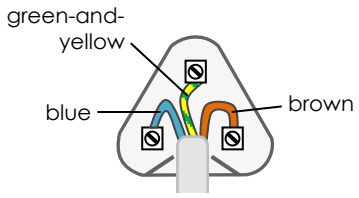
Question 37

37.1 How are light bulbs connected in the lighting circuit in houses?

37.2 Name **two** advantages of this type of connection.

37.3 Explain the danger of connecting too many electrical appliances to a multiplug at a single power point.

37.4 What safety mechanism is generally used in houses' main circuit to safeguard people using electricity? It functions by interrupting the current in case of an overload or a short circuit.

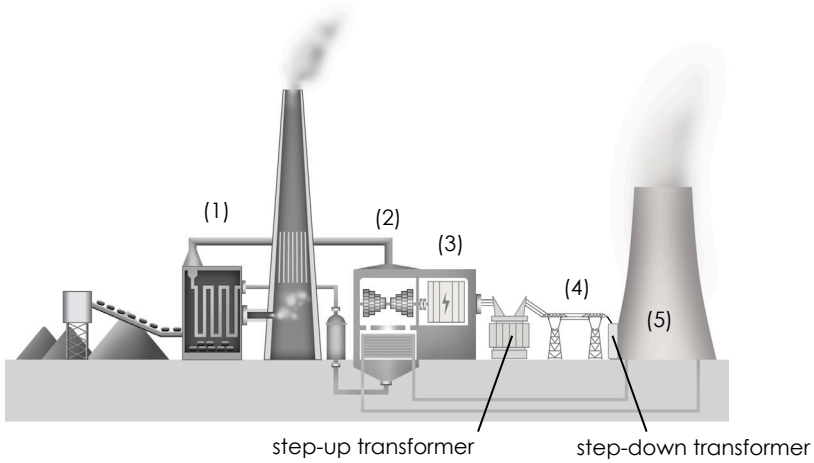


37.5 Many appliances have a three-pin plug as a safety precaution for the connection to the main circuit. Name the three wires connected to a three-pin plug. Explain the function of (i) an earth wire and (ii) an earth cable.

TOPIC 6 ENERGY AND THE NATIONAL ELECTRICITY GRID

Question 38

38.1 Briefly explain the functioning of a coal power station by referring to the diagram below.



38.2 Name the parts numbered (1) to (5) in the accompanying diagram.

38.3 Name **three** disadvantages of using coal or other fossil fuels for electricity generation.

38.4 Name **five** alternative sources of energy that can be used for electricity generation instead of coal.

38.5 What is the purpose of

38.5.1 step-up transformers and

38.5.2 step-down transformers

in the national electricity grid?

Question 39

39.1 Is wind power a renewable or non-renewable energy source?

39.2 Massive areas of land are demarcated for electricity generation via wind power.

39.2.1 What is a requirement for the selected areas?

39.2.2 What are these areas called?

39.2.3 How can one identify these areas?

39.3 Briefly describe the functioning and benefits of wind power.

39.4 Name **three** disadvantages of using wind power for electricity generation.

Question 40

40.1 Complete the following sentences: The heat of the sun is focussed with the aid of thousands of ___40.1.1___ on high sun-___40.1.2___ to heat water to produce ___40.1.3___. This (40.1.3) can be used to spin a ___40.1.4___ that, in turn, spins a ___40.1.5___ in order to generate electricity.

40.2 Another application of solar power is through using solar ___40.2.1___ and ___40.2.2___ that release electrons when hit by small 'packages' of energy (photons) in sunlight. This generates an electric current.

40.3 Name **two** advantages of solar power.

40.4 Why is it not possible to convert the entire country's power to solar power?

Question 41

41.1 Where in South Africa is the only nuclear power station situated?

41.2 Nuclear power stations use radioactive elements as fuel for electricity generation. Name **one** element that is mostly used for this purpose.

41.3 The radioactivity of this element leads to nuclear fission, releasing large amounts of energy. The energy in the form of heat is transferred to a cooling medium.

41.3.1 Name the cooling medium used by the nuclear power station mentioned in Question 41.1.

41.3.2 In broad terms, describe the **three** remaining steps for electricity generation at a nuclear power station.

41.3.3 How is electrical energy supplied to houses and factories in towns and cities with the least possible energy loss?

COST OF ELECTRICAL POWER

Question 42

42.1 What is another term for electrical energy supplied/used per unit time?

42.2 How would you describe and define this term?

42.3 What unit is used to indicate electrical power?

42.4 Complete: 1 Watt $= \frac{1\_\_}{1\_\_} = 1\ \_\_\_$

42.5 Convert kilowatt into watt: 1 kW = ___ W

42.6 What is meant by a:

42.6.1 100 W light bulb

42.6.2 1 100 W hairdryer

42.7 What unit is used to measure and indicate electrical power consumption?

42.8 How is a consumer's electrical power consumption calculated?

42.9 How is the cost of electrical power consumption calculated? (Give a word equation.)

42.10 Calculate the cost of power consumption in the following cases:

42.10.1 An electric heater of 2 000 W is used for 6 hours. The unit price of electricity (tariff) is 80 cent per kWh.

42.10.2 Sanet uses her hairdryer, labelled 1 100 W, 220V, for 10 minutes. The municipal tariff is R1,20 per kWh.

42.10.3 The 1 800 W geyser switches on at 15:00 and off again at 19:00 every afternoon. The municipal tariff for 2019 was R2,20 per kWh. Calculate the cost of using the geyser during February 2019.

NOTES

MODULE 4 PLANET EARTH and BEYOND

EARTH AND BEYOND

US 7507

Demonstrate an understanding of the concept of science

	SO1	SO2	SO3	SO4	SO5
TOPIC 2					X
TOPIC 5		X			

US 7509

Apply basic concepts and principles in Natural Sciences

	SO1	SO2	SO3	SO4
TOPIC 1	X			X
TOPIC 2	X	X		X
TOPIC 3	X			
TOPIC 4	X			X
TOPIC 5	X	X	X	X

US 7511

Analyse how scientific skills and knowledge contribute to sustainable use of resources

	SO1	SO2	SO3	SO4
TOPIC 2		X	X	
TOPIC 3	X	X	X	
TOPIC 4	X		X	

US 7513

Assess the impact of scientific innovation on quality of life

	SO1	SO2	SO3	SO4
TOPIC 3	X	X		

TOPIC 1: THE EARTH AS A SYSTEM

US 7509: SO 1 – AC 1-3; SO 4 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to the earth as a system
- Apply knowledge and skills to explain the interaction between earth spheres

Resources

- Class text & Study guide

TOPIC 2: LITHOSPHERE

US 7507: SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 1-2
US 7511: SO 2 – AC 1; SO 3 – AC 1

Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of the rock cycle for human use
- Define concepts and principles relating to the lithosphere
- Demonstrate the rock cycle
- Apply knowledge and skills to familiar and unfamiliar phenomena
- Explain how different types of rock are utilised by humans

Resources

- Class text & Study guide
- Different types of rock samples (igneous, sedimentary and metamorphic rock)

TOPIC 3: MINING OF MINERAL RESOURCES

US 7509: SO 1 – AC 1-3
US 7511: SO 1 – AC 2; SO 2 – AC 1; SO 3 – AC 2
US 7513: SO 1 – AC 1-3; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to mining of mineral resources
- Explain the interaction between humans and natural resources
- Explain the negative environmental impact of the mismanagement of natural resources
- Discuss how mining has affected economic development

Resources

- Class text & Study guide

TOPIC 4: ATMOSPHERE

US 7509: SO 1 – AC 1-3; SO 4 – AC 1
US 7511: SO 1 – AC 2; SO 3 – AC 2,3

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to the atmosphere
- Apply knowledge of the atmosphere to explain the greenhouse effect
- Describe how the mismanagement of resources can lead to global warming

Resources

- Class text & Study guide

TOPIC 5: DIGESTIVE SYSTEM

US 7507: SO 2 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1; SO 3 – AC 1-3; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to stars
- Describe the nature of scientific knowledge in star life cycles
- Demonstrate the life cycle of a star
- Interpret scientific evidence and apply knowledge and skills in star life cycles

Resources

- Class text & Study guide

TOPIC 1 THE EARTH AS A SYSTEM

US 7509: SO 1 – AC 1-3; SO 4 – AC 1

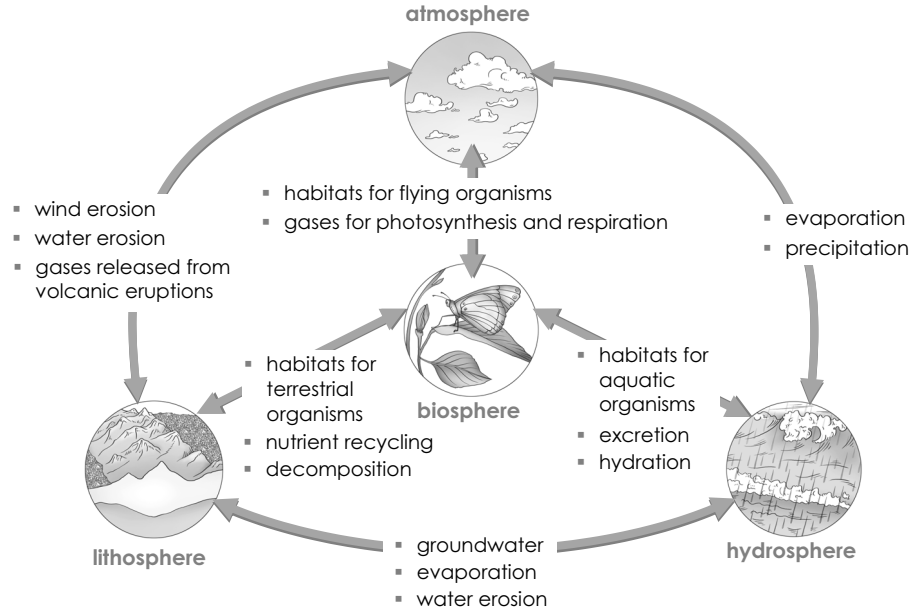
Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to the earth as a system
- Apply knowledge and skills to explain the interaction between earth spheres

A system consists of different parts that work and interact together.

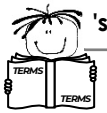
- Some examples of systems include:
  - body systems (composed of multiple organs working together)
  - the solar system (composed of planets, moons, rocks and stars)
  - ecosystems (composed of interacting living and non-living components)
- The earth can also be considered as a complex **system**.
- The parts that make up the earth are known as **spheres**.
- Four spheres interact on or near the surface of the earth to sustain life:
  - **lithosphere** – solid rock and soil
  - **hydrosphere** – water
  - **atmosphere** – gases
  - **biosphere** – living organisms
- A change or disturbance in one sphere will affect the other spheres.



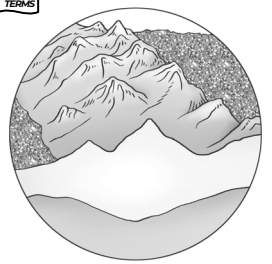
UNIT 1 SPHERES OF THE EARTH

LITHOSPHERE

'litho' = stone/rock
'sphere' = ball



- The lithosphere is the solid, rocky layer covering the earth.
- It includes rocks, soil and minerals.
- Soil is essential for living organisms:
  - anchor for plants
  - habitats for animals
  - source of nutrients for crops
  - rich source of minerals for humans, e.g. mining for coal, iron, gold, etc.



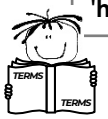
NOTE

The lithosphere will be discussed in more detail in Topic 2.

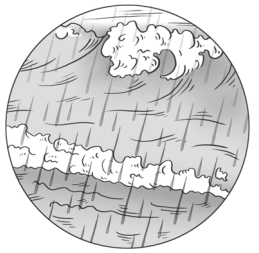
The rocky lithosphere is a layer of about 55 km thick. It reaches a peak on Mount Everest 8,9 km above sea level and a depth of 10,9 km below sea level in the Mariana Trench in the Pacific Ocean.

HYDROSPHERE

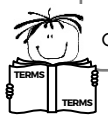
'hydro' = water



- The hydrosphere is composed of water in all its forms on the earth including liquid, gas or solid form.
- It includes water in the oceans, rivers, lakes, as well as moisture in the air and solid ice.
- 97% of the earth's water is salt water in the oceans.
- 3% is fresh water – with 2% frozen in the polar caps.
- Water helps to maintain constant temperatures on the earth.



ATMOSPHERE



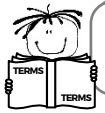
'atmo' = air/vapour

- The atmosphere is the layer of various gases which surrounds our planet.
- The majority of the atmosphere is located close to the earth's surface where it is most dense.
- The air of our planet is 79% nitrogen and just under 21% oxygen; the small amount remaining is composed of carbon dioxide (±0,04%) and other gases.
- The atmosphere is vital for living organisms of the biosphere:
  - provides oxygen for respiration
  - maintains constant temperatures
  - traps heat from the sun to sustain life
  - ozone layer prevents damage from UV rays

NOTE

The atmosphere will be discussed in more detail in Topic 4.

BIOSPHERE

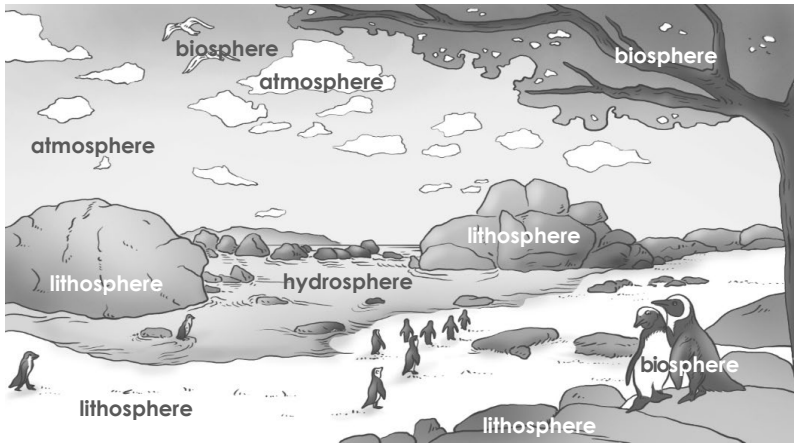


'bio' = life/living

- The biosphere is composed of all living organisms.
- This includes plants, animals and microorganisms and their interactions with the other spheres, i.e. land, air and water.
- Most terrestrial life is found from 3 metres below ground-level to about 30 metres above it.
- Most aquatic life exists in the top 200 metres of the oceans and seas.

UNIT 2

INTERACTIONS BETWEEN THE SPHERES

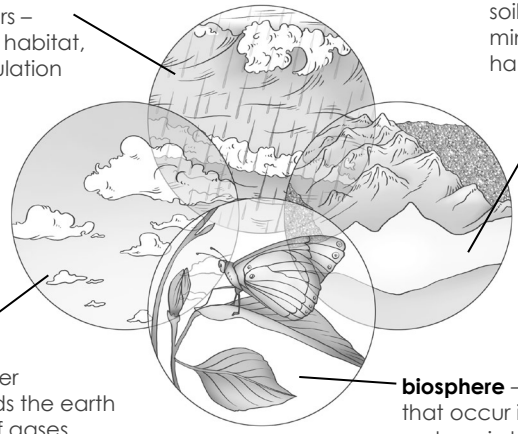


Interaction of spheres in a coastal ecosystem

- All four spheres are often present in the same place at the same time.
- Many physical and biological processes are examples of how the different spheres interact with one another.

hydrosphere – water in liquid/gas/solid form found in oceans, rivers, lakes, mist, glaciers – provides support, habitat, temperature regulation

lithosphere – solid outer layer on the earth's surface including rocks, soil, minerals – provides minerals, nutrients, habitat, support



atmosphere – thin layer of gases that surrounds the earth – provides balance of gases, traps heat, protects from UV rays

biosphere – living organisms that occur in all spheres: water, air, land – provides food, recycles minerals

Examples of Interactions between Spheres

- A volcanic eruption where dust and gases are thrown into the air is an interaction between the lithosphere (volcano/dust) and the atmosphere (air).
- Evaporating water or cloud formation and rain in the water cycle is an interaction between the atmosphere and the hydrosphere.
- Ocean waves that weather a cliff face is an interaction between the hydrosphere and the lithosphere.

- Photosynthesis occurs in plants (biosphere) growing in the soil (lithosphere) and involves the absorption of water (hydrosphere) and carbon dioxide (atmosphere) as well as the release of oxygen (atmosphere).
- Groundwater (hydrosphere) fills spaces in the soil and between the rocks (lithosphere) after rainfall.
- Gases (atmosphere) occur in the sea and fresh water (hydrosphere) as well as in soil (lithosphere) to provide oxygen for organisms (biosphere).
- Large bodies of water (e.g. seas, lakes, rivers of the hydrosphere) surround areas of land (lithosphere) and moderate the temperature to create optimum conditions for living organisms (biosphere).

- Plant roots (biosphere) grow into the soil (lithosphere) to absorb water (hydrosphere) and mineral salts (lithosphere) and release oxygen (atmosphere) for the benefit of other living organisms (biosphere).
- Humans may upset the balance of the spheres by building a dam. Water supply (hydrosphere) to living organisms (biosphere) changes and affects the conditions of the surrounding soil (lithosphere) and air (atmosphere).

TOPIC 2 LITHOSPHERE

US 7507: SO 5 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1-2; SO 4 – AC 1-2
US 7511: SO 2 – AC 1; SO 3 – AC 1

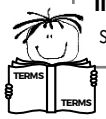
Lesson Outcomes

By the end of this topic, learners should be able to:

- Illustrate the significance of the rock cycle for human use
- Define concepts and principles relating to the lithosphere
- Demonstrate the rock cycle
- Apply knowledge and skills to familiar and unfamiliar phenomena
- Explain how different types of rock are utilised by humans

UNIT 1 LITHOSPHERE

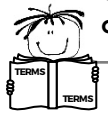
STRUCTURE OF THE EARTH



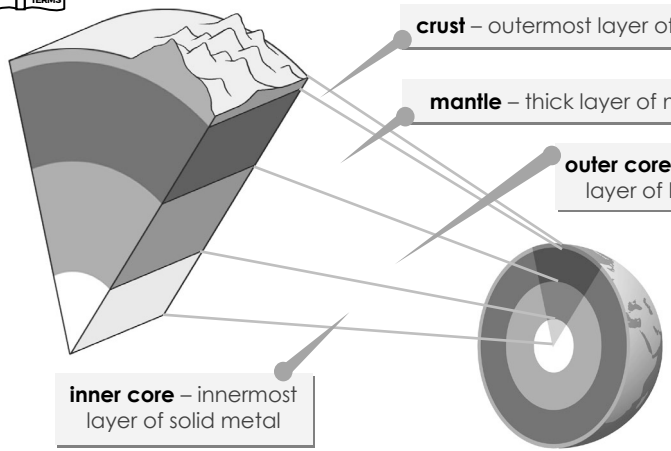
'litho' means stone/rock

The earth consists of four concentric layers:

- crust
- mantle
- outer core
- inner core



concentric layers: different layers that have the same **centre** and each circular layer becomes larger in diameter



Crust

- the outermost layer of the earth
- thin shell of solid rock (5 – 50 km thick)
- consists of moving slabs called **tectonic plates**
- exposed surface is weathered to form **soil**

Mantle

- the layer under the crust
- thickest layer (2 900 km thick)
- innermost/lower mantle is very hot with soft molten rock (liquid) called **magma** that can flow slowly and form **lava** if it comes to the surface e.g. volcanic eruption
- outermost/upper mantle is cooler with solid rock
- the upper mantle is in contact with the crust and forms part of the lithosphere

Outer Core

- the liquid layer of the earth surrounding the inner core
- liquid metal (2 250 km thick)
- molten metallic rock (liquid) made of nickel and iron

Inner Core

- the innermost solid core
- solid metal (2 440 km thick)
- very high temperatures and pressure
- consists of iron

STRUCTURE OF THE LITHOSPHERE

The lithosphere is between 5 – 70 km thick and has two concentric layers:

- Crust – thin layer of rock including soil
  - soil is a very thin layer that forms from weathering of the crust
  - soil is composed of rocky particles mixed with organic and inorganic materials
- Upper solid mantle – thick rocky layer

organic materials: include compounds containing carbon from living organisms

inorganic materials: include minerals, water and gases that occur naturally

MINERALS IN THE CRUST OF THE LITHOSPHERE

- The lithosphere is made of solid elements and inorganic compounds called **minerals**.
- A mineral is a naturally occurring material and not produced by living organisms.
- Minerals are valuable resources, e.g. copper, diamond, platinum.
- A mineral has one specific chemical composition, whereas a rock can be a mixture of different minerals.
- There are more than 5 500 known minerals.
- Some minerals exist as **elements** in the crust in their pure form and include:
  - gold (Au), copper (Cu)
- Most minerals occur as **compounds** (elements react with other elements to form compounds) and include:
  - hematite (iron oxide Fe_2O_3), calaverite ($AuTe_3$), malachite ($Cu_2CO_3OH_2$), bauxite (aluminium oxide $A\ell_2O_3$), silica (silicon dioxide SiO_2)

elements: consist of one type of atom, e.g. iron (Fe)

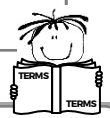
compounds: consist of atoms of different elements, e.g. water (H_2O)

ROCKS OF THE LITHOSPHERE

- Minerals are the building blocks of rocks. Rocks are essentially mixtures of different minerals.
- Common rock granite is a combination of the quartz, feldspar and biotite minerals.
- Rocks have been used by mankind throughout history to make tools and weapons.
- The minerals and metals found in rocks are essential to human civilisation.

minerals: naturally occurring, inorganic solids in the earth's crust that have a specific chemical composition of one or more elements

metals: elements or alloys (mixtures, e.g. steel) that are shiny, malleable, hard substances; they conduct heat and electricity; they form crystals when solid and naturally occur in minerals



- There are three rock types according to their formation:
  - **igneous rock** – formed from cooled magma, e.g. granite, basalt
  - **sedimentary rock** – formed from layers of sediment under pressure, e.g. sandstone, limestone, shale

sediment: solid particles from weathering of rock that are transported to settle in layers

Sandstone Karoo sedimentary rock

  - **metamorphic rock** – formed from igneous or sedimentary rock that is exposed to heat and pressure, e.g. slate, marble

UNIT 2

THE ROCK CYCLE

The rock cycle is a natural continuous process in which rocks form, break down and re-form over long periods of time.

The rock cycle can be explained in four stages of rock formation:

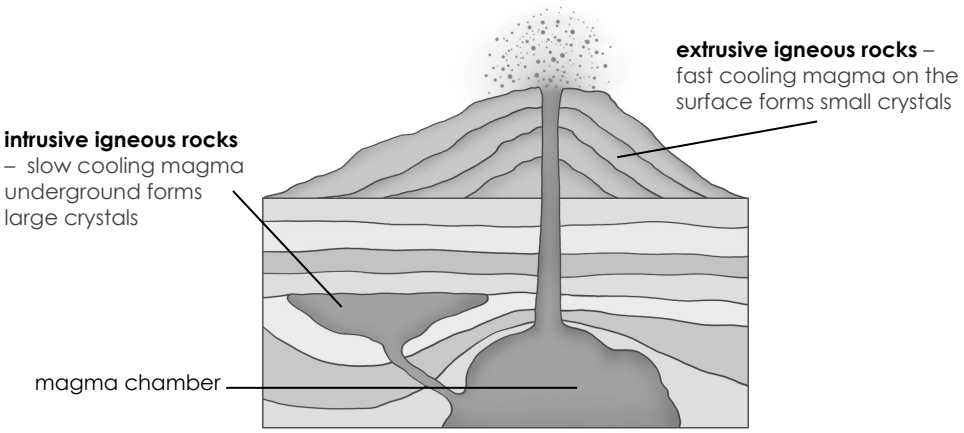
- formation of igneous rock
- formation of sedimentary rock
- formation of metamorphic rock
- formation of magma

STAGE 1

Formation of Igneous Rock

- Magma (molten rock) from the mantle pushes up through the crust.
- As the magma nears the surface it cools down and solidifies to form igneous rock.
- Elements in the rock combine during cooling to form crystals:
  - slow cooling allows time to form large crystals
  - rapid cooling forms small crystals (less time for crystallisation)
- Igneous rock can be **intrusive** (formed in the crust) or **extrusive** (formed on the surface).

NOTE
Igneous rock has crystals but no layers.



Formation of igneous rock

intrusive rock: is formed internally

extrusive rock: is formed externally

- **Intrusive rock** forms when cooling occurs **slowly** in the crust to form rocks with large crystals, e.g. **granite**.

Intrusive igneous rock – granite

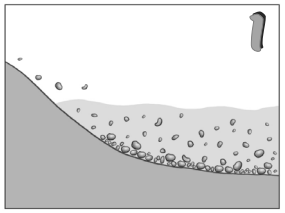
Extrusive igneous rock – basalt

- **Extrusive rock** forms when magma escapes to the surface as **lava** from a volcano and cools down **rapidly** to form rocks with small or no crystals, e.g. **pumice stone**, **basalt**.

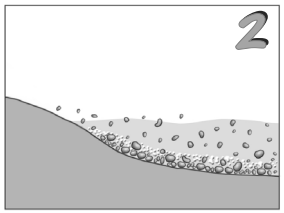
Pumice stones with large air spaces and tiny crystals caused by rapid cooling

STAGE 2 Formation of Sedimentary Rock

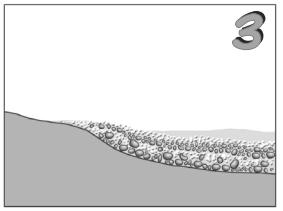
- Rocks exposed on the surface are **weathered** by heat, cold, wind and water to form smaller particles.
- **Erosion** by wind, water, glaciers and gravity transports these particles and deposits them as **sediment** in layers on land (strata) or sea.
- The pressure of many layers compacts the lower older layers of sediment into **sedimentary rock**.



Weathering and erosion causes deposit of particles as sediment = **deposition**



More layers of sediment are formed and cause pressure on lower layers = **compaction**



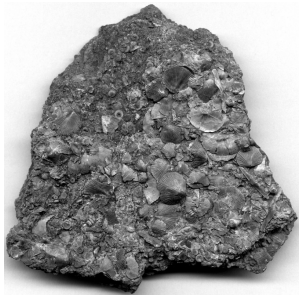
More layers cause more pressure and particles are glued together = **cementation**

- Examples of **sedimentary rock**:
  - sandstone – formed from sand grains and used as a building material
  - limestone – formed from shells of marine organisms and used to purify iron and manufacture glass
  - shale – formed from clay particles and is a source of natural gas and oil

- Fossils are **only** found in sedimentary rock as they are covered rapidly by layers of sediment.

NOTE
Sedimentary rock has layers (strata) but no crystals.

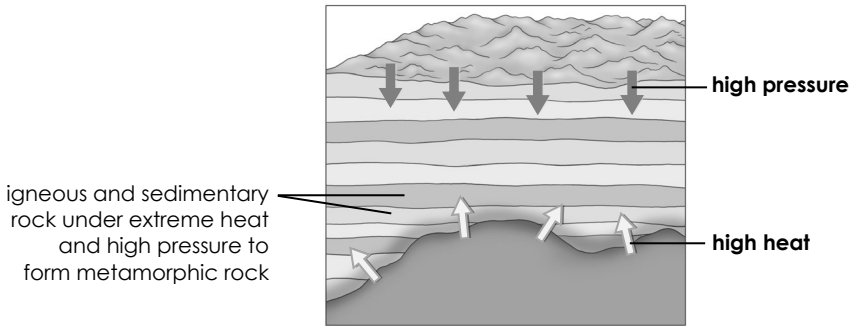
Sandstone formations showing the layers of sediment deposited after weathering and erosion



Fossil-filled limestone – sedimentary rock

STAGE 3 Formation of Metamorphic Rock

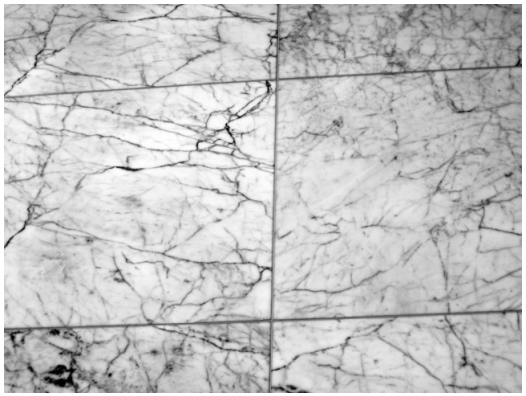
- Hot magma from the mantle heats the surrounding rock (sedimentary or igneous).
- The **intense heat** and **high pressure** changes the chemical structure; elements form new crystals to form metamorphic rock.
  - metamorphic rock is harder and has many thin layers



Formation of metamorphic rock

- Examples of **metamorphic rock**:
  - slate – formed from sedimentary rock (shale) and used for roof tiles
  - marble – formed from sedimentary rock (limestone) and used for carving statues

NOTE
Metamorphic rock has many thin layers and crystals.



White marble – metamorphic rock formed from limestone (sedimentary rock)

Marble – metamorphic rock

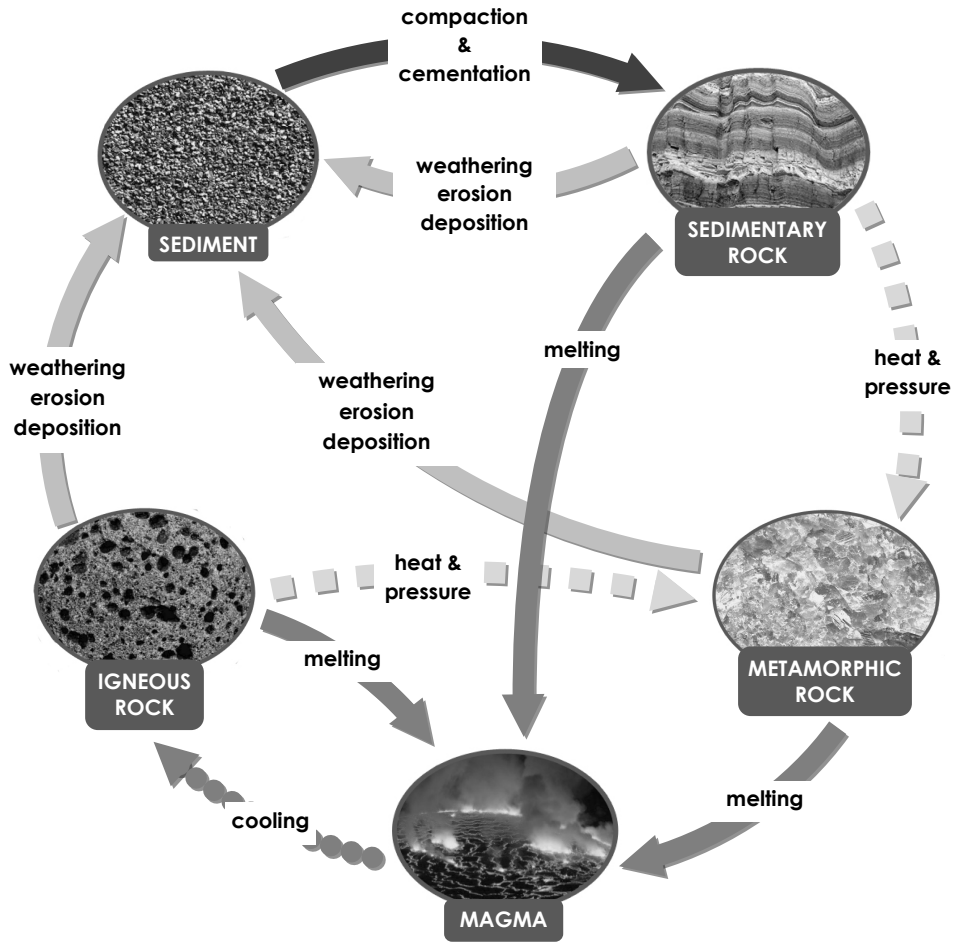
Slate – metamorphic rock

STAGE 4

Formation of Magma

- Movement of the mantle may push rock below the crust.
- Rock melts and becomes liquid, magma (molten rock) again.

The rock cycle is complete after Stage 4 and the magma may push up through the crust to form igneous rock again (see Stage 1).



The rock cycle

TOPIC 3

MINING OF MINERAL RESOURCES

US 7509: SO 1 – AC 1-3
US 7511: SO 1 – AC 2; SO 2 – AC 1; SO 3 – AC 2
US 7513: SO 1 – AC 1-3; SO 2 – AC 2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to mining of mineral resources
- Explain the interaction between humans and natural resources
- Explain the negative environmental impact of the mismanagement of natural resources
- Discuss how mining has affected economic development

- From the earliest times, humans have used the mineral resources and other materials that occur in the lithosphere on the earth's surface.
- Some minerals occur as **elements**, e.g. sulphur, iron, carbon in diamonds, silver, gold. Others occur as **compounds**, e.g. sodium chloride, calcium carbonate.
- The value of minerals to humans is either functional (iron/copper/coal) or aesthetic (gemstones) or both (gold, silver, platinum, diamonds).

aesthetic: attractive in appearance

- Early human civilisations are distinguished by the types of minerals they used as their primary technology:
  - **The Stone Age (< 2 000 BC)** – pieces of stone were cut into tools like hand axes, spear heads and scrapers
  - **The Bronze Age (± 3 300 – 1 200 BC)** – metals were extracted from the earth, melted together to forge alloys like bronze and then formed into tools and weapons
  - **The Iron Age (1 200 BC – 500 AD)** – iron or iron alloys are much stronger than other common metals and were instrumental in the development of machinery and weapons
- Two processes make many minerals available for human use:
  - **extracting** the minerals from the earth
  - **refining** the minerals

UNIT 1

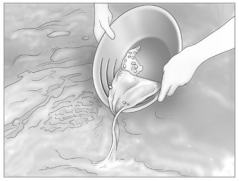
EXTRACTING ORES

- Valuable minerals are extracted from the earth's crust.
- Rock that contains sufficient amounts of a valuable mineral for mining is called an **ore**.
- Ore is removed from the crust by **mining**.

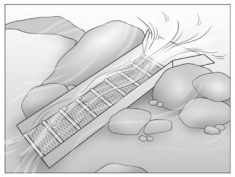
TYPES OF MINING

Placer Mining

- E.g. gold and gemstones
- Some minerals can be found in river beds and can be separated out using shallow pans in **panning**, or a device called a sluice box in **dredging**.
- Water and soil from the riverbed is placed into the pan or sluice box and denser material, e.g. gold, sinks to the bottom of the pan.
- Dune/sand mining extracts minerals from sand in river/sea beds.



Panning



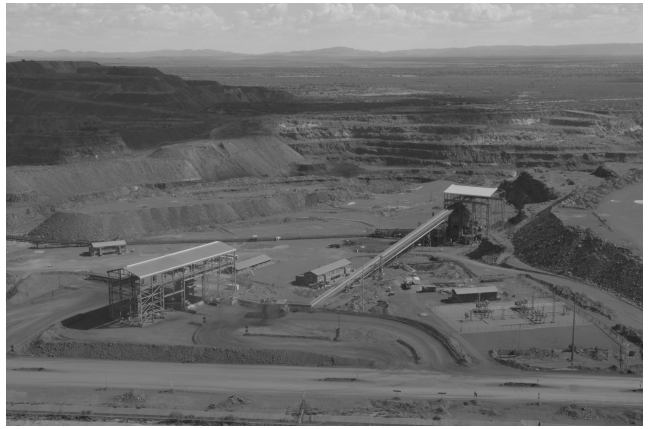
Sluice box

Opencast Mining

- E.g. coal, iron ore, diamond, copper
- Used to mine minerals that are **near the surface**, examples include:
  - diamond mining – Big Hole in Kimberley
  - copper mining – Phalaborwa, Limpopo

**Opencast copper mine in Phalaborwa –
widest man-made opencast mine in Africa (2 km wide)**

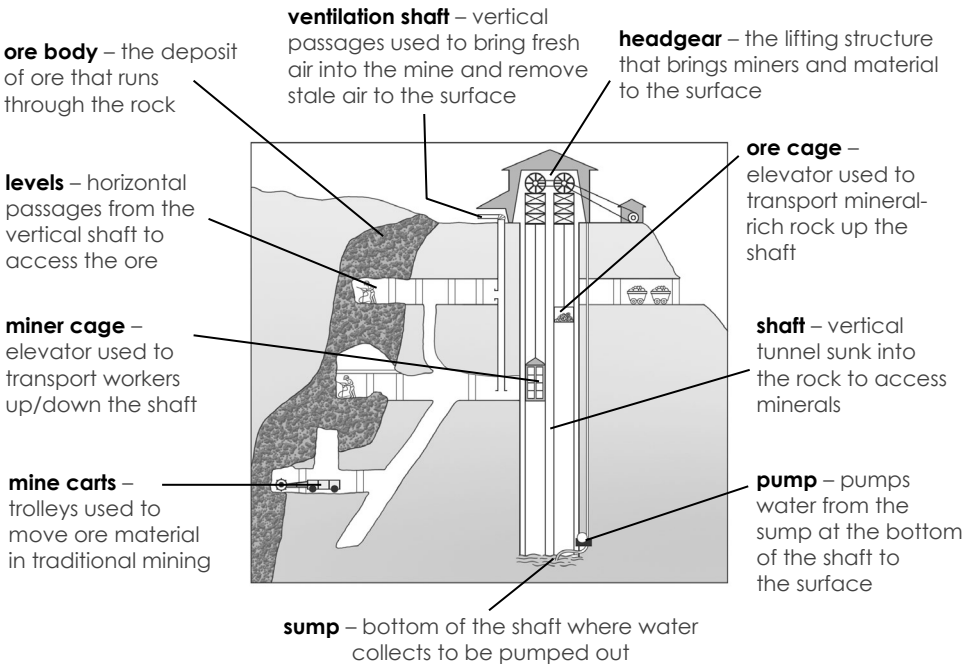
- The top layer of soil and rock is removed by digging and explosives to access the deposits underneath.
- Large open pits form as layer after layer of ore is removed.
- Opencast mining is cheaper, safer and simpler than shaft mining.



**Opencast iron ore mine in Sishen –
one of the largest in the world (14 km long)**

Shaft Mining

- E.g. gold, platinum
- Used to mine minerals **deep below the surface**, e.g.:
  - platinum mining – Merensky Reef
  - gold mining – Mponeng is the deepest mine in the world (4km)
- A mine shaft (main tunnel) is drilled into the ground.
- A headgear (mine shaft tower) with a lift is constructed in the shaft.
- Mine workers dig tunnels (levels) from the main shaft so that the gold reef (a vein of gold) can be reached.
- Holes are drilled into the gold-bearing reefs at regular intervals and packed with explosives to break the rock containing gold ore.
- Shaft mining is a very expensive and dangerous process.



Shaft mine

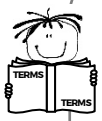
UNIT 2

REFINING MINERALS

- Refining is a process that **purifies** a substance by removing the unwanted material.
- Some minerals can be used in their natural form such as sand, salt, sulphur, potash and gemstones.
- Other minerals form compounds in the rock and require a **chemical** or **physical process** to extract the valuable material from the **ore**.
- Once ore is extracted from the earth, it is brought to the surface, crushed and then processed.
- Humans have been extracting and refining iron and copper for thousands of years.
- South Africa has archaeological sites in KwaZulu-Natal and Limpopo that provide evidence of this industry.
- **Chemical processing** of ore involves the use of chemicals, heat and oxygen to dissolve the metal and separate the metal from the ore.
- **Physical processing** includes:
  - crushing
  - filtering
  - smelting

CHEMICAL PROCESSING

- Iron is refined from iron-ore in a chemical process called **smelting**.
  - Iron ore is placed in a blast furnace together with limestone and charcoal/coke (carbon).



Coke is a carbon-rich fuel with few impurities made from purified coal and used in modern iron/steel production.

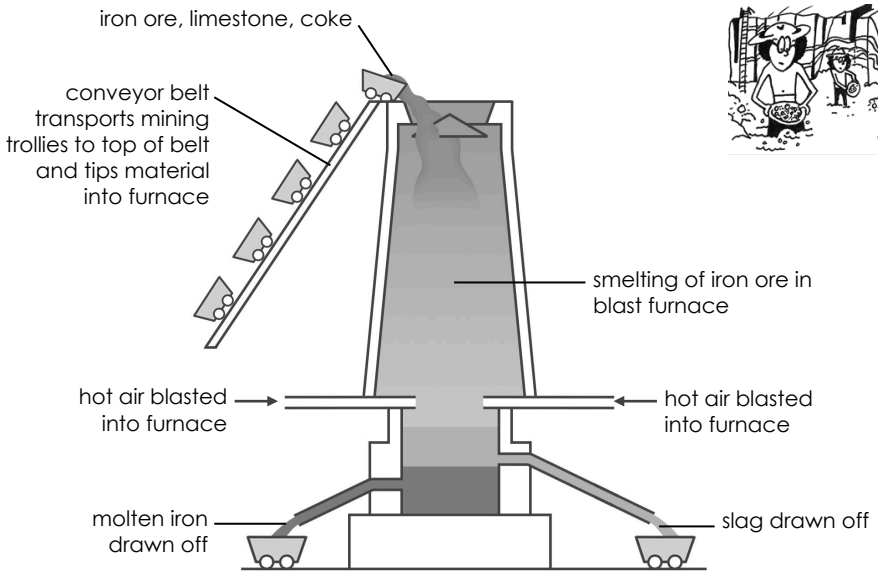
Charcoal is a carbon fuel made from partially burnt wood that was used in ancient iron production.

Coal is a mineral fossil fuel that occurs naturally in the ground.

NOTE

The diagram of a blast furnace on p. 207 illustrates this process.

  - Hot air is blasted into the base of the furnace.
  - Coke burns in oxygen to form carbon dioxide (CO_2) and then carbon monoxide (CO).
  - CO reacts with the iron oxide in the ore and converts it to iron.
  - Iron melts and is drawn off into moulds.
  - Remaining ore reacts with limestone to form a floating liquid called **slag** which is also drawn off and cooled.
  - Iron smelting reaction: iron oxide + carbon → iron + carbon dioxide
    (Fe_2O_3) (C) (Fe) (CO_2)
- Steel, a purified form of iron, is also formed from iron ore and coke in the chemical process of **smelting**.
  - The molten iron is purified by intense heating and combined with other metals to form steel.
  - Steel is stronger, lighter and more resistant to rust than iron.



Blast furnace

PHYSICAL PROCESSING

- Gold is refined from gold ore in a physical process.

NOTE

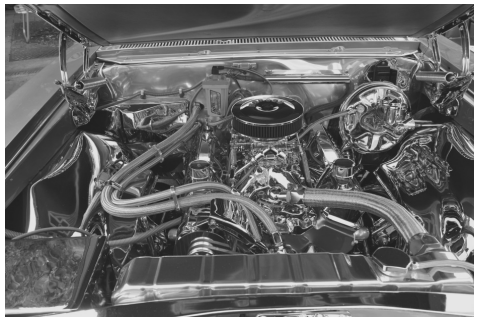
Gold can be refined in various physical processes. The cyanide-carbon process is discussed here.

  - Ore is crushed into smaller pieces.
  - Gold-bearing ore is separated from other rock and crushed finely.
  - Water, cyanide and lime are added to dissolve the gold.
  - The mixture is ground to a muddy paste called **slurry**.
  - Excess water is removed, carbon is added to attach to the gold, and the slurry mixture is stirred in tanks.
  - Dissolved gold combines with carbon.
  - Gold is separated from carbon using washing solutions and electrolytes.
  - Waste material, known as tailings, is removed.

UNIT 3

MINING IN SOUTH AFRICA

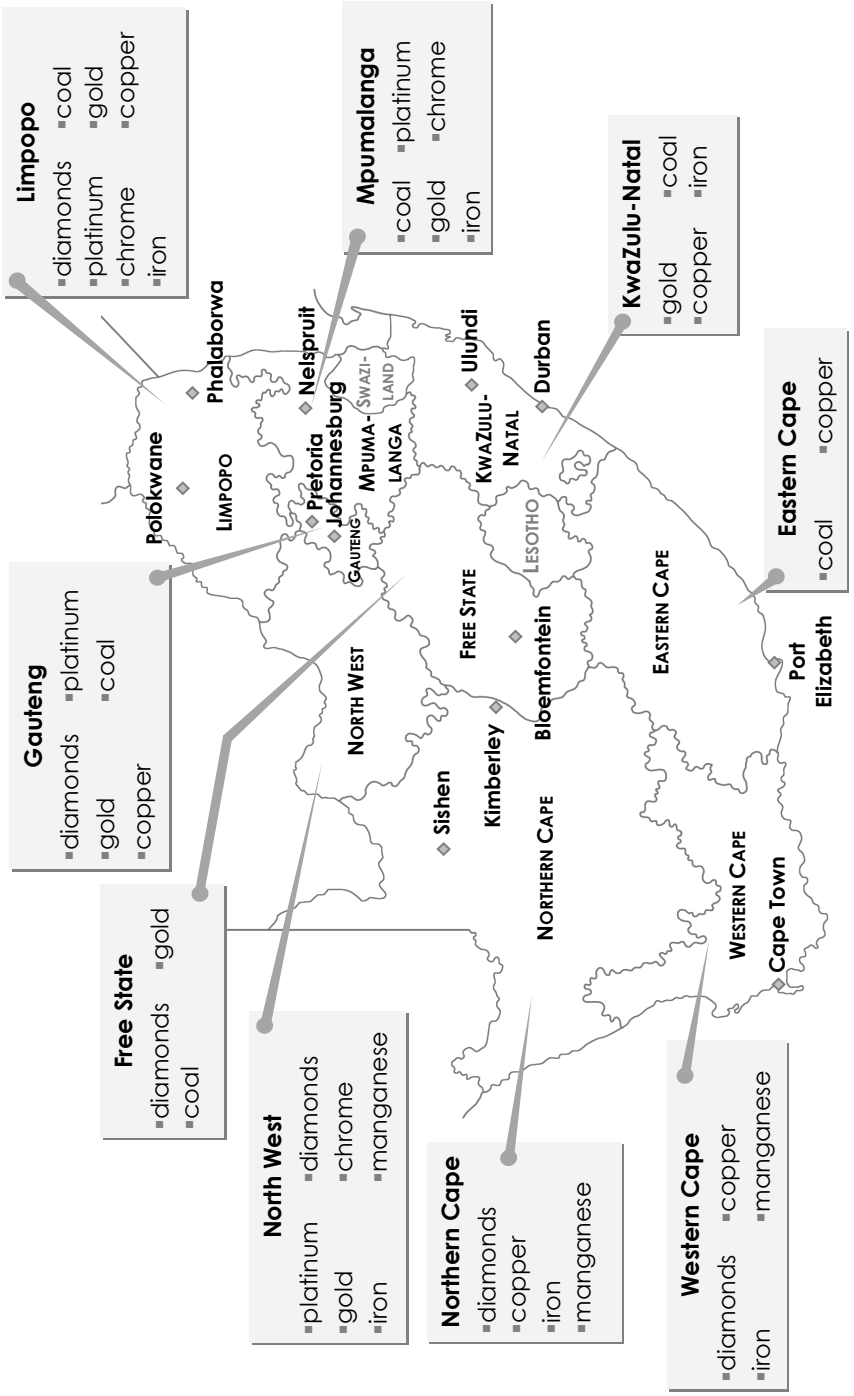
- There is large scale mining activity in South Africa.
- The mining industry has been possibly the most influential shaper of South African geography, economy and society.
- Export of valuable minerals brings foreign currency into the country.
- Many of South Africa's major cities were originally founded due to mining prospects in the area:
  - Johannesburg / Witwatersrand (gold)
  - Kimberley (diamonds)
  - Newcastle (coal)
- SA is one of the world's leading mining economies with some of the richest mineral reserves:
  - SA produces 77% of the world's platinum, 11% of gold and 5% of diamonds.
  - It is the third biggest coal exporter and the world's largest producer of chrome.
  - Mining represents 60% of all exports out of South Africa.



Chrome in engine

- The mining industry employs just less than 500 000 people in South Africa, but indirectly supports 1,5 million jobs.
- Many miners are migrants. They live in accommodation on the mining compound away from their families.

- Migrant labour is criticised for breaking down the family unit in many South African communities.



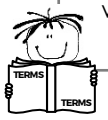
IMPORTANCE OF SOUTH AFRICA'S MOST IMPORTANT MINERALS

- *Gold (**Au**) – dentistry, jewellery, coins, scientific instruments, electroplating, electronic circuits*
- *Platinum (**Pt**) – catalytic converters for industrial/vehicle emissions, jewellery, catalysts, medicines, electronic circuits, dentistry*
- *Chromium (**Cr**) – production of steel*
- *Iron ore (**Fe**) – production of steel, magnets, catalysts, paints, inks*
- *Copper (**Cu**) – electrical wiring, plumbing piping, roofing, coins, jewellery*
- *Manganese (**Mn**) – production of steel and iron*
- *Coal – production of steel, electricity generation, heat production*
- *Diamonds – drill bits, saw blades, jewellery, cutting and polishing*

ENVIRONMENTAL IMPACT OF MINING

Mining has a significant negative environmental impact. The government has a responsibility to protect the environment and local populations from the damaging effects of mining.

- Mining companies must have an environmental assessment study to ensure they minimise damage to the environment.
- Mines that become inactive have a responsibility to:
  - rehabilitate damaged vegetation
  - secure dangerous areas (tailings dams, open shafts) with boundary fencing
  - rehabilitate mine dumps created by mining activity



tailings dams: dams filled with waste material

Creation of Mine Dumps

- A mine dump is an accumulation of the waste material that remains after the valuable mineral has been extracted from the ore.
- This waste is piled into giant mounds that occupy potentially useful land and release vast quantities of dust into the air.

- The waste combines with rainwater to form sulphurous acid which then dissolves uranium and other heavy metals as it flows or seeps into local groundwater.
- Mine dumps contain chemicals (heavy metals and radioactive materials) that are toxic to humans, animals, plants and microorganisms.

https://visibleearth.nasa.gov/view.php?id=44264

Mine dumps (slag piles) of waste from gold mining near Soccer City, Johannesburg

Pollution of Water Resources

- Rain washes toxins from exposed rock surfaces and from the air into water supplies.
- Chemicals from mine dumps, abandoned mines and active mines can leach into local water supplies.
- These chemicals change the pH of the water to become highly acidic.
- Organisms living in the water cannot tolerate the pollution, they die out which leads to a loss of biodiversity.
- The water is unsuitable for cooking and cleaning and pose serious health risks to consumers.
- Some toxic, waste material (tailings) from mining is stored in dams. Any leakage from a tailings dam will have serious environmental consequences.

NOTE

***Acid mine drainage (AMD)** is the accumulation of water in abandoned mines. The maze of shafts and tunnels fill up with water which reacts with exposed chemicals in the rocks to form a weak acid. This acid water is hazardous and slowly leaks out into the environment and causes harm to organisms and humans.*

Damage to Places with High Tourist or Cultural Heritage Value

- Mining practices change the landscape of a region.
- It also produces air pollution which discourages tourism and damages buildings, statues and monuments.
- It may displace communities that already live in the area and have a cultural history there.
- The iSimangaliso Wetland Park (Greater St. Lucia Wetland Park) in KwaZulu-Natal and the Wavecrest community in the Eastern Cape have been under threat from mining companies.
- Underground activity of mining destabilises the land surface and makes it unstable for development.
- Opencast mining destroys vast areas of land regardless of archaeological or cultural value.

Destruction of Habitats and Farm Land

- Farming lands and wild life environments are also under threat with large-scale removal of soil and vegetation, leading to soil erosion.
- Pollution of water affects biodiversity as it destroys plant and animal species.
- Contaminated water used for irrigation affects quality of crops and cause accumulation of toxins in food.
- Air pollution can result in acid rain, which damages vegetation or crops.
- Disused mines create a damaged environment with waste material dumps that occupy habitats of indigenous species and open shafts creating a safety hazard for humans and animals.

- Mining uses massive quantities of water which are diverted from rivers or dams. This water is thus not available for local species, farmers and crops that depend on it.

Photo by Mpumalanga Tourism & Parks Agency

Environmental impact of Mpumalanga coal mines on agricultural land – destroying fertile soil and habitats

Negative impact of mining in Phalaborwa – satellite photograph shows environmental damage to agricultural land surrounding the mine

TOPIC 4 ATMOSPHERE

US 7509: SO 1 – AC 1-3; SO 4 – AC 1
US 7511: SO 1 – AC 2; SO 3 – AC 2,3

Lesson Outcomes

By the end of this topic, learners should be able to:

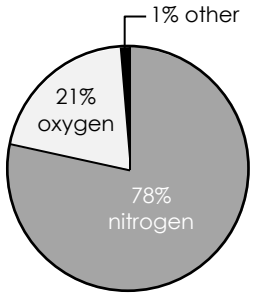
- Define concepts and principles relating to the atmosphere
- Apply knowledge of the atmosphere to explain the greenhouse effect
- Describe how the mismanagement of resources can lead to global warming

UNIT 1 ATMOSPHERE

- Gravity traps gases near the earth's surface to form the atmosphere.
- Air gets less dense as you move further away from sea level (the greater the distance from the earth, the thinner the air).

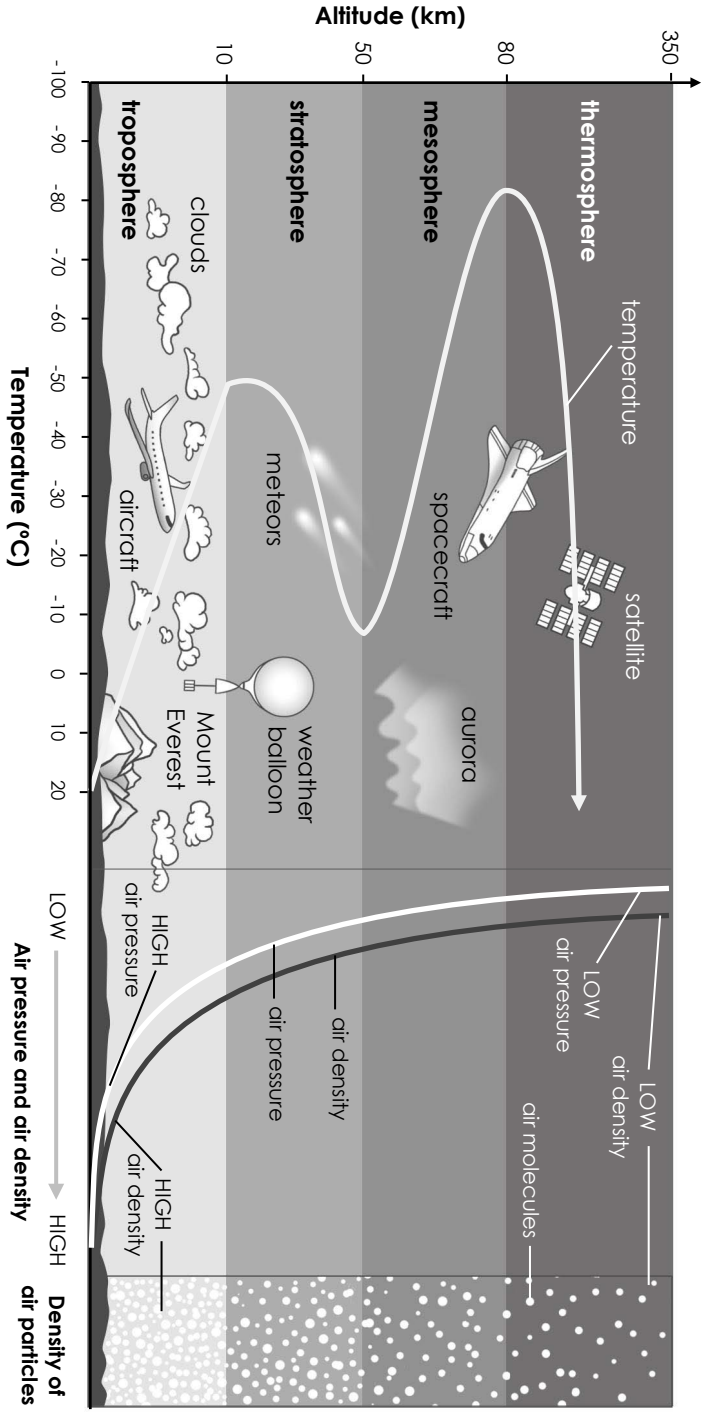
GASES IN THE ATMOSPHERE

- The mixture of gases in the air is called the atmosphere.
- The atmosphere consists of:
  - 78% nitrogen
  - 21% oxygen
  - 1% all other gases (e.g. CO_2, water vapour, helium or neon)

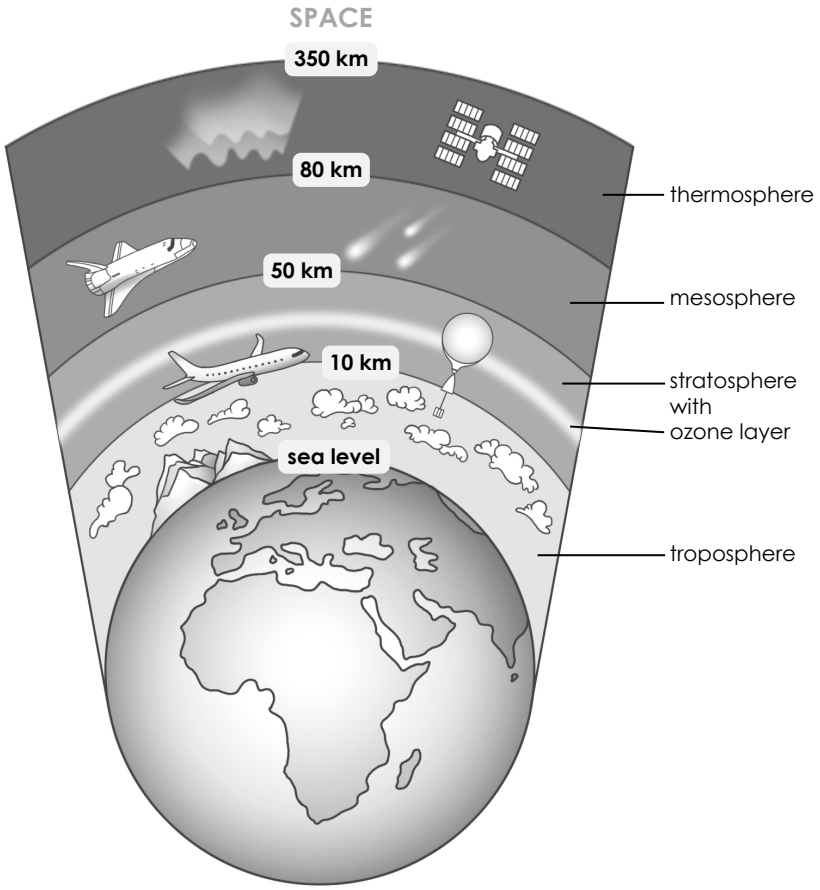


LAYERS IN THE ATMOSPHERE

- There are four distinct layers in the atmosphere, i.e.:
  - **troposphere** (sea level to 10 km)
  - **stratosphere** (10 – 50 km)
  - **mesosphere** (50 – 80 km)
  - **thermosphere** (80 – 350 km)

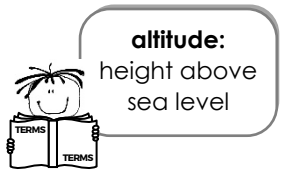


Summary diagram to show different layers of the atmosphere at different altitudes, changes in temperature, changes in air pressure and air density



Layers of the atmosphere

- Layers of the atmosphere are not separated by a definite line, but by changes in temperature.
- Temperature changes with altitude is known as the **temperature gradient**.
- Each layer has a different temperature gradient, i.e. temperature increases/decreases with altitude.
- Space extends from about 350 km above the surface of the earth. It is the area beyond the atmosphere where the density of air is very low.

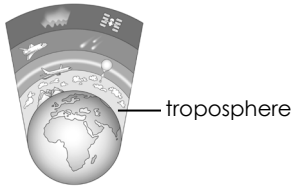


altitude: height above sea level

NOTE

Atmospheric pressure *is the pressure created by gas particles in the air. Air is dense (with closely packed gas particles) at low altitude (sea level) ∴ higher atmospheric pressure. Air is less dense (with fewer gas particles) at higher altitudes ∴ lower atmospheric pressure.*

UNIT 2 TROPOSPHERE

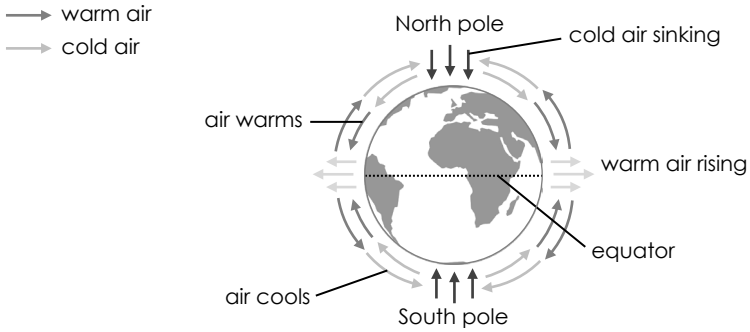


- This layer extends from sea level to about 10 km above the surface of the earth.
- More than 70% of the mass of the atmosphere occurs in the troposphere.
- It has the greatest density as the air particles are very close together.
- The temperature decreases as the distance from the surface increases.
- The further away from the earth, the colder the air.
- It is the only layer that has water vapour and clouds. The warmer the air, the more water vapour it holds.

NOTE

Refer to the graphs on the summary diagram on p. 211 that illustrate these changes.

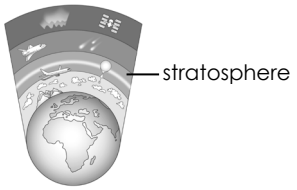
- Water vapour forms part of the water cycle: liquid water on the earth evaporates and forms clouds. It returns to the earth as rain, hail or snow to complete the cycle.
- Weather patterns form in this layer:
  - more direct sunlight at the equator creates a warmer atmosphere
  - air warmed at the equator rises to higher altitudes
  - warm air at high altitudes moves towards the colder North/South poles where it cools
  - cooled air sinks at the poles towards the earth's surface where it gradually warms again as it moves back towards the equator



- All animals and plants live in the troposphere where there is sufficient oxygen and water vapour to support life.

The temperature gradient in the troposphere decreases by approximately 1°C per 100 m increase in altitude. e.g. If you reach 300 m, the temperature decreased by 3°C from the temperature at the earth's surface.

UNIT 3 STRATOSPHERE

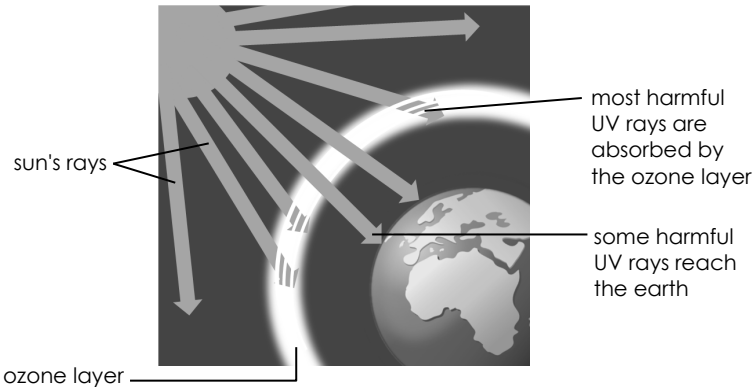


- This layer extends from about 10 km – 50 km above the earth's surface.
- The air in the stratosphere is much thinner (less dense) compared to the air in the troposphere.
- Some aeroplanes fly in the lowest parts of the stratosphere as the less dense air provides less friction and enables faster speeds and lower fuel consumption. Flights in the stratosphere also avoid stormy weather patterns that occur in the troposphere.
- The upper stratosphere includes a band of ozone gas (O_3) called the ozone layer.
- Ozone absorbs high energy ultraviolet radiation from the sun, thus protecting living organisms from dangerous levels of radiation.
- As UV rays are absorbed, the temperature of the stratosphere increases.

NOTE

Note the temperature increasing in the temperature graph on the summary diagram on p. 211.

- The further away from the earth, the warmer the air becomes.
- Older refrigerators, air conditioners and aerosol cans used to release chemicals called CFCs (chlorofluorocarbons) which react with ozone molecules, removing them from the ozone layer.
- This resulted in the ozone layer becoming thinner and offering less protection against ultraviolet radiation.

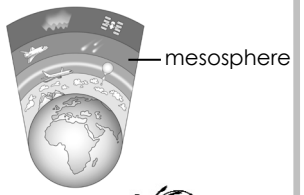


Ozone function

- Excess UV radiation affects life on Earth:
  - human health – causes skin cancer and can damage eyesight by promoting the formation of cataracts as well as affecting the immune system
  - photosynthesis – kills plankton, the primary producer in almost all marine food chains and disturbs photosynthesis in plants
  - life cycles – affects life cycles that depend on changing temperatures of seasons
  - population size – affects populations of plant and animal species by reducing the number of seedlings or offspring produced

- The use of CFCs has been banned in many countries. This is slowly allowing the ozone layer to regenerate.

UNIT 4 MESOSPHERE



- This layer extends from about 50 – 80 km above the earth's surface.
- The air is extremely thin (less dense) and very cold, dropping to -90°C in the higher layers.

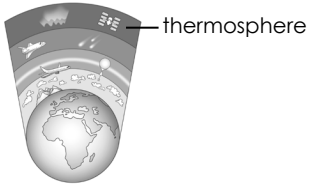
NOTE

Note the temperature decreasing in the temperature graph on the summary diagram on p. 211.

- The air has enough particles, however, to create friction when small rocks and dust enter this layer from space.
- The friction causes intense heat which burns these rocks and releases heat and light.
- Burning rocks are visible from the earth and known as **'shooting stars'** or **meteors**.
- **Meteorites** are meteors from space that entered the atmosphere and hit the earth's surface.

Meteor shower

UNIT 5 THERMOSPHERE

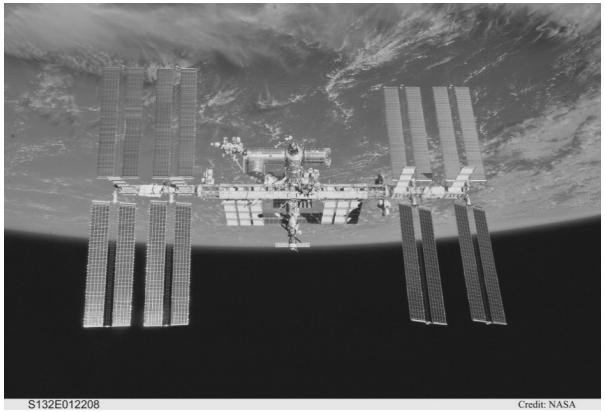


- This layer starts above 80 km from the earth.
- The thermosphere slowly fades out at about 350 km from the earth and then space begins.
- The lower thermosphere absorbs ultraviolet radiation and dangerous X-rays from the sun.

- The temperatures increase from -100°C to higher temperatures with an increase in altitude.

> **NOTE**
> *Note the temperature increasing in the temperature graph on the summary diagram on p. 211.*

- The upper part of the thermosphere contains a layer of charged particles/ **ions** formed by UV radiation. This layer is known as the **ionosphere** and it **reflects radio waves** from TV, radio broadcasts and GPS back to Earth, contributing to radio communication and navigation.
- Satellites orbit the earth just above the thermosphere and provide a base for scientific research.
- The International Space Station (ISS), with astronauts working in the laboratory onboard, orbits the earth at a height of about 370 km.
- Auroras/Northern lights:
  - the atmospheric effect produced when charged particles (ions) in the ionosphere interact with the magnetic fields near the North and South poles
  - solar radiation energy (from the sun) affects the earth's magnetic field and causes 'excitation' of ions in the ionosphere
  - the energised/'excited' ions collide with gas atoms (e.g. nitrogen and oxygen) causing them to emit light
  - the colours emitted depend on the type of ion
  - these light-emitting ions create impressive light displays in polar skies



International Space Station

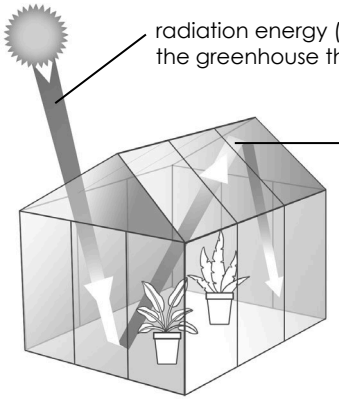
UNIT 6

THE GREENHOUSE EFFECT

WHAT IS THE GREENHOUSE EFFECT?

The greenhouse effect is a **natural phenomenon** where greenhouse gases trap radiation and warm the air close to the earth to sustain life.

> **NOTE**
> *A greenhouse allows radiation from the sun to enter through the glass, but prevents the escape of most heat energy.*
> *The air in the greenhouse becomes warmer than the surroundings as the glass traps heat and reduces airflow, keeping warm air inside.*
> *Greenhouse gases act like the glass of a greenhouse and trap heat.*



How a greenhouse works

> **NOTE**
> *A greenhouse actually retains more heat by reducing airflow, so it does not function exactly the same way as the greenhouse gases.*

- Life on Earth depends on radiant energy from the sun which travels as short waves (visible light) through the atmosphere to the earth.

> **NOTE**
> *The atmosphere is permeable to visible light.*

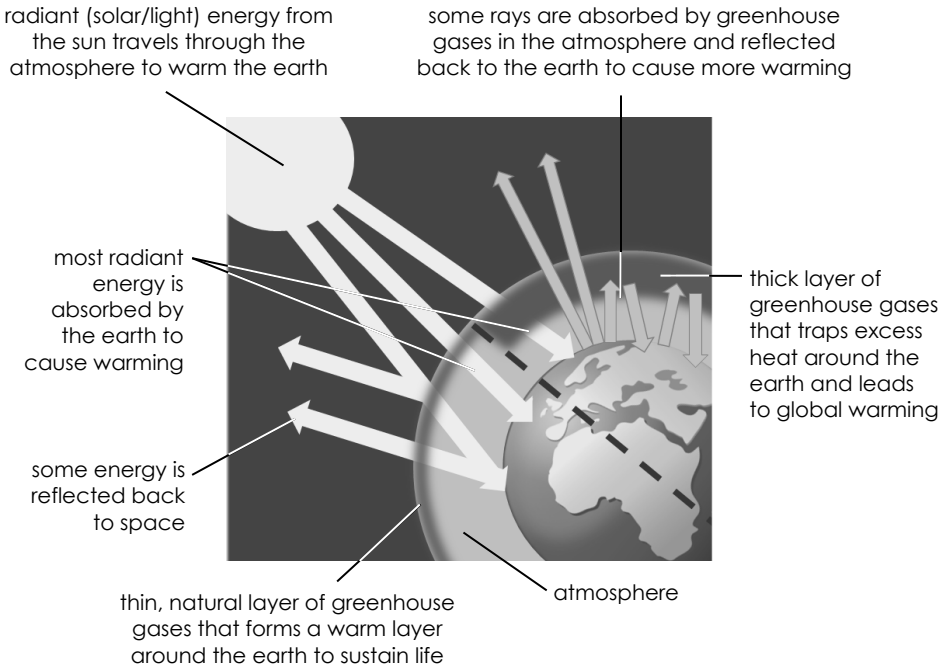
- A part of the incoming radiant energy is reflected back into space by the atmosphere as well as by the earth's surface.
- Most of the radiant energy is absorbed by the earth's surface and converted into heat energy, thus heating the earth.
- Some of this heat energy is emitted into the atmosphere as invisible, long-wave infrared rays.

- Some of the infrared rays pass through the atmosphere and are lost in space.
- Most of the infrared rays are absorbed by gases in the atmosphere, known as **greenhouse gases**, and are reflected back to the earth's surface and lower atmosphere.

NOTE

Water vapour is the main greenhouse gas that occurs naturally, absorbs heat and thus causes the natural greenhouse effect.

- The reflected infrared rays heat the atmosphere directly above the earth and prevent extreme drops in temperature at night.
- The atmospheric greenhouse gases act as a natural 'insulating blanket' that traps heat energy and makes the earth warm and habitable.
- Without the natural greenhouse effect, the earth's average temperature would be about 33ºC lower which is too cold to support life.



Greenhouse effect

GREENHOUSE GASES

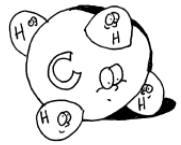
- Gas molecules in the earth's atmosphere that have three or more atoms are called **greenhouse gases**.
- These heat-trapping gases absorb heat energy in the form of infrared rays and include:
  - water vapour (H_2O)
  - carbon dioxide (CO_2)
  - methane (CH_4)
  - nitrous oxide (N_2O)
- Greenhouse gases are essential for maintaining optimum temperatures for life on earth.
- An excess of greenhouse gases, however, leads to global warming.

GLOBAL WARMING

global warming: the increase in the average temperature of the atmosphere

Causes of Global Warming

- The use of fossil fuels (coal, oil, gas) has increased considerably since the Industrial Revolution in the 1700s.
- The burning of fossil fuels has led to an increase in greenhouse gases, e.g. CO_2, released into the atmosphere.
- Deforestation has removed vegetation that would normally absorb CO_2 and reduce the levels in the atmosphere.
- Increased temperatures increase the amount of evaporation which results in more water vapour released into the atmosphere.
- An increase in waste in landfills and sewage increases the amount of methane produced.
- Methane is released from:
  - gas and oil industries
  - cow manure
  - decomposition of waste in landfills
  - decomposition in sewage plants



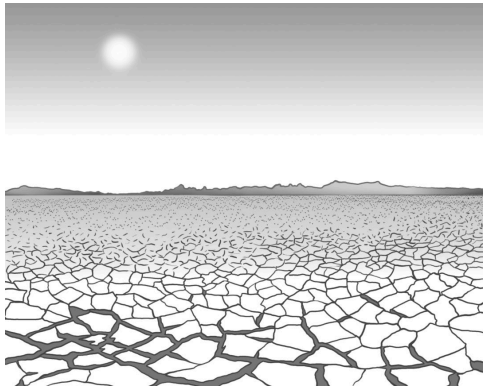
- The higher CO_2 and other greenhouse gas levels cause further heating of the atmosphere.

Impact of Global Warming

Global warming is a potentially life-threatening problem on earth and may cause:

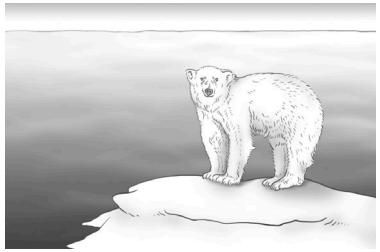
Climate change

- Higher temperatures lead to a higher rate of evaporation and droughts in areas where water is already scarce.
- The rainfall figures in some areas are lower than normal.
- High temperatures and increased evaporation may also cause heavy rainfall, thunderstorms and flooding.
- Prolonged droughts may lead to desertification.
- Dry areas are more vulnerable to large fires which destroy vegetation and release more greenhouse gases into the atmosphere.



Rising sea levels

- The increase in atmospheric temperature causes the polar ice caps, ice sheets and glaciers to melt.
- The melting of polar ice caps and glaciers, as well as the expansion of warmer sea water cause sea levels to rise and increase the incidence of flooding in low-lying areas.



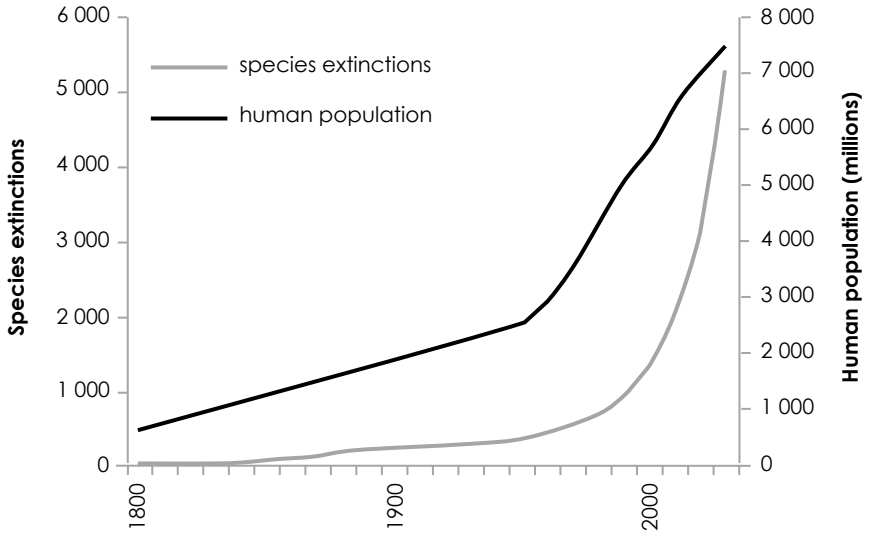
Food shortages

- Elevated temperatures and associated drought conditions reduce:
  - the availability of drinking water
  - crop productivity
- Lack of food can lead to migration and displaced populations.

Mass extinctions

- As their habitats are destroyed by climate change, plant and animal species may become extinct.
- As temperatures increase, animal species either move to cooler habitats or they may become extinct.
- Particularly vulnerable species are at risk of becoming threatened species, e.g. coral reefs and polar animals.
- Due to climate change, co-existing species may not have corresponding life cycles any more, e.g.:
  - flowers produce pollen at a different time to the active season of the pollinator
  - migration patterns change which affects predator-prey food sources
- If many species become extinct in a short period of time, it is known as a mass extinction.

Impact of human population on number of species extinctions over time

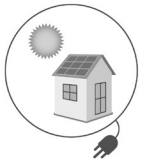
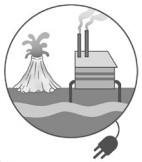


- Global warming is a worldwide phenomenon that needs the cooperation of all major governments to reduce the use of fossil fuels and limit the release of greenhouse gases.

NOTE

Individuals can contribute to decrease global warming by:

- *using public transport/walking/cycling*
- *supporting local produce*
- *limiting air travel*
- *using alternative/renewable energy sources*
- *recycling waste*
- *re-use instead of replace*
- *using energy-saving devices*
- *building an energy-wise insulated home*

- Countries need to develop alternative renewable sources of energy:
  - solar energy 
  - hydrogen power 
  - wind energy 
  - geothermal energy e.g. hot springs 
  - wave energy 
  - hydroelectric energy 
  - biomass energy e.g. methane 

TOPIC 5 BIRTH, LIFE AND DEATH OF STARS

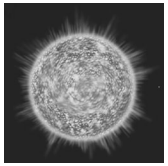
US 7507: SO 2 – AC 1-2
US 7509: SO 1 – AC 1-3; SO 2 – AC 1; SO 3 – AC 1-3; SO 4 – AC 1-2

Lesson Outcomes

By the end of this topic, learners should be able to:

- Define concepts and principles relating to stars
- Describe the nature of scientific knowledge in star life cycles
- Demonstrate the life cycle of a star
- Interpret scientific evidence and apply knowledge and skills in star life cycles

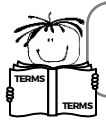
- A **star** is a naturally occurring object in the universe consisting of a luminous ball of burning gas held together by its own gravity.
- The sun is the nearest star to Earth.
- Stars exist for a finite period of time, i.e. they have a definite beginning (birth) and end point (death).



Sun

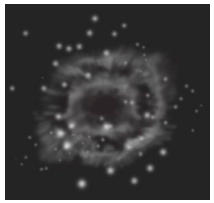
UNIT 1

THE BIRTH OF A STAR

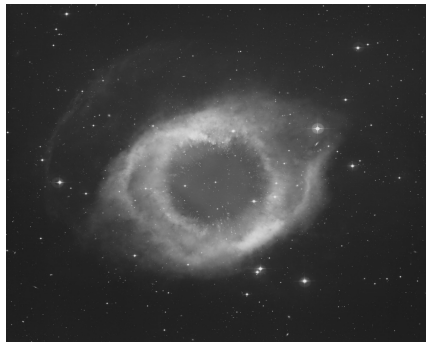


nebula = singular
nebulae = plural

- Stars form inside **nebulae** in space.
- A **nebula** is a thick cloud of gas and dust in space.
- The dust and gas particles are pulled together by their own gravity and slowly contract.
- Eventually the nebula collapses into a glowing ball of burning gas called a **protostar**.
- The pressure and temperature at the core increases as it contracts.
- Once the pressure and temperature is high enough, a **nuclear fusion reaction** begins.



Nebula

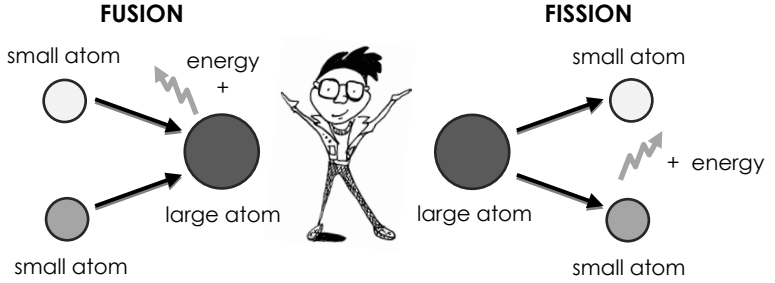


Helix Nebula

Mystic Mountain – a tall pillar of gas and dust in the Carina Nebula

- Atoms fuse to form different elements, e.g. hydrogen atom nuclei fuse together to form helium.
- Nuclear fusion releases large amounts of energy into space in the form of **heat** and **light** as well as other forms of radiation.
- The protostar develops into a **star** when it obtains its energy from nuclear fusion and radiates light and heat.

NOTE
*A **nuclear fusion** involves the joining of 2 nuclei of atoms to form a heavier nucleus and releases energy.*



NOTE
*A **nuclear fission** is when nuclei of atoms are split apart to release energy.*

- A protostar either develops into a small/medium size star, known as an **average star** or a very large star, known as a **massive star**.

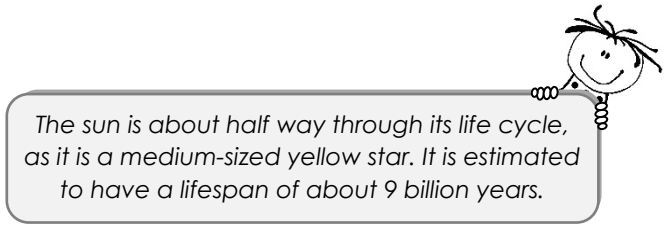
NOTE
*The **summary diagram** on p. 221 shows the different stages of the life cycle of a star.*

UNIT 2

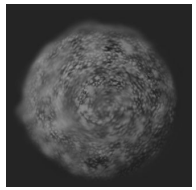
THE LIFE OF A STAR

- The nearest star to Earth, the sun, burns up 600 million tons of hydrogen per second, to form helium in **nuclear fusion**. The energy released from this process provides us with the optimum levels of heat and light necessary for life on earth.
- The most stable period in the lifetime of a star is the **main sequence** phase.
- During this phase, the inward force of gravity is equal to the outward force of the heat caused by the nuclear fusion reactions.

- Stars change in their appearance over time:
  - younger stars are hotter and blue in colour
  - stars become cooler, yellow then orange as they age
  - older stars are much cooler in temperature and often appear red
- The colour and brightness of a star depends on its temperature.



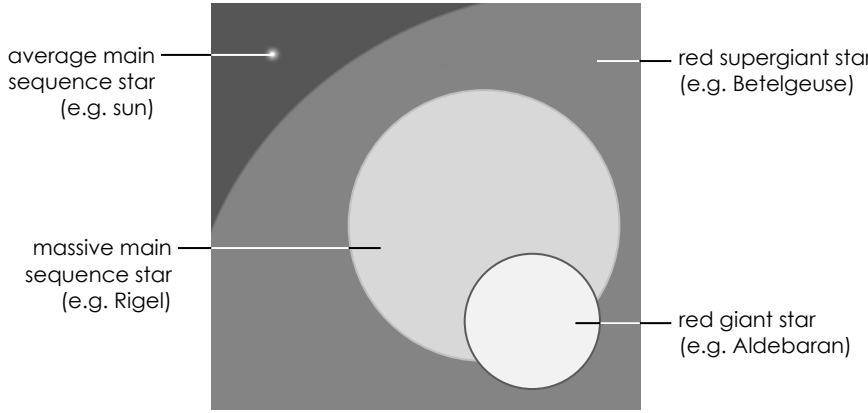
- Stars change hydrogen to helium throughout most of their lifespan and release energy.
- When stars use up their hydrogen fuel supply, they start to burn helium and continue to shrink.
- Towards the end of their lifespan, average stars (e.g. sun) swell up to form a **red giant**.
- Massive stars swell up to form a **supergiant**.



Red giant

NASA and The Hubble Heritage Team (AURA/STScI)

A red supergiant star surrounded by a halo of dust

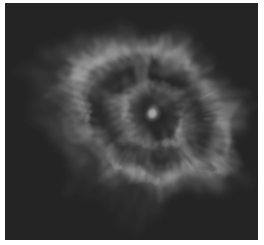


Comparative sizes of stars

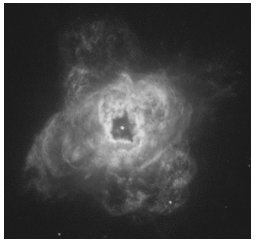
UNIT 3

THE DEATH OF A STAR

- Stars eventually run out of fuel, e.g. hydrogen, for the nuclear fusion reaction.
- Stars use other elements for fuel and the core heats up.
- The process leading to the ultimate death of a star depends on the size and mass of the star.
- **Death of a RED GIANT** – small or medium star (e.g. the sun)
  - The core of the star contracts to become extremely hot.
  - The outer layers of gases are driven off into space forming an expanding cloud around the core of the ageing star.
  - This cloud of gases is known as a **planetary nebula**.



Planetary nebula



https://www.flickr.com/photos/hubble_heritage/3200045914

Flower-shaped planetary nebula

- The core contracts to become a **white dwarf** which slowly cools down.
- A white dwarf is very dense and fades with cooling.

White dwarf

Black dwarf

- The cooled white dwarf may become a dark body called a **black dwarf** according to some theories.

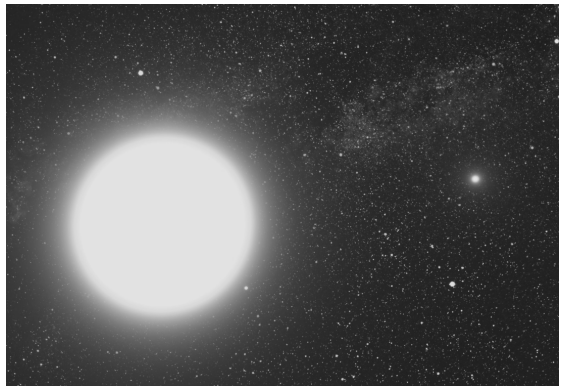
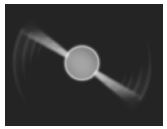


Image credit: NASA

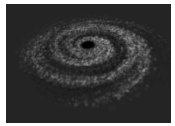
An artist's impression of the brightest star in the sky, Sirius A (main sequence star) on the left and Sirius B (a white dwarf) on the right. White dwarfs are the remains of larger stars that have used up their fuel, collapsed and cooled

- **Death of a SUPERGIANT** – very large star
  - The core of the star contracts and collapses.
  - This results in a massive explosion of the star which is called a **supernova**.
  - The remnants of the core either:
    - contract into a very small, dense ball that seems to spin, called a **neutron star**

Supernova

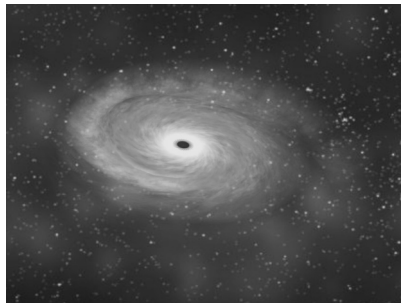


Neutron star



Black hole

    - collapse completely and form a **black hole** with very strong forces of gravity that trap any object that approaches it, including light



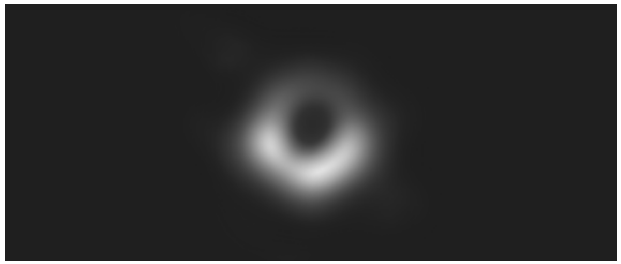
Attribution: By Dana Berry/NASA [Public domain], via Wikimedia Commons

Black hole devours a neutron star

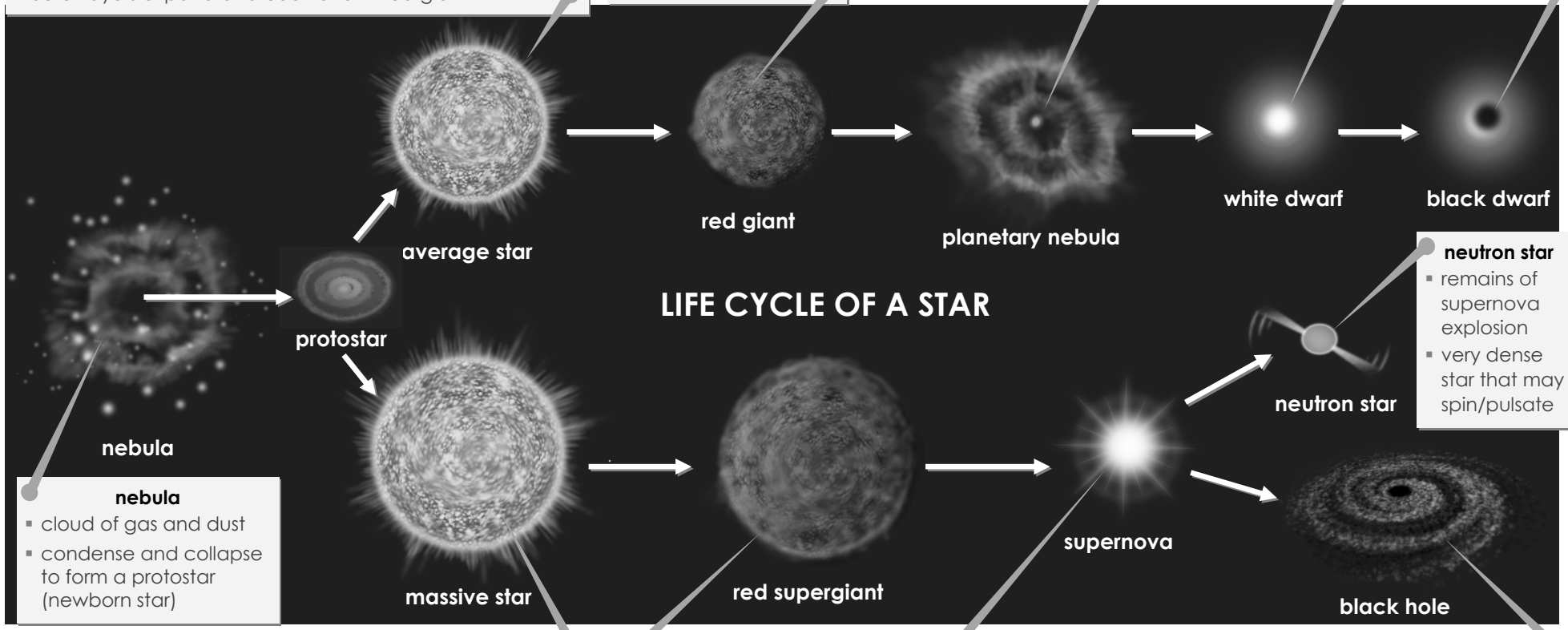
- The gases and dust from dying stars that collapsed or exploded, form **nebulae**.
- The nebulae may contract with gravity to form new stars and begin another star life cycle.

FIRST IMAGE OF A BLACK HOLE

In April 2019, over 200 scientists from around the world collaborated to capture the first image of a black hole using Event Horizon Telescope observations. The image shows light bending around a black hole (with a mass 6,5 billion times greater than the sun) at the centre of a massive galaxy (M87).



Event Horizon Telescope Collaboration



average star
- small/medium size star formed from a protostar
- lower mass star
- e.g. sun
- main sequence star in its stable phase
- nuclear fusion in the core converts hydrogen fuel to helium
- nuclear fusion produces energy (heat and light)
- core runs out of hydrogen fuel and contracts
- outer layers expand and cool to form red giant

red giant
- very large star
- cooler than main sequence stars
- core uses helium fuel
- core contracts
- outer layers of gas are ejected to form a planetary nebula

planetary nebula
- cloud of gases released by dying red giant star
- hot core forms white dwarf

white dwarf
- very dense, hot, white, shrinking stars
- cools and dims to form black dwarf

black dwarf
- remains of white dwarf
- cold and dark

neutron star
- remains of supernova explosion
- very dense star that may spin/pulsate

nebula
- cloud of gas and dust
- condense and collapse to form a protostar (newborn star)

massive star
- very large size star formed from protostar
- great mass star
- e.g. Rigel
- main sequence star in its stable phase
- nuclear fusion in the core converts hydrogen fuel to helium
- nuclear fusion produces energy (heat and light)
- swells and expands to form red supergiant

red supergiant
- largest stars
- core contracts and collapses
- star undergoes supernova explosion
- sheds outer layers of gas that form nebulae

supernova
- explosion of red supergiant due to loss of fuel
- core contracts to form very dense neutron star or collapses completely to form black hole

black hole
- remains of supernova explosion
- very dense area with strong gravity that draws all matter including light

MODULE 4

QUESTIONS

TOPIC 1

THE EARTH AS A SYSTEM

Question 1

Give **one word** or **term** for each of the following statements:

1.1 The part of the earth where life is found.

1.2 The sphere that consists of all the water on Earth.

1.3 The sphere that consists of the soil, rocks, crust and part of the mantle.

1.4 The sphere that contains the oxygen and carbon dioxide which is essential to life.

1.5 Part of the atmosphere that protects the earth from harmful ultra-violet rays.

Question 2

2.1 Read the following and answer the questions that follow.

A system is a general term to describe something or a process that has many smaller parts that are connected and working together. If one part changes it can affect the other parts. The earth is a system as it has four major parts working together in harmony to make the planet function properly. Some studies have included two extra parts: the cryosphere (ice and snow) and anthroposphere (human-made objects and processes).

Planet Earth is made up of many parts: water, trees, animals, air, wind, rocks, etc. and is grouped into four main spheres. These spheres are not static – they are constantly changing. The atmosphere produces different weather every day; wind, rain or sunshine changes daily. New animals are born while older ones die. Seeds germinate and grow up towards the light. Deep down in the earth, there is melted rock that gets pushed upwards during volcanic eruptions in the form of lava. It is a dynamic Earth.

Adapted from: https://eschooltoday.com/earth-system/what-is-earth-system.html

2.1.1 What do you understand by the term *system*?

2.1.2 Name the **four** major spheres of the earth that make it a system.

2.1.3 Write down the **four** major spheres and next to each sphere, give an example of part of the sphere from the extract.

2.2 Draw a table with the **four** main spheres as headings. Complete the table by matching the following terms under the correct heading:

rocks, earthworms, ozone, humans, minerals, gold, oxygen, glaciers, salt, rivers, carbon dioxide, bacteria, snow, nitrogen, methane, oceans, water vapour, coal

Question 3

The figure alongside shows a terrarium. This terrarium consists of a sealed glass container and is self-regulating. In many ways a terrarium can represent the system of the earth. The earth system is a closed system. A closed system does not exchange any matter with another system but it can exchange energy.

3.1 Using the terrarium illustrated above, explain why you think that the earth system can be referred to as a closed system.

3.2 How does the terrarium exchange energy with another system? Compare this with the earth system.

3.3 Which parts of the terrarium represent the:

3.3.1 atmosphere 3.3.2 lithosphere

3.3.3 hydrosphere 3.3.4 biosphere

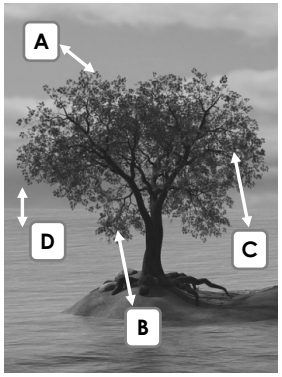
3.4 In the terrarium explain how the plants affect/influence the:

3.4.1 air 3.4.2 soil

3.5 Why would the terrarium not be self-regulating if the plants were removed?

Question 4

The diagram below represents the four spheres of the earth.



4.1 Using the letters, which arrow(s) A, B, C or D represents the following:

4.1.1 interaction between the biosphere and lithosphere

4.1.2 interaction between the hydrosphere and biosphere

4.1.3 interaction between the hydrosphere and atmosphere

4.1.4 the process of photosynthesis

4.2 Identify which sphere(s)of the earth system are involved in the following interactions:

4.2.1 plants release water vapour through their leaves by the process of transpiration

4.2.2 a volcanic eruption

4.2.3 protection of the ozone layer

4.2.4 soil erosion by wind

4.2.5 a person smoking a cigarette

4.2.6 rocks at low and high tide

4.2.7 respiration of living organisms

Question 5

Decomposition is very important to life on Earth. Use your knowledge of decomposition to write a mini-paragraph and identify which sphere is involved in each step of this process.

TOPIC 2 LITHOSPHERE

Question 6

Give **one word** or **term** for each of the following statements:

6.1 The outermost layer of the earth which contains the tectonic plates.

6.2 The layer of the earth that consists of molten rock composed of nickel and iron.

6.3 The sphere that is between 5 – 70 km thick and is composed of soil and solid rock.

6.4 The elements and compounds that make up rock and include iron oxide and silicon dioxide.

6.5 The type of rock that includes both granite and basalt.

6.6 The type of rock formed by either sedimentary or igneous rock that is exposed to heat and pressure.

6.7 The part of the mantle from which rocks are ultimately formed.

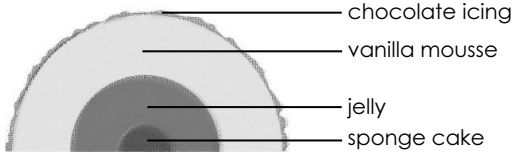
6.8 The process by which exposed rocks are broken up into small particles.

6.9 The pressure on lower layers that is caused by the formation of more layers of sediment.

6.10 A natural process that involves the ongoing formation, breakdown and re-formation of rocks.

Question 7

You have a friend who loves baking desserts. They invite you for a meal and serve a dome-shaped pudding. They cut it in half to show the layers inside. It has a core of sponge cake, surrounded by a layer of jelly, which is surrounded by vanilla mousse and covered with chocolate icing. It resembles the concentric layers of the earth.



7.1 Which part of the earth is represented by the:

7.1.1 chocolate icing? 7.1.2 vanilla mousse?

7.1.3 jelly? 7.1.4 sponge cake?

7.2 The vanilla mousse represents the thickest layer of the earth which can be divided into an inner and an outer layer. Briefly describe this layer of the earth and include how it affects the layer represented by the outermost chocolate icing.

7.3 The following statements are either **true** or **false**. State whether they are true or false and if false, correct the statement.

7.3.1 The innermost layer is made up of solid rock.

7.3.2 The outer core consists of rock made up of metal in a liquid state.

7.3.3 The mantle is made up of rocks which become harder at deeper levels.

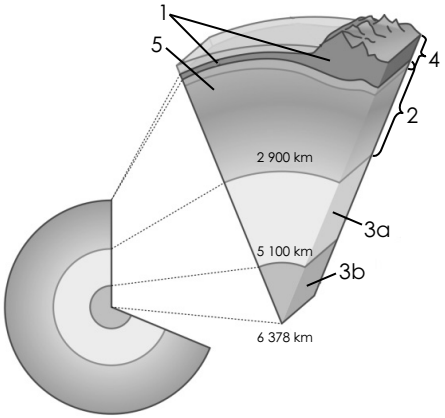
7.3.4 Soil is part of the crust and consists of weathered minerals.

7.3.5 Rocks are made up of different elements and compounds called minerals.

Question 8

The lithosphere is the solid outer part of the earth. It consists of the soil of the crust, the rock of the crust and the solid upper part of the mantle. It is bounded by the atmosphere above and the softer, more movable, upper mantle, which is called the asthenosphere. The lithosphere is thus positioned on top of the asthenosphere.

Diagram showing the outer layers of the earth



8.1 Provide labels for 1, 2, 4 and 5.

8.2 What makes up the lithosphere?

8.3 Which layer contains magma?

8.4 Using the diagram, what can you deduce about the thickness of the crust underneath the continents compared to underneath the oceans?

8.5 Which layer(s) contain solid rock?

8.6 'Ultimately all **three** types of rock originate from layer 2.'
Briefly explain this statement and refer to the three types of rocks in your answer.

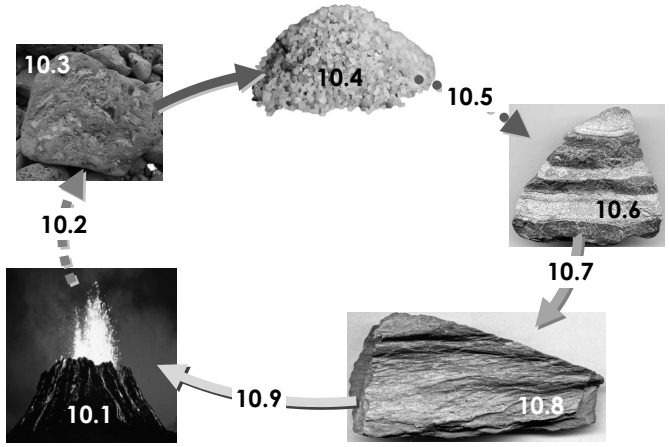
Question 9

Complete the table below.

Types of rock	**A**	**B**	metamorphic
Formation	magma that has cooled	**C**	**D**
Presence of crystals	**E**	none	**F**
Presence of fossils	**G**	**H**	none
Examples	granite and **I**	sandstone, **J** and **K**	marble and **L**

Question 10

Simplified representation of the rock cycle



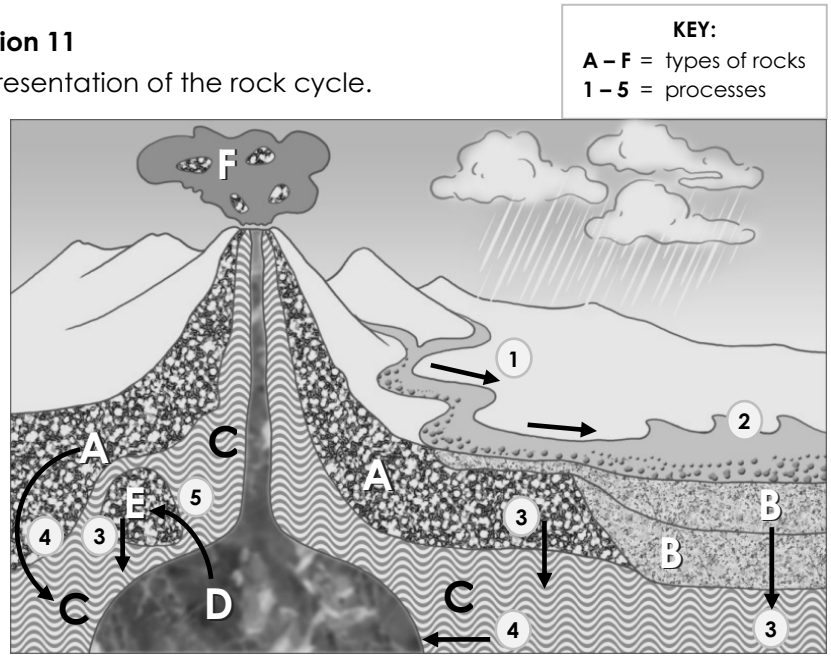
Match up the processes and rock types listed below (A – I) with the stages in the rock cycle diagram (10.1 – 10.9) on p. 224.

Write down the correct letter only next to the number.

A - Igneous rocks are formed by cooled magma.
B - Sedimentary rocks deposited deep in the earth's crust are exposed to intense heat and pressure until they undergo metamorphosis.
C - Metamorphic rock melts, is pushed under the crust and the cycle begins once more.
D - Magma cools and hardens/crystallises.
E - Metamorphic rocks are formed.
F - Sediment accumulates and the layers are compacted together.
G - Magma or molten rock is pushed through the earth's surface by a volcanic eruption.
H - Sedimentary rocks are formed.
I - Weathering and erosion cause igneous rocks to break up into tiny particles.

Question 11

A representation of the rock cycle.



11.1 Identify the rock types labelled A – D.

11.2 Process 1 represents *weather* and *erosion*. Explain what happens during these processes.

11.3 Rock B is formed by process 2.

11.3.1 Identify process 2.

11.3.2 Give **two** examples of rock B.

11.3.3 Which **two** factors are necessary for rock B to be transformed into rock C during process 3?

11.3.4 Would you consider this process a chemical or physical process? Explain your answer.

11.4.1 Identify process 4.

11.4.2 Would you consider the process in Question 11.4.1 a chemical or physical process?

11.5 Identify process 5.

11.6 E and F are both igneous rocks. Distinguish between E and F by naming them, explaining their origin and providing an example for each.

11.7 Name **two** examples of metamorphic rocks.

TOPIC 3 MINING OF MINERAL RESOURCES

Question 12

Give **one word** or **term** for each of the following statements:

12.1 Rock that contains a large quantity of valuable minerals.

12.2 When minerals are made purer through a series of processes.

12.3 The type of mining that involves minerals found in river beds and uses a pan or sluice box.

12.4 The type of processing that involves crushing or heating or filtering the ore to extract the mineral.

12.5 The type of processing that involves chemicals, heat and oxygen to dissolve the mineral during extraction.

12.6 The chemical process that is involved in refining iron from iron ore.

12.7 The mineral mined in Phalaborwa, the widest opencast mine found in Africa.

12.8 The structure where iron ore is placed together with limestone and coke in the chemical refining of iron.

12.9 Mining waste water with a low pH that can potentially cause damage to the environment.

12.10 The accumulation of large mounds of waste material that remains after the mineral has been extracted from the ore.

Question 13

Humans have used mineral resources from the lithosphere from earliest times. The following questions deal with minerals and mining.

13.1 Name **two** uses of metal from the Stone, Bronze and Iron Ages.

13.2 List **two** minerals that can be used in their natural form.

13.3 Define *mining*.

13.4 In which layer of the earth is copper ore found?

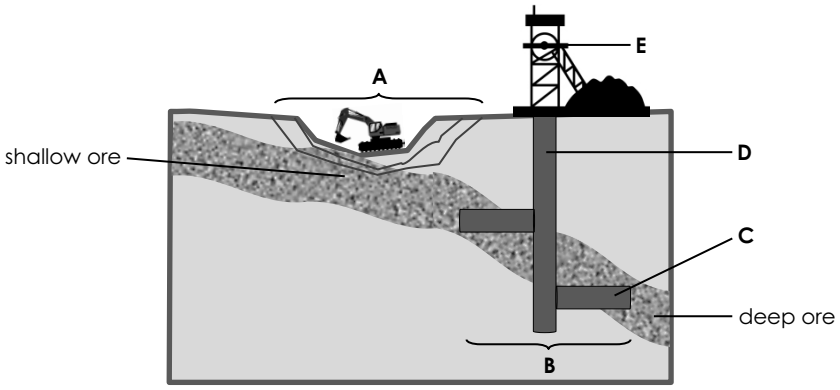
13.5 Is copper classified as an element or a compound? Explain your answer.

13.6 Explain what is meant by an *opencast mine*.

13.7 Name the purified form of carbon that is used in the refining of iron.

Question 14

Minerals are found in various quantities in the lithosphere. A mine is used to extract the mineral from areas where the ore occurs in high quantities. Technology helps geologists find the high quantity ore before digging.



14.1 What type of mining will occur at A? Explain.

14.2 Coal is an example of a mineral that would occur at A. Give another example of a functional mineral that could be mined at A.

14.3 What type of mining will occur at B? Explain.

14.4 Gold is an example of a mineral that could be mined at B. Give another example of an aesthetic mineral that could be mined at B.

14.5 Give labels for C, D and E and provide the functions of each in the mining process.

Question 15

Duma and Ester conducted an investigation on three different soil samples to determine the iron content. They also had a soil sample of building sand acting as the control. Each soil sample weighed 150 g and had been passed through a sieve, so there were no particles larger than 2 mm^3 in each sample. The soil was dried in an oven for 5 hours at 1 000°C. During the investigation, each soil sample was placed on the same piece of cardboard. Duma used the same magnet each time, placed it under the cardboard and moved it 5 cm. Ester used the same scientific scale to weigh the amount of soil that moved 5 cm. Duma and Ester repeated the investigation 3 times. The results are shown in the table below.

Table showing the amount of soil moved as an indicator of iron present in the soil

	Investigation 1 (g)	Investigation 2 (g)	Investigation 3 (g)
Soil A	0	0	0
Soil B	1,3	1,1	1,4
Soil C	2,7	2,5	2,5
Soil D	1,8	1,5	1,7

15.1 Write a hypothesis for this investigation.

15.2 List **three** fixed variables.

15.3 Give the letter of the soil sample that acts as the control. Explain your answer.

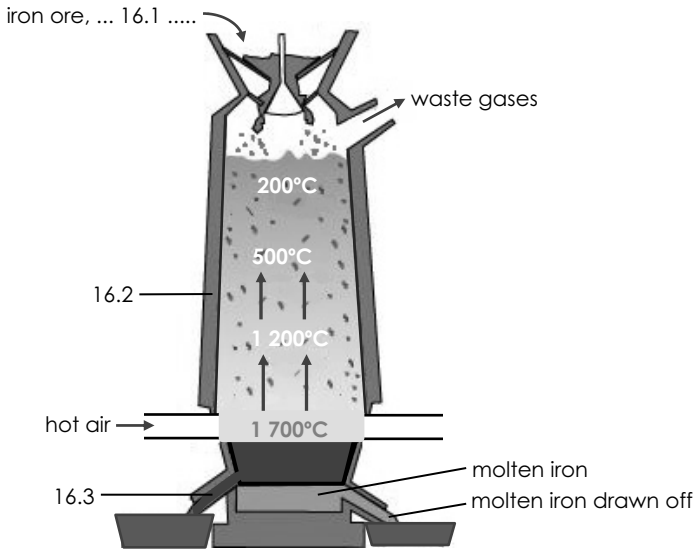
15.4 Why do you think it was necessary to dry the soil?

15.5 Rank the soils from least iron to most iron (use the letters A, B, C and D).

15.6 What is the average mass of soil D that moved 5 cm? Show your working.

Question 16

Diagram to illustrate the chemical refining process of iron. The labels correspond to the questions provided below.



16.1 Which **two** substances are heated with the iron ore in this structure?

16.2 Identify this structure in which iron ore is heated.

16.3 Name the floating liquid that is drawn off and cooled.

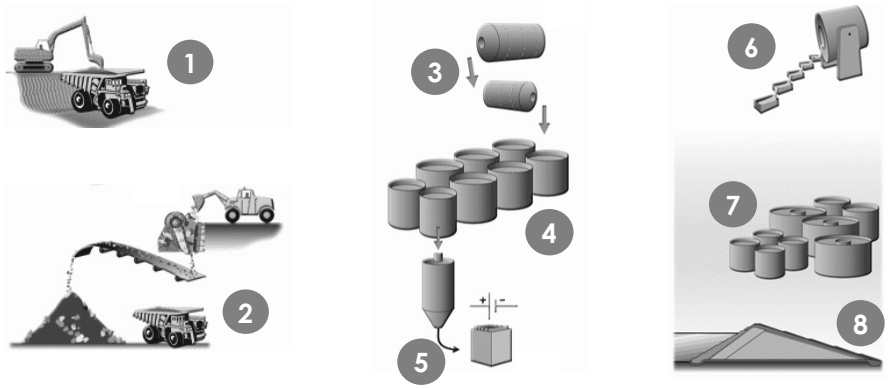
16.4 Which chemical refining process is illustrated above?

16.5 What is the connection between steel and iron?

16.6 List **three** advantages of steel above iron.

Question 17

The extraction of gold from gold ore involves the following:



17.1 Match up the processes of the extraction and refining of gold listed below (A – H) with the corresponding diagrams above. Write down the letter and correct number only.

A - gold is refined in a furnace and poured into moulds

B - a slurry is formed of ground ore, water, cyanide and lime to dissolve the gold and is passed through tanks containing carbon which attaches to the gold

C - gold is separated from the carbon in electrolyte washing solutions

D - gold ore is crushed into smaller pieces

E - waste water from mining processes is stored and recycled or treated

F - gold ore is extracted from deep in the lithosphere

G - waste rock and tailings slurry are removed and form mine dumps or tailings dams

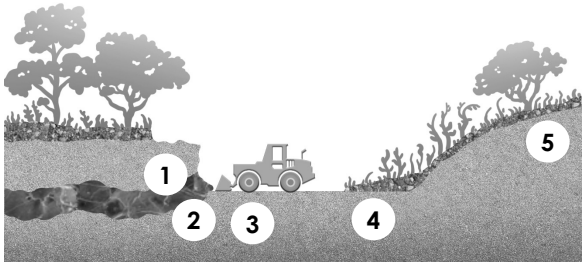
H - a mill grinds small pieces of ore into a fine sand

17.2 What is the main purpose of processes 2 and 3?

Question 18

The following are key steps in the establishment of a coal mine:

Step 1: The topsoil layer is removed
Step 2: The overburden (rock above the layer of coal) is removed
Step 3: The coal is mined
Step 4: After the coal is removed, the topsoil and overburden is replaced to restore the natural vegetation
Step 5: The land is rehabilitated



18.1 What is the relationship between step 1 and biodiversity?

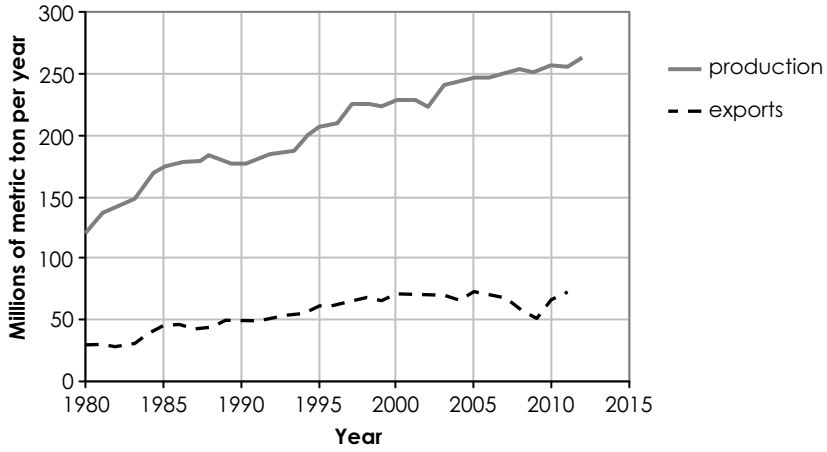
18.2 What type of mining is shown at step 3?

18.3 List **three** environmental impacts of step 3.

18.4 Suggest reasons why steps 4 and 5 do **not** often occur in South Africa.

Question 19

The graph below shows the production and export of coal in South Africa.



19.1 How many millions of metric ton of coal was produced in 1985?

19.2 In which year were coal exports the highest?

19.3 Is coal a non-renewable resource? Explain your answer.

19.4 Name **two** things coal is used for in South Africa.

19.5 Explain why the use of coal is seen as environmentally harmful.

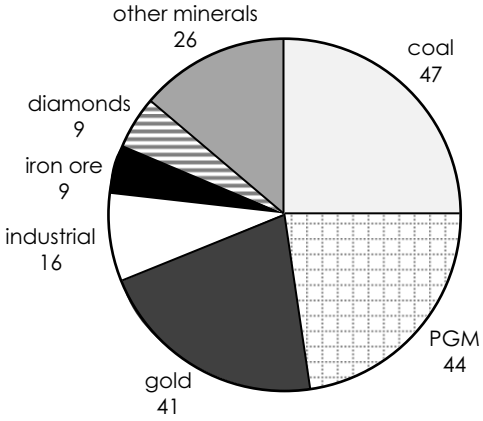
19.6 Name **two** provinces in South Africa where coal is mined.

19.7 List **two** economic benefits of coal mining for South Africa.

19.8 What conclusion can you make from the data provided on the production graph?

Question 20

The pie graph below shows the number of different mining projects in South Africa that were ready to start production in 2017. A total of 192 mining projects could be started if money was secured to finance them.



NOTE

PGM = platinum group of metals

20.1 Read the following statements and determine whether they are true or false:

A PGM and coal make up more than half the possible new mines that were ready for production.

B Gold makes up half of the possible new mines that were ready for production.

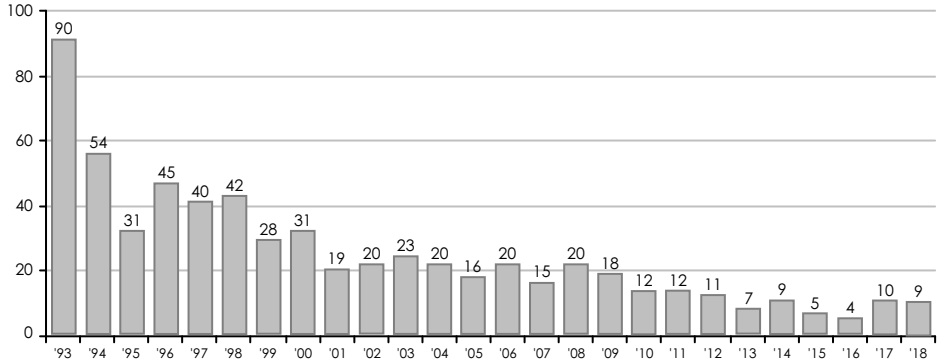
C The percentage of diamond mines that were ready for production could be calculated as follows:

$$\frac{9}{192} \times \frac{360}{1}$$

D Iron ore projects make up 4,7% of the total number of mining projects that were ready for production.

20.2.1 Convert the data from the bar graph below into a table. **Only** use the years 2010 to 2018.

Number of fatalities in South African coal industry (1993 - 2018)



20.2.2 What percentage does the number of deaths in 2018 form of the total deaths recorded in 1993?

20.2.3 Suggest a reason for the significantly low number of fatalities in 2016.

TOPIC 4

ATMOSPHERE

Question 21

Give **one word** or **term** for each of the following statements:

21.1 The layer of the atmosphere closest to the earth.

21.2 The gas that makes up the highest composition of air.

21.3 The layer of the atmosphere where the ozone layer occurs.

21.4 Chemicals which were released into the atmosphere and thinned the ozone layer.

21.5 The layer in the atmosphere that starts above 80 km from the earth.

21.6 The effect that helps maintain the temperatures on the earth and acts like a protective blanket.

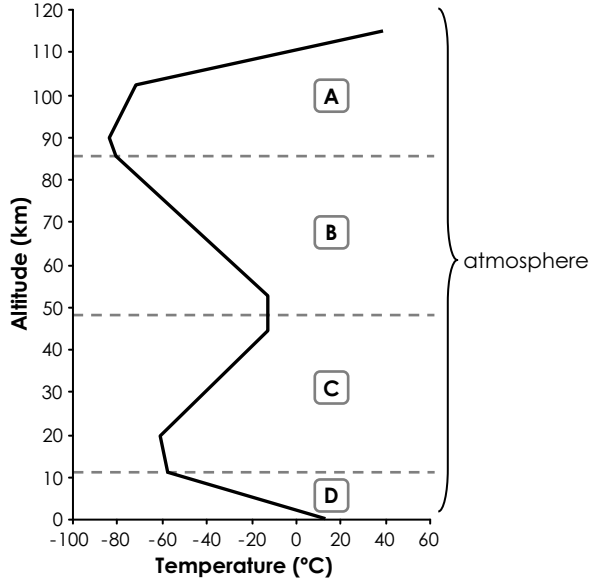
21.7 The type of radiation which the ozone layer provides protection against.

21.8 A phenomenon where the average temperature worldwide is increasing and leading to climate change.

21.9 Death of many species in a short period of time.

21.10 A type of energy that will limit the release of greenhouse gases.

Question 22



22.1 Provide labels for A, B, C and D.

22.2 Provide a suitable heading for the graph above.

22.3 Use the information from the diagram above and the list of items below to complete the table.

mountain peaks, ozone layer, passenger aeroplanes, meteors, rainbow, weather balloon, radio waves, satellites, spacecraft, animals, clouds, Northern lights (Auroras)

Label	Layer in the atmosphere	Altitude/ height above sea level	Thickness of layer	Temperature changes with altitude i.e. increases/decreases	Items (matched to the layer)
A					
B					
C					
D					

22.4 Give the name of the layer(s) in the atmosphere that is associated with each of the following statements:

22.4.1 It contains more than 70% of the mass of the atmosphere.

22.4.2 High energy ultraviolet radiation from the sun is absorbed in the ozone layer.

22.4.3 The layer in the atmosphere where weather patterns form.

22.4.4 Burning rocks visible from the earth and known as meteors or shooting stars.

22.4.5 Radio waves are reflected back to the earth for TV broadcasts.

22.4.6 The International Space Station (ISS), where astronauts work in a laboratory onboard, orbits in this layer.

22.4.7 Animals and plants live in this layer where there is sufficient oxygen and water vapour to sustain life.

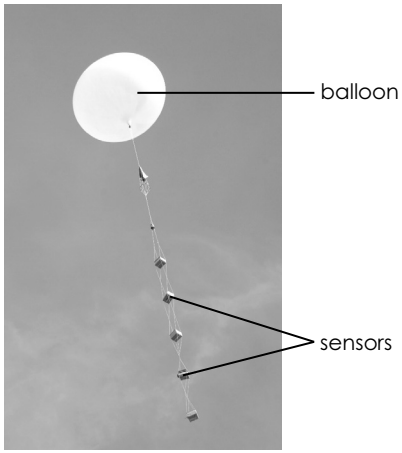
22.4.8 The only layer to have water vapour and clouds.

22.4.9 The layer(s) in the atmosphere where temperature increases as altitude increases.

22.4.10 The layer in the atmosphere where greenhouse gases are mainly found.

Question 23

A weather balloon measures temperature at different altitudes in the atmosphere. It consists of a balloon filled with helium gas and attached to the balloon are sensors that transmit data back to the earth.



In still air, it has been shown that the temperature decreases with altitude in the troposphere. It decreases about 1°C per 100 m.

23.1 Why will the diameter of the balloon increase as it rises?

23.2 On a warm day with no wind the temperature at sea level is 33°C. Calculate the approximate air temperature at an altitude of:

23.2.1 600 m

23.2.2 1 000 m

23.3 An aeroplane is flying at about 1400 m above sea level and it records an air temperature of -5°C. Calculate the approximate air temperature at an altitude of:

23.3.1 500 m

23.3.2 sea level

23.4 In less than an hour the balloon can reach a height of 20 000 m.

23.4.1 What is this height if measured in kilometres above sea level?

23.4.2 Which layer of the atmosphere does the balloon reach at this altitude?

23.4.3 How will the scientist, who monitors the data transmitted from the weather balloon, know that the balloon has left the troposphere?

23.4.4 Explain why the temperature changes in this layer of the atmosphere.

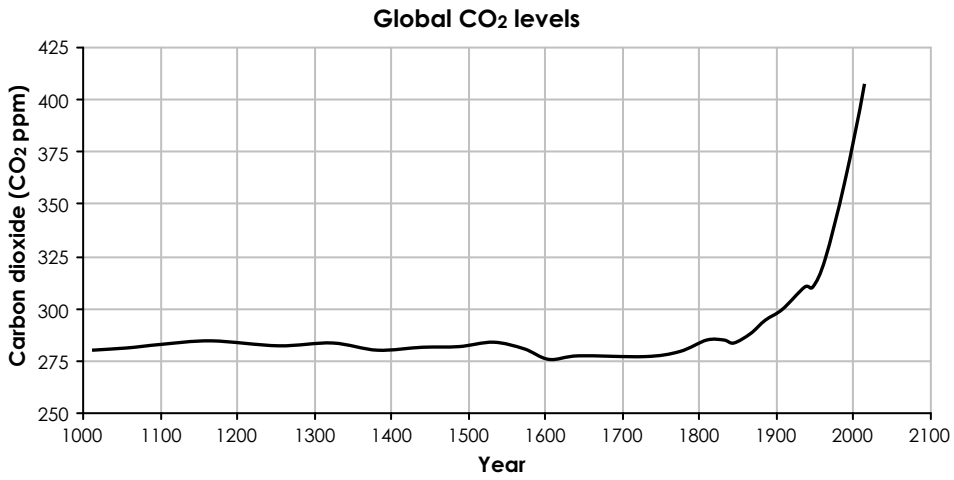
23.5 As the balloon keeps rising it will reach a band of gas called ozone gas which makes up the ozone layer.

23.5.1 What is ozone?

23.5.2 Why is this layer so important to life on Earth?

23.5.3 Explain how human activities have reduced this layer.

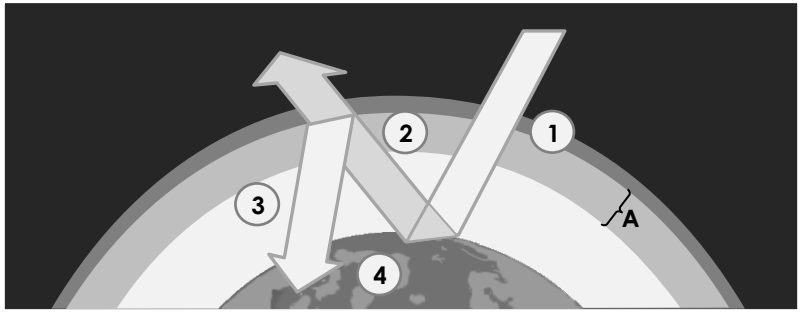
Question 24



24.1 What trend is this graph showing?

24.2 Explain the main cause for the trend observed.

24.3 The diagram given below illustrates the natural greenhouse effect.



24.3.1 Label A represents the layer of greenhouse gases.

(a) What are greenhouse gases?

(b) List **three** greenhouse gases.

(c) Name the main greenhouse gas that occurs naturally in the atmosphere.

24.3.2 Explain the process of the greenhouse effect by referring to numbers 1 – 4 on the diagram.

24.3.3 What is the advantage of the natural greenhouse effect for life on Earth?

24.3.4 Human activities are having an effect on layer A. This layer is becoming thicker. Explain how the following activities are contributing to the increased thickness of layer A:

(a) deforestation (b) burning of fossil fuels

(c) landfills (d) dairy farms

24.3.5 An increase in the thickness of layer A results in the **enhanced greenhouse effect** and a consequence of this enhanced greenhouse effect is **global warming**.

(a) What do you understand by the *enhanced greenhouse effect*?

(b) What is meant by *global warming*?

(c) List **four** consequences of global warming.

TOPIC 5

BIRTH, LIFE AND DEATH OF STARS

Question 25

Give **one word** or **term** for each of the following statements:

25.1 A thick cloud of gas and dust from which stars are formed.

25.2 A reaction that occurs when the nuclei inside atoms join together.

25.3 A gigantic explosion that finishes off a supergiant star.

25.4 The most stable period in the lifetime of a star.

25.5 Colour of young stars.

25.6 Stars which are red in colour.

25.7 The cloud of gases that surround a contracting core resulting from the death of a small or medium star.

25.8 Remains of a supernova explosion that forms a small, dense ball that spins.

Question 26

Just like living organisms, stars have a life cycle. Stars are born, live their lives, changing as they age, and eventually they will die. Scientists speak of stellar evolution when talking about the birth, life and death of stars. The life cycle of a star spans over billions of years. There are many stars in our galaxy which are in different stages of their lives. Scientists are therefore able to build up an understanding of the process of stellar evolution. The following are stages (**A** – **E**) in the lifecycle of a star and they are not in order:

A When the main sequence star begins to run out of hydrogen fuel, it either develops into a red giant or a red super giant, depending on its mass.

B Heat and pressure build in the core of the protostar until nuclear fusion takes place.

C Gravity can draw some of the gas and dust in the nebula together, forming contracting clouds called protostars.

D Stars start out as clouds of gas and dust drifting through space. A single cloud is called a nebula.

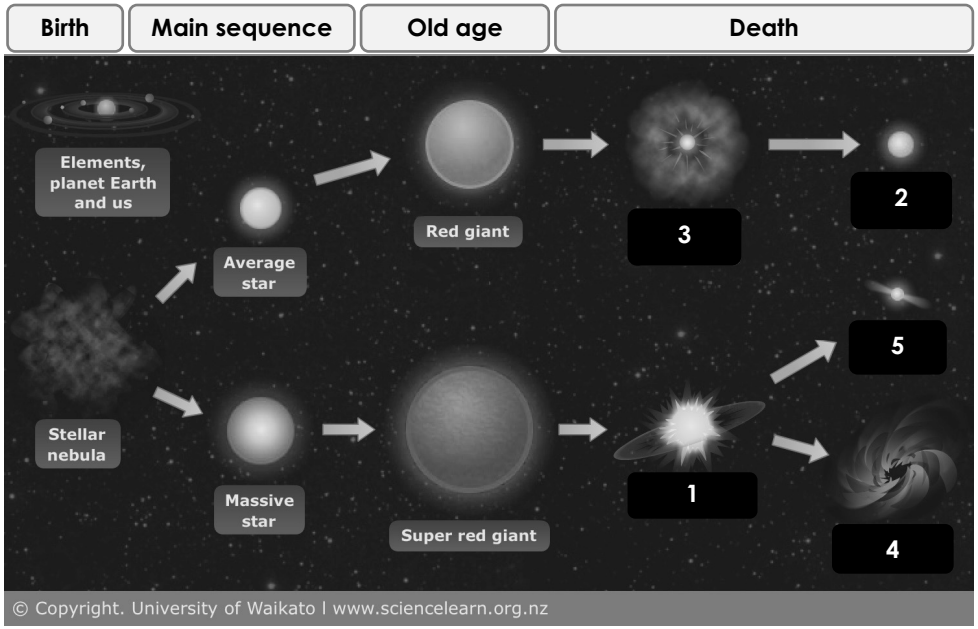
E Once the star has 'switched on', it is known as a main sequence star. This is the most stable period in the lifetime of a star.

26.1 Using the letters (**A** - **E**) arrange the statements in the correct sequence.

26.2 Write down the letters of the stages in stellar evolution that represent the birth of a star.

26.3 Write down the letters of the stages in stellar evolution that represent the life of a star.

26.4 The diagram below shows the stellar evolution of a star:



26.4.1 Provide labels for 1 – 5.

26.4.2 Place the following stages in the life of a star in the correct order (use the letters only).

A main sequence B protostar

C white dwarf D red giant

26.4.3 Which main sequence star represents our sun?

26.4.4 What will happen to the sun after it has been through all the stages in Question 26.4.2?

26.4.5 Why is it not possible for light to escape a black hole?

26.4.6 Why does a white dwarf eventually become a black dwarf?

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