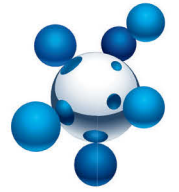


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# Natural Sciences Teacher's Guide

Grade 9-A (CAPS)

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*reaching new frontiers*



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### Periodic Table of the Elements

		No Element																																	
		1	2	3	4	5	6	7	8	9	10	11	12	13	14	15	16	17	18																
1	H																																		
3	Li	4	Be																																
11	Na	12	Mg																																
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
55	Cs	56	Ba	57-71	La-Lu	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
87	Fr	88	Ra	89-103	Ac-Lr	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Uut	114	Uuq	115	Uup	116	Uuh	117	Uus	118	Uuo



- Transition Metal
- Metal
- Metalloid
- Non-metal
- Noble Gas
- Lanthanide
- Actinide

57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr

# Natural Sciences

Grade 9-A

CAPS

developed by



funded by

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foundation

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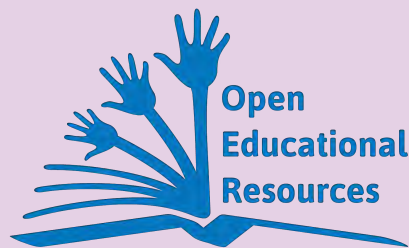
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This book was written by Siyavula with the help, insight and collaboration of volunteer educators, academics, students and a diverse group of contributors. Siyavula believes in the power of community and collaboration by working with volunteers and networking across the country, enabled through our use of technology and online tools. The vision is to create and use open educational resources to transform the way we teach and learn, especially in South Africa.

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To learn more about the project and the Sasol Inzalo Foundation, visit the website at:

**[www.sasolinzalofoundation.org.za](http://www.sasolinzalofoundation.org.za)**

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# Teacher's Guide Overview

## Curious? Discover the possibilities!

### VISIT

Carl Sagan was an astronomer, astrophysicist, cosmologist, author, science popularizer and science communicator. Watch one of his most pertinent messages for humanity here [bit.ly/1bbVDqg](http://bit.ly/1bbVDqg)

Asking questions and discovering our world around us has been central to human nature throughout our history. Over time, this search to understand our natural and physical world through observation, testing and refining ideas, has evolved into what we loosely think of as 'science' today. Key to this, is that science is a continuous revision in progress, it is a mechanism rather than a product, it is a way of thinking rather than a collection of knowledge, whose driving force is not certainty in a truth, but rather being comfortable with uncertainty, thereby cultivating curiosity.

However, as Carl Sagan famously said in 1994:

*"We live in a society absolutely dependent on science and technology, and yet have cleverly arranged things so that almost no one understands science and technology. That's a clear prescription for disaster."*

We need to replace fear of the unknown and the difficult with curiosity, as Marie Curie said:

*"Nothing in life is to be feared, it is only to be understood. Now is the time to understand more, so that we may fear less."*

We would like to instill this sense of curiosity and an enquiring mind in learners. Science, technology, engineering and mathematics are not subjects to be feared, rather they are tools to unlock the potential of the world around you, to create solutions to problems, to discover the possibilities.

But, how do we practically do this in our classrooms? We would like this workbook to become a tool that you can use to do this. The theme for the presentation of this content in Gr 7-9 Natural Sciences is 'Curious? Discover the possibilities.' We have shown everyday science and objects with 'doodles' over them to show how if you are curious, intrigued and investigate the world around you, there are many possibilities for discovery. Sometimes these doodles are science or technology related, and sometimes they are more fantastical and fun. Learners should be inspired to discover, but also imagine the possibilities, as Freeman Dysan said:

*"The glory of science is to imagine more than we can prove."*

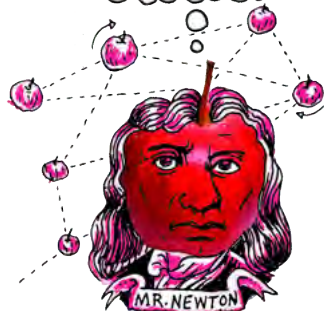
Learners must be encouraged to 'doodle' themselves, take notes during your class discussions, write down their observations, reflect on what they have learned. They must not be afraid of drawing and writing in these books. Science is also about being creative in your thinking.

We have aimed to present the content in an investigative, questioning way. At the beginning of each chapter, the topics are introduced by asking questions to which you will discover the answers as you go through the chapter. In teaching learners to ask questions, make observations, think freely and creatively, they



### DID YOU KNOW?

Marie Curie was a chemist and physicist famous for becoming the first person to be awarded two Nobel Prizes.



will be rewarded. Although, possibly not every time - it requires patience and determination. Although your learners will be exploring science and the world around us within a classroom context where assessment is integral, keep in mind this idea from Claude Levi-Strauss, when instilling the ethos of science in your learners:

*"The scientist is not a person who gives the right answers, but one who asks the right questions."*

Science is relevant to everyone. Scientific principles, knowledge and skills can be applied in creative and exciting ways to solve problems and advance our world. It is not just a subject restricted to our classrooms, but reaches far beyond, and within. Ultimately, we also want learners to embark on a personal discovery and be curious about their own potential and possibilities for the future.

Albert Einstein certainly did this when he observed:

*"The most beautiful experience we can have is the mysterious - the fundamental emotion which stands at the cradle of true art and true science."*

**TAKE NOTE**

Albert Einstein repeatedly did poorly at school, dropped out at 16 and failed his first university entrance examinations. Every child deserves a chance to become someone, sometime in some place.



## The Natural Sciences curriculum

As learners enter the Senior Phase in their schooling, the focus is now purely on Natural Sciences within this subject, and Technology is a separate subject. However, there are close links between the content in both of these subjects as they complement each other. The Natural Sciences curriculum also links to what learners cover in Social Sciences and Life Orientation. Whether you are a subject specialist teacher, or a class teacher, it is worthwhile to take note of where Natural Sciences overlaps with and integrates with some of the other subjects that learners are covering.

### Organisation of the curriculum

In the Natural Sciences curriculum, the knowledge strands below are used as a tool for organising and grouping the content.

Natural Sciences Knowledge Strands
Life and Living
Matter and Materials
Energy and Change
Planet Earth and Beyond

These knowledge strands follow on from Gr 4-6. The strands also link into each other, and these have been pointed out both within the learners' workbook and here in the teachers guide.

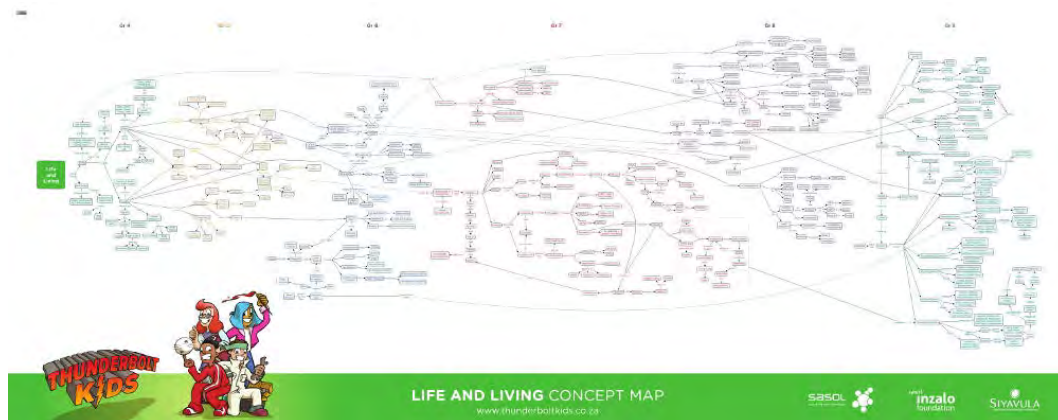
We have also produced **concept maps** which show the progression of concepts across the grades, within a strand, and how they build upon each other. These concept maps are useful tools for teaching to see what learners should have covered in previous grades, and where they are going in the future.

**VISIT**

If you would like to see what learners covered in **Gr 4-6 with the Thunderbolt Kids**, visit [www.thunderboltkids.co.za](http://www.thunderboltkids.co.za)







## Allocation of teaching time

The time allocation for Natural Sciences is as follows:

- 10 weeks per term with 3 hours per week
- Grades 7, 8 and 9 have been designed to be completed within 34 weeks
- Terms 1 and 3's work will cover 9 weeks each with 3 hours (1 week) allocated to assessment within each of these terms
- Terms 2 and 4's work will cover 8 weeks each, with 2 weeks allocated to revision and examinations at the end of each of these terms

Below is a summary of the time allocations per topic in Grade 9. This time allocation is a guideline for how how many weeks should be spent on each topic (chapter).

### Life and Living



Chapter	Time allocation
1. Cells as the basic units of life	2 weeks
2. Systems in the human body	2 weeks
3. Human reproduction	2 weeks
4. Circulatory and respiratory systems	1.5 weeks
5. Digestive system	1.5 weeks

### Matter and Materials

Chapter	Time allocation
1. Compounds	1 week
2. Chemical reactions	1 week
3. Reactions of metals with oxygen	1.5 weeks
4. Reactions of non-metals with oxygen	1 week
5. Acids, bases and pH value	1 week
6. Reactions of acids with bases	2 weeks
7. Reactions of acids with metals	0.5 weeks

### Energy and Change

Chapter	Time allocation
1. Forces	2 weeks
2. Electric cells as energy systems	0.5 weeks
3. Resistance	1 week
4. Series and parallel circuits	2 weeks

5. Safety with electricity	0.5 weeks
6. Energy and the national electricity grid	1 week
7. Cost of electrical power	2 weeks

## Planet Earth and Beyond

Chapter	Time allocation
1. The Earth as a system	1 week
2. Lithosphere	2 weeks
3. Mining of mineral resources	2 weeks
4. Atmosphere	2 weeks
5. Birth, life and death of stars	1 week

We have provided a finer breakdown of the time into the number of hours to spend on each section within a chapter in the Chapter overviews in the Teacher's Guide. However, again, this is a guideline or suggestion and should be applied flexibly according to circumstances in the classroom and to accommodate the interests of your learners.

### Specific aims

There are three specific aims in Natural Sciences which are covered in these workbooks in the range of tasks provided and in the way the content is presented.

#### Specific Aim 1: 'Doing Science'

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

There are many practical tasks within this workbook that provide the opportunity to conduct investigations to answer questions using the scientific method, to use scientific apparatus, instruments and materials and to develop a range of process skills, such as observing, measuring, identifying problems and issues, predicting, hypothesizing, recording, interpreting and communicating information. The skills associated with each task in this workbook have been identified in the chapter overviews in this Teacher's Guide.

Learners also need to be aware of the ethical concerns and values that underpin any science work that they do, as well as health and safety precautions. Where appropriate, these have been pointed out in the learners workbook and in this Teacher's Guide.

#### Specific Aim 2: 'Knowing the subject content and making connections'

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

In teaching and discovering the content in Natural Sciences, the aim for learners is not to just recall facts, but to also use the knowledge to make connections between the ideas and concepts in their minds. Most of the activities in this workbook have questions at the end which aim to consolidate the knowledge and skills learned in the task, and also help learners to make connections with what they have previously learned.

There are many opportunities for discussion when going through the content in these workbooks. This is often highlighted in the Teacher's Guide with suggestions for how to lead the discussion and what questions to ask your

learners to stimulate their minds and create links between what they are learning. There are often questions within the learners' workbooks which relate what they are learning at that point to previously acquired knowledge and experience.

Many of the links between content and also between strands and grades are pointed out within this Teacher's Guide. We suggest also making use of the concept maps when creating a clear picture in your own mind of the framework of knowledge that learners should have up to that point about a particular topic.

### **Specific Aim 3: 'Understanding the uses of Science'**

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

There is a strong emphasis in these workbooks to show that science is relevant to our everyday lives, and it is not restricted to what we learn within the classroom. Rather, we are learning about the natural and physical world around us and how it works, as well as how our own bodies function.

These workbooks aim to show learners that many of the issues in our world can be solved through scientific discovery and pursuit. For example, improving water quality, conserving our environment, finding renewable energy sources and medical research into cures for diseases. Where appropriate, the history of various scientific discoveries and inventions, as well as the scientists involved, have been discussed.

These workbooks also aim to highlight the beauty, diversity and scientific achievements, discoveries and possibilities in our country, South Africa. An appreciation of local indigenous knowledge is very important. When going through particular topics in class, encourage your learners to talk about their own experiences so that learners are exposed to the indigenous knowledge of different cultures, to different belief systems and worldviews.

Understanding how scientific discovery has shaped and influenced local and global communities will enable learners to see the connections between Science and Society. This will help to reinforce that Science is practical and relevant, and it can be used as a tool together with other subjects like Mathematics and Technology to find solutions and understand our world.

### **How to use this workbook**

We would like these Curious workbooks and Teacher's Guides to become a tool for you in your classrooms to teach, explore and discover Natural Sciences.

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We would also love it if you told us how you are using this content as it helps us refine our processes.

## Structure of the book

There is an A and a B book for the Natural Sciences content.

The A book covers term 1 and 2:

- Life and Living
- Matter and Materials

The B book covers terms 3 and 4:

- Energy and Change
- Planet Earth and Beyond

These books are an amalgamation between workbooks and textbooks. They have spaces for learners to write and draw whilst completing their tasks. Learners must be encouraged to write in these books, take notes, and make them their own. These workbooks also contain the content to support the various tasks. This makes these books slightly longer than usual.

The beginning of each chapter starts off with **KEY QUESTIONS**. These introduce the content that will be covered in the chapter, but rather phrased as questions. This reinforces the idea of questioning, being curious and the investigative nature of science to discover the world around us and how it works.



**TAKE NOTE**

A suggestion is to use the concept maps as a self-study homework exercise for learners to go over what they have learned in the chapter.



The content and various **ACTIVITIES** and **INVESTIGATIONS** follow:

- **Investigations** are those tasks where learners will be using the scientific method to answer a question, test a hypothesis, etc. These are science experiments.
- **Activities** are all other tasks where the learner is required to do something whether it is making a model, researching a topic, discussing an idea, doing calculations, filling in a table, doing a play, writing a poem, etc.

At the end of each chapter there is a **SUMMARY**, where the **KEY CONCEPTS** highlight the main points from the chapter. Following this, there is a **CONCEPT MAP** for each chapter. One of the aims for these workbooks is to also teach various methods of studying and taking notes. Producing concept maps is one way to consolidate information. Throughout the year, the skill of making concept maps will be taught as the maps have more and more for the learners to fill in themselves as the year progresses.

Lastly, there is **REVISION** at the end of each chapter. There are mark allocations for these questions. These revision exercises can be used as formal or informal assessment.

At the end of each strand there is a **GLOSSARY** which contains the definitions for all the **NEW WORDS** which are highlighted throughout that strand.

**Going through the content**

These workbooks are a tool for you to use in your classroom and to assist you in your teaching. You will still need to plan your lessons and decide which activities you would like to do. There are sometimes more activities provided than what is possible within the time allocation. We have specifically done this to give teachers a choice, providing different levels of tasks.

The tasks which are suggested in CAPS have been identified here in the teachers guide, and we have marked those that are **optional** or **extensions**.

When going through the content in class and you are using the workbook, there are various questions within the content. These questions are aimed at stimulating class discussions where learners can take notes, or they link back to what learners have already done. The answers are provided in the Teacher's Guide. Use these questions to check learners understanding and keep engaged with the content.

The various activities and investigations often contain questions at the end. The questions can often be used as a separate activity, even the next day in class or as homework, to reinforce what was learned.

**Teacher's notes**

The way this Teacher's Guide is structured to provide the content of the learner's book, but with all the model solutions written in italic blue text, and with many **Teacher's notes** embedded within the content.

An example of a teacher's note:

**TEACHER'S NOTE**

This is an example of what a teacher's note looks like. It can contain:

- chapter overviews
- suggestions on how to introduce a topic

- guidelines for setting up or demonstrating a practical task
- general tips for teaching the content
- extra background information on a topic
- misconceptions which can easily be introduced to learners, or which learners might already have

At the beginning of each chapter, there is a **CHAPTER OVERVIEW**. This is crucial for your planning. This overview contains:

- the number of weeks allocated to the chapter, as suggested in CAPS
- an introduction to the chapter, highlighting any links to previous content that learners have already covered, or anything to be aware of when going through the content
- tables highlighting the various tasks for the chapter

The tables for each section can be used to plan your lessons. We have suggested an **hours break down** to spend on each section within the chapter, based on how much content there is to cover, and the number of tasks. This is only a suggested guideline.

Within each table, we have listed the different Activities and Investigations and the **process skills** associated with each task.

The third column contains the Recommendation for the task. These recommendations are, in order of priority:

- **CAPS suggested** (a task suggested in CAPS)
- **Suggested** (a task we suggest doing, but is not suggested in CAPS)
- **Optional** (an additional activity which is optional if you have time or would rather do this than the other suggested tasks)
- **Extension** (an additional activity which is optional and also an extension)

An example of one of these tables is given below:

### 1.1 Cell structure (2.5 hours)

Tasks	Skills	Recommendation
Activity: Brainstorm the Seven Functions of Life	Recalling information	Optional (Revision)
Activity: Summarise what you have learnt	Recalling information, identifying, writing	Suggested
Activity: Cell 3D model	Planning, identifying, describing	CAPS suggested

You will need to look at how many hours you have for each section, and then decide which tasks you would like to do with your learners. These tables provide a useful overview and will also help you choose tasks so that you cover a range of process skills and specific aims.

## Assessment

The assessment guidelines for Gr 7-9 Natural Sciences are outlined in CAPS on page 85.

There are many opportunities for informal assessment within these workbooks. Any of the tasks can be chosen to continuously monitor your learners' progress as well as checking the short answers they provide to questions interspersed in the content.

At the end of each strand in the CAPS document, there is a section on assessment guidelines. There is a column entitled 'Check the learner's knowledge and that they can:' and there is a list. These items are included within the content for that strand and can be used for assessment.

The questions in the revision exercises at the end of each term can be used as formal assessment and you can use these questions, as well as your own, to make class tests and examinations.

At the end of the Teacher's Guide, there is an appendix with Assessment Rubrics. These rubrics are a guideline for assessment for the different tasks which you would like to assess, either informally (to assess learners' progress) or formally (to record marks to contribute to the final year mark).

The various rubrics provided are:

- Assessment Rubric 1: Practical activity
- Assessment Rubric 2: Investigation
- Assessment Rubric 3: Graph
- Assessment Rubric 4: Table
- Assessment Rubric 5: Scientific drawing
- Assessment Rubric 6: Research assignment or project
- Assessment Rubric 7: Model
- Assessment Rubric 8: Poster
- Assessment Rubric 9: Oral presentation
- Assessment Rubric 10: Group work

### Margin boxes

You may have already noticed some of the margin boxes in this Teacher's Guide overview so far. These boxes contain additional information and enrichment.

The **NEW WORDS** highlight not only the new words used, but also the key words for the chapter or section. The definitions for all these new words are listed in the glossary at the back of the strand.

**DID YOU KNOW** has some fun, interesting facts relating to the content.

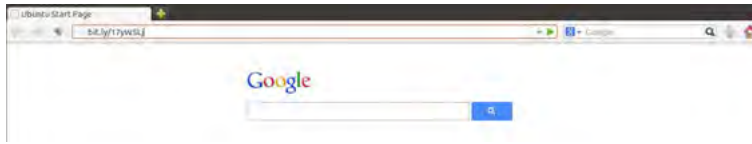
**TAKE NOTE** points out useful tips, with a special focus on language usage and the origins of words. This may be useful to second language learners.

The **VISIT** boxes contain links to interesting websites, videos relating to the content or simulations. This enrichment is also aimed to encourage learners to be curious about their subject in their own time by discovering more online. We feel it is important for learners to be aware that science is a rapidly advancing field and there are many exciting, innovative and useful discoveries being made all the time in science, mathematics and technology research.

To access the links in the VISIT boxes, you will see there is a bit.ly link. This is a shortened link that we created, as sometimes the website links to Youtube videos can be very long! You simply need to type this whole link into the address bar in your internet browser, either on your PC, tablet or mobile phone, and it will direct you to the website or video.

For example, in this Teacher's Guide overview, there is the link to a video about why open education matters. It is [bit.ly/17yW5Lj](http://bit.ly/17yW5Lj) Simply type this into your address bar as shown below and press enter.





This will either direct you to a website page, or to our website where you can watch the video online.

**Discover more online at** [www.curious.org.za](http://www.curious.org.za)

## Get involved

When we first embarked on this journey to create these books, our first step was to hold a workshop with volunteer teachers to get their perspective, suggestions and experience. Just turn to the front cover of this book to see how many people contributed in some way to these books! At Siyavula, we believe in openness and transparency and we would love your input in the next phase.

These books are not perfect and we will be continuously improving them. We would find your input and experience as a teacher crucial and highly beneficial in this process.

- Do you have any feedback about the books?
- Do you have suggestions?
- Would you like to share how you use these books in your classroom?
- Have you found any errors you would like to point out so we can fix them?
- Have you tried an activity and found a better way of doing it?
- What more would you like to see in these workbooks?

Get involved and let us know!



Find out more about our Siyavula Community at [projects.siyavula.com/community](http://projects.siyavula.com/community)

And sign up by following this link [bit.ly/15eiA6u](http://bit.ly/15eiA6u). Specify Gr 7-9 Natural Sciences to stay informed about this process going forward in the future.



Download more resources like this on [ECOLEBOOKS.COM](http://ECOLEBOOKS.COM)







# LIFE AND LIVING





**TEACHER'S NOTE****Chapter overview**

2 weeks

This chapter introduces learners to the cell. They may have encountered the cell before, but here we will look at the structure of cells, including the organelles common to most eukaryotic cells. We will also look at the differences between plant and animal cells. Later we look at the hierarchical organisation of cells into tissues then into organs then into systems and then into an organism. Some information has been included on specialised cells. This was thought to be important to introduce the idea of a biological structure being adapted to its function to ensure *functional efficiency*. To be able to describe and explain how a structure is adapted to its perform its functions is an important skill in Life Sciences, especially if learners carry on with the subject in Gr. 10-12. This is an ideal opportunity to start practicing and also to realise that there is huge variety in the types, sizes, and shapes of cells depending on their function.

Learners also have to make a 3D model of a cell in this chapter. This activity may be treated as a project. A suggestion is to turn to this activity at the start so that learners are aware of this and can start thinking about their models at home and what they could use to make them as you are going through the content and learning about the cell. You could then set a deadline for the model, for example one week after you finish this chapter (ie. three weeks then from when you start the chapter), for them to have completed their models.

**IMPORTANT NOTE**

1.1 Cell structure (2.5 hours)

Tasks	Skills	Recommendation
Activity: Brainstorm the Seven Functions of Life	Recalling information, listing	Optional
Activity: Summarise what you have learnt	Recalling information, identifying, writing	Suggested

1.2 Differences between plant and animal cells (2 hours)

Tasks	Skills	Recommendation
Activity: Identify differences between plant and animal cells	Comparing, identifying, describing, writing	CAPS suggested
Activity: Comparing plant and animal cells	Comparing, describing	CAPS suggested
Activity: Cell 3D model	Planning, constructing, identifying, describing	CAPS suggested

### 1.3 Cells in tissues, organs and systems (1.5 hours)

Tasks	Skills	Recommendation
Activity: Evaluating microscopic images	Examining, observing, comparing	CAPs suggested
Activity: Making a wet mount with onion and cheek cells	Preparing and examining specimens, observing, recording, writing	CAPS suggested
Activity: Research the discovery of light and electron microscopes	Researching, writing	CAPS suggested

#### KEY QUESTIONS:

- What are cells?
- Why are cells so small?
- What does it mean to be microscopic?
- Are there different types of cells?
- What is inside a cell and why is it there?
- Are plant and animal cells the same?



In this chapter we will learn about the basic units of life which enable all of functions within living organisms - cells.

## 1.1 Cell structure

#### TEACHER'S NOTE

This website has many interesting articles about science and science-related jobs. They have been classified according to topics and also provide tips on how to incorporate the articles into your classroom and what questions to ask. If you are interested in incorporating real world science into your classroom, this is one website to start looking at: <sup>1</sup> [bit.ly/13ZkfNQ](http://bit.ly/13ZkfNQ)

### What are cells?

All living **organisms**, including plants, animals, bacteria and fungi, are made up of **cells**. Cells are the smallest parts of all living organisms.

If we look at all the living organisms in the world we see that there are two main types of organisms based on the structures of their cells. The most important difference in structure is the presence of a **nucleus**. Cells that contain a nucleus are classified as **eukaryotic** cells, while those without a nucleus are **prokaryotic** cells. In this chapter we will specifically look at eukaryotic cells that make up organisms such as plants and animals. Examples of organisms with prokaryotic cells are bacteria.

### TEACHER'S NOTE

In Gr. 7 CAPS, learners would have learnt about the classification system of organisms into the 5 kingdoms, namely; Bacteria, Protista, Fungi, Plants and Animals. This is a good opportunity to remind learners of this and ask them if they remember what the 5 kingdoms are.

We can say that cells are the basic *structural* and *functional* units of all living organisms. You cannot see individual cells with the naked eye, because they are too small - you need to use a **microscope** to be able to see cells. We say cells are **microscopic** because they can only be seen under a microscope.



Robert Hooke (1635 - 1703)

Robert Hooke was the first cytologist to identify cells under his microscope in 1665. He decided to call the microscopic shapes that he saw in a slice of cork "*cells*" because the shapes reminded him of the cells (rooms) that the monks in the nearby monastery lived in.



### ACTIVITY: Brainstorm the Seven Functions of Life

Do you remember the test you learnt about in previous grades to decide whether an organism is living or non-living? Perhaps you had an mnemonic to remember the seven processes, such as "MRS GREN".

1. Work in your group and see how many of the seven functions of life you can remember. Write them down below.

*Movement*

*Respiration*

*Sense*

*Growth*

*Reproduction*

*Excretion*

*Nutrition*

2. Do you think that an individual cell is living? Explain your answer.  
*Cells are the smallest unit of life and are therefore living.*

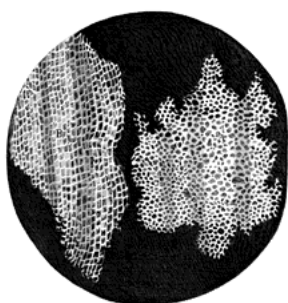


### TEACHER'S NOTE

This is a chance for learners to express their opinion. As we have not yet learned about cells in any great detail, they might not yet agree with the fact that an individual cell is living. Allow learners to express their opinions and justify them. You can also come back to this question at the end of the chapter and reflect on the answers to see if the learners might have changed their minds.

### TAKE NOTE

In this section you'll often read the prefix **cyto-** as in cytoplasm, cytosol or cytoskeleton. **Cyto-** means 'cell' so if you read cytoskeleton it actually says: 'cell-skeleton'.



Robert Hooke was the first to use the term 'cell' when he studied thin slices of cork with a microscope.



Robert Hooke's microscope that he used to first view cells.

### TAKE NOTE

The **Visit** boxes in the margins contain links to interesting websites and videos. Simply type the link exactly as it is into the address bar in your browser.

## Different types of cells

### TEACHER'S NOTE

As an entry point to this section, you may want to use these types of questions to ask at the start of the lesson: Do you think all cells are the same? If they are not the same, can you think of reasons why they differ or how they might differ? Discuss your thoughts with the class.

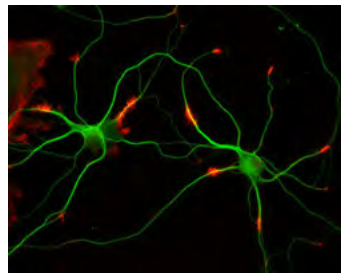
Your body is made up of many different kinds of cells. We say your cells are **specialised** to perform a specific function. Depending on the function of the cell, it can be specialised by having a different shape or size or may have some components which other cells do not have. Have a look at the differences between nerve cells and red blood cells in the images.

### TEACHER'S NOTE

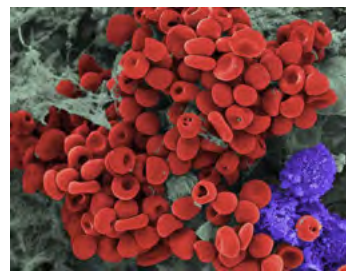
Ask your learners to describe the differences in shape between the nerve cells and the red blood cells in the images. Take note however, that the images have been coloured in afterwards - these are not the real colours of the cells, so learner must not say that nerve cells are green, etc.

As an extension ask them how they think the shape helps with the function of the cells. Describing how the structure of a particular biological component is suited to (adapted to) its function (ie. **functional efficiency**) is a very important skill in Life Sciences and should be developed from early on. You can give brief descriptions of the function of the cells:

- Nerve cells transmit (send) messages throughout the body from the brain to perform functions. So the fact that nerve cells are elongated (like long thin wires) and branched, helps them to send these messages over long distances and make connection with many other cells.
- Red blood cells carry oxygen from the lungs to the rest of the body. Their shape is adapted to carry oxygen and pass easily through very narrow capillaries to get to the individual cells. Red blood cells also do not have a nucleus so that there is more space for oxygen to be transported.



*These nerve cells appear green under a fluorescence microscope.*



*Red blood cells have a round, biconcave shape.*

Even though there are many different types of cells, there are components of the cell structure which are common to all cells. There are also some structures which most, but not all, cells have. Let us take a look at this in the next section.

#### TEACHER'S NOTE

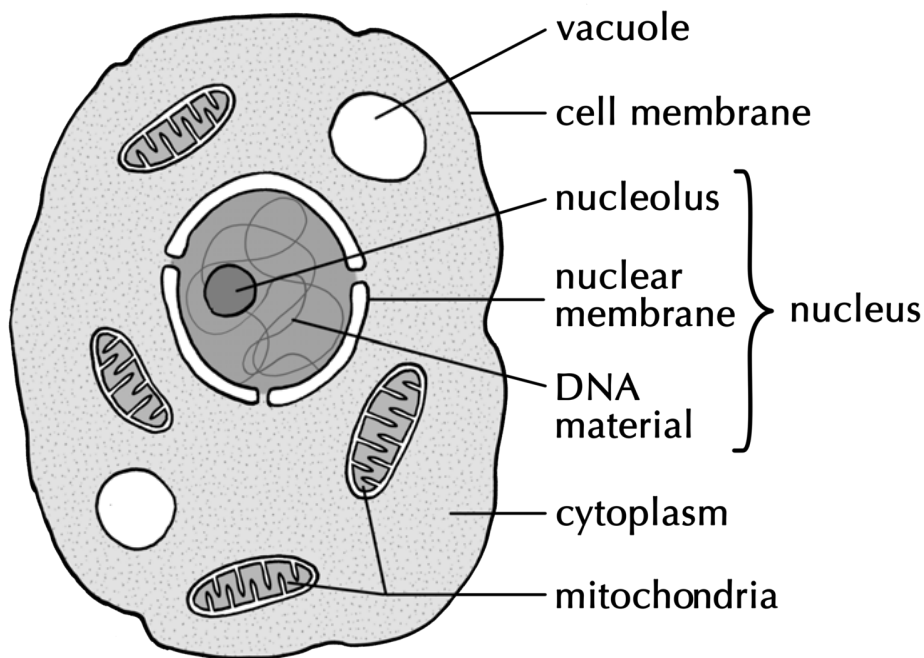
As an introduction to the cell organelles teachers might want to show learners one or two of the YouTube songs included in the margin. They offer a fun entry-point into this topic.

### Cell Structure

As we have mentioned before, all cells have some common structures. These are:

- a **cell membrane**
- **cytoplasm**; and
- in most eukaryotic cells, a nucleus

Let's now have a look at the structure of these components of the cell, and some of the other organelles common to cells. An **organelle** is a specialised structure within the cell that performs a function for the cell. Examples of organelles in cells are **vacuoles** and **mitochondria**. Look at the diagram which identifies the different components in a simple animal cell.



A drawing of a typical animal cell

#### VISIT

Videos about the cell and cell organelles.  
[bit.ly/14k3Q5S](https://bit.ly/14k3Q5S) and  
[bit.ly/19bsCKt](https://bit.ly/19bsCKt)

#### TAKE NOTE

If something is 'permeable', then it means that substances, such as gases and liquids, can pass through it freely.

#### TAKE NOTE

In Natural Sciences we speak of a **medium** when we talk about a solution in which organelles, cells or organs are grown or suspended. Can you think of other meanings for the word medium?

## Cell membranes

All cells have a cell membrane around them. The cell membrane is a thin layer that encloses the cell's contents and separates the cell from its environment.

Many different substances have to pass in and out of a cell in order for it to function. The cell membrane controls which substances are allowed to enter and leave the cell. We say the cell membrane is **selectively permeable**. The organelles are also surrounded by membranes.

### TEACHER'S NOTE

In order to explain the idea of 'selective permeability', you could use the analogy of a gate and security wall around someone's home - explain that only certain people get access to a private home and the gate serves to deny access to undesirable people. Also waste products in the form of garbage bags are put outside the perimeter fencing to be removed and food and water is allowed to enter. As with viruses and diseases, thieves and criminals can however still penetrate the home's defences and will then attack the owners/cell organelles.

## Cytoplasm

### TEACHER'S NOTE

The cytoplasm is often referred to as the jelly-like substance within cells. This is only partly true as the cytoplasm actually consists of the jelly-like substance (called cytosol) **and** all the cell organelles (**except the nucleus**). The term for the combined cytoplasm (cytosol + organelles) and the nucleus (containing

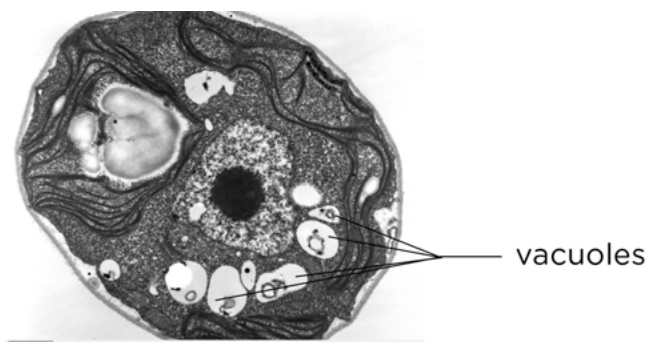
nucleoplasm) is **protoplasm**. You should be aware of this when introducing the cytoplasm to learners so that this misconception can be avoided later on in their school career.

The cytoplasm includes all living parts of the cell within the cell membrane, but excluding the nucleus. The cytoplasm is made up of the cytosol and the cell organelles. The cytosol is a watery, jelly-like medium made of 70%-90% water, and is usually colourless.

The cytosol is a mixture of different substances dissolved in water. Do you remember what a mixture is from Matter and Materials? These substances within the cytosol include salts, various elements, such as sodium and potassium, and more complex molecules, such as **proteins**.

The cytosol is also where many chemical reactions take place. Next term, in Matter and Materials, we will learn more about chemical reactions.

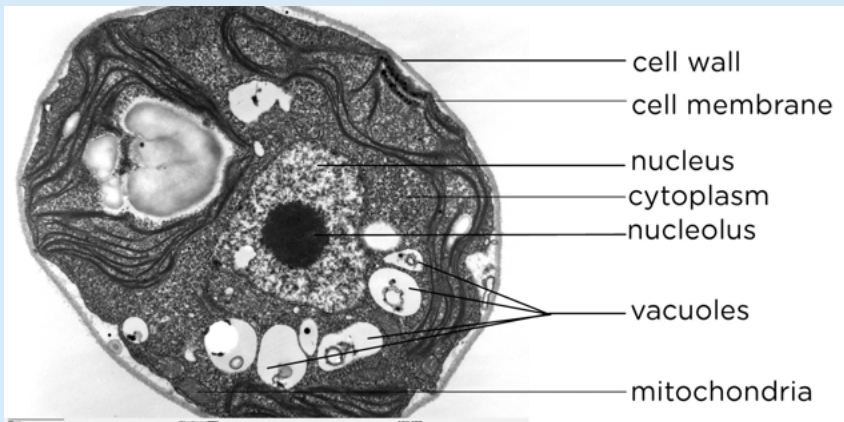
The cell organelles making up the cytoplasm include mitochondria, chloroplasts and vacuoles. Vacuoles are organelles enclosed by a membrane and contain mostly water with other molecules in solution. The size and number of vacuoles within a cell varies greatly and depends on the type and function of the cell.



*This is a micrograph of a plant cell. Can you see the clear, white organelles, which are the vacuoles? The cytoplasm appears very granular in this image.*

#### TEACHER'S NOTE

In this image of a plant cell, there are several vacuoles present, as is the case in many plant cells. The nucleus, with its dark nucleolus is also very clear. You can come back to this image a bit later to look at the nucleus again. If learners ask what the grey-white structure in the top left hand side is, this is a starch grain. Plants store starch grains within the cytoplasm. You can get your learners to provide labels for the vacuoles and cytoplasm in this image. Also visible is the cell wall of the plant cell - the cell membrane is the inner, more folded boundary, whereas the cell wall is the light grey, more rigid structure on the outside. Faintly visible are several mitochondria, for example the grey oval structures at the bottom left. Come back to this image once you have done these structures to add these labels in.



*A labelled micrograph of a single-celled plant*

#### **TAKE NOTE**

The difference between eukaryotic and prokaryotic cells is that eukaryotic cells have a nucleus which contains the genetic material surrounded by a membrane. Prokaryotic DNA floats in the cytoplasm without a membrane.

## **Nucleus**

Plant and animal cells have a **nucleus** inside the cytoplasm. It controls all the processes and chemical reactions that take place inside the cell. The nucleus also contains the cell's genetic material which is organised into long **DNA** molecules.

The nucleus is structured as follows:

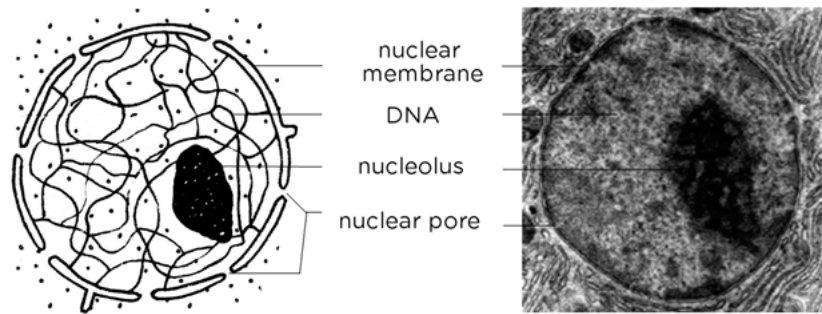
- A double membrane called the **nuclear membrane** encloses the DNA. This nuclear membrane contains pores (holes) for substances to pass through.
- There is a **nucleolus** inside the nucleus. This is often seen as a darker area within the nucleus.
- The DNA contains information about **inherited** characteristics (**hereditary**), such as whether the person will have blue, brown or green eyes.

Have a look at the micrograph of a nucleus and the diagram of the nucleus.

#### **TEACHER'S NOTE**

Studying micrographs is a very important skill to develop for later in Life Sciences. Learners are often only exposed to schematic diagrams of cells which present an idealised view of the cell. They then find it very difficult to identify these structures within a micrograph of an actual cell. Encourage your learners to take note of how the diagram below was drawn and how it differs to the micrograph of the nucleus. Remind your learners that a micrograph is a photograph taken through a microscope, and in this case, a transmission electron microscope.





Left) A Diagram of a nucleus. Right) A micrograph of a cell nucleus.

DNA is a very important part of all cells and therefore of all life. DNA contains information that encodes all our inherited traits or characteristics. This refers to characteristics which are passed down in families, such as your skin and eye colour, whether you have allergies and also the likelihood of contracting different types of illnesses.

Every organism has unique DNA. The difference in DNA that occurs between individuals is called **variation**. Even the slightest difference in DNA might cause significant variations within **species** and between species. Within species DNA differences or variations can lead to albino animals or the transference of similar illnesses, like sickle cell anemia.



An albino (white) lion lacks pigment due to an alteration in the lion's DNA.

**VISIT**

Learn more about genes  
[bit.ly/lbmf0w0](http://bit.ly/lbmf0w0)

**Mitochondria**

Do you remember that we spoke about food as the energy source for our bodies? Just as wood is burned to use the stored potential energy to make a fire to heat some water, the food that we eat needs to be broken down in order to release the energy so that our bodies can function. **Mitochondria** are responsible for doing this.

**TEACHER'S NOTE**

You can use this opportunity to revise what is meant by stored potential energy and the fact that food is seen as a fuel for our bodies.

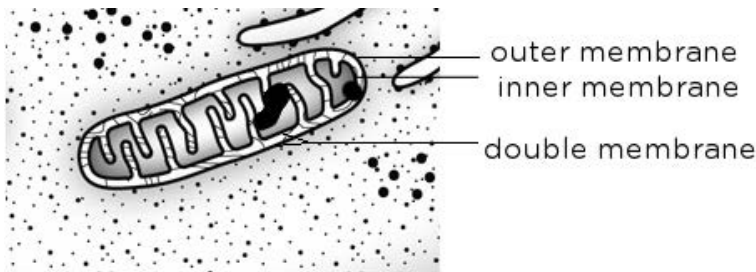


Diagram of a mitochondrion

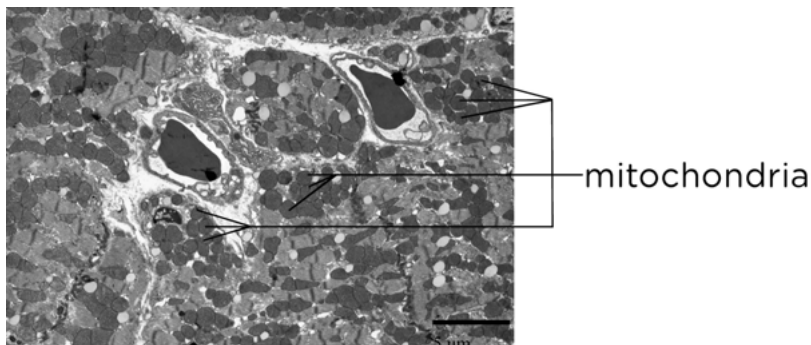
**TAKE NOTE**

Singular or Plural?  
mitochondrion is the singular and mitochondria is the plural form of the word.

Mitochondria are organelles enclosed by a double membrane. Cells that are very active would typically have more mitochondria than cells that are less active. Which type of cell, do you think, will have more mitochondria: a muscle cell or a bone cell?

**TEACHER'S NOTE**

A muscle cell will contain more mitochondria as muscle cells need a huge supply of energy for movement. You can point this out in the following image of mouse heart muscle tissue. Cardiac muscle tissue is very active and therefore needs a big energy supply, hence the frequency of mitochondria present in the tissue, as seen below.



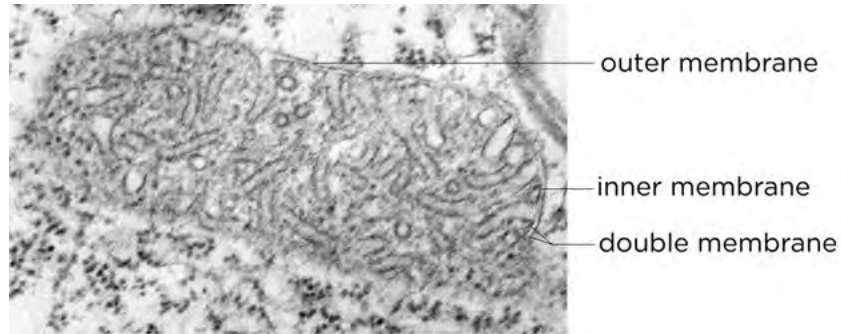
A micrograph of muscle tissue in a mouse. Can you see all the darker grey circles? These are mitochondria.

Once food molecules enter the cells and pass into the mitochondria, they are used by the mitochondria in a process called **cellular respiration**. During respiration the mitochondrion can combine molecules from food with **oxygen** to release energy that the cell can use. **Carbon dioxide**, water and waste materials are by-products of this process.

**TEACHER'S NOTE**

With reference to the did you know fact in the margin about mitochondrial DNA, learners might ask what we can deduce from the fact that there is such a thing. One theory is that mitochondria originated from bacteria that invaded ancient eukaryotic cells and started living in a symbiotic relationship with the host, eventually losing its ability to live independently. This idea is still very controversial and not universally accepted. MtDNA seems to have an influence

in gene expression and can be used to trace maternal lineage, since we inherit all of it from our mothers, not fathers.

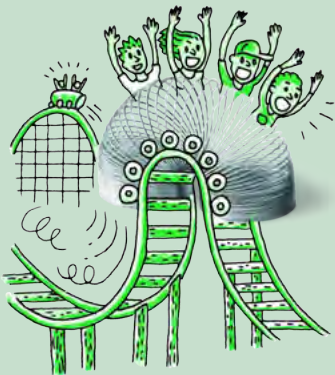


*Micrograph of a mitochondrion within a cell.*

**VISIT**

If you would like to find out how mitochondrial DNA (mtDNA) is responsible for 'old age', read this article by Dr Barry Starr from Stanford University [bit.ly/164z730](http://bit.ly/164z730)

Look at the micrograph of the mitochondrion in the image. What differences can you see between this mitochondrion and the diagram shown previously? In the diagram, it was very clear that the inner membrane folds, whereas in the micrograph it is not as easy to see this. This is because of the way that the cell was sectioned (cut) before it was viewed on the transmission electron microscope. In a diagram, we show an ideal representation of the organelle. But, when we view an actual organelle under a microscope, it may look quite different depending on how it was cut into a very thin section to view.



**ACTIVITY:** Summarise what you have learnt

Now that you've studied the internal structure of a cell, let us summarise what we have learnt so far. Complete this table filling in the main function of each of the cell structures.

**TEACHER'S NOTE**

Cell Structure	Function(s)
Cell membrane	regulates / controls passage of substances in and out of cell
Cytoplasm	where many of the chemical reactions and processes in the cell takes place
Nucleus	contains DNA (hereditary material) of cell and controls the cell's activity
Mitochondrion	releases energy from food for the cell
Vacuole	stores substances, water, nutrients

## 1.2 Difference between plant and animal cells

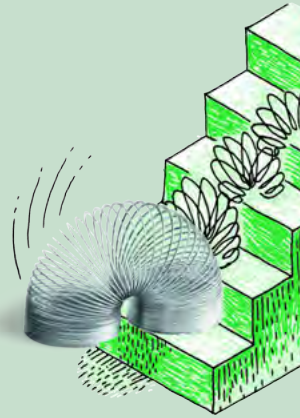
Now that we know what the main similarities are between all plant and animal cells, let's see how they are different.

### ***Plant cells differ from animal cells***

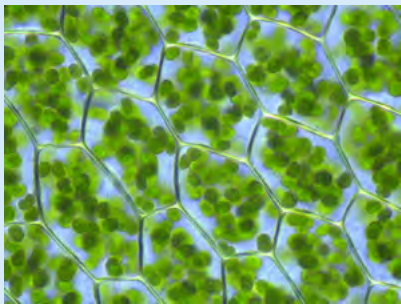
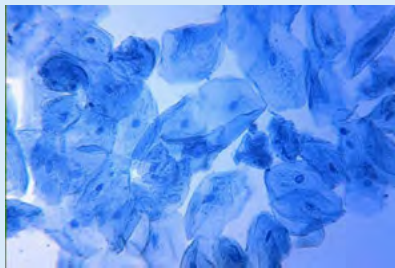
Why do plant and animal cells have differences? Plant and animal cells differ because they have to perform different functions.

### **ACTIVITY:** Identify differences between plant and animal cells

1. Study the pictures below. On the left is a picture of plant cells and on the right is a picture of some animal cells, which have been stained blue.
2. Write differences that you observe in the table below the pictures of the cells.



#### TEACHER'S NOTE

Plant cells	Animal cells
	
<ul style="list-style-type: none"><li>• Plant cells have a regular shape and structure and keep their shape easily</li><li>• A thick outer layer (two 'layers' enclose the cell although this is not very evident in the image)</li><li>• Green chloroplasts for photosynthesis.</li></ul>	<ul style="list-style-type: none"><li>• Animal cells have an irregular shape and structure and bend and fold easily</li><li>• Thin outer layer (only a cell membrane encloses the cell.)</li><li>• No green chloroplasts can be seen.</li></ul>



## Cell wall

All animal and plant cells are enclosed or surrounded by a cell membrane as we learned before. However, as you probably noticed in the previous activity, animal cells often have an irregular shape, whereas plant cells have a much more regular, rigid shape.

Plant cells have an additional layer surrounding the cell on the outside of the cell membrane. This is called the **cell wall**. This wall provides a protective framework for support and stability for the plant cell.

The cell wall is formed from various compounds, the main one being **cellulose**. Cellulose helps maintain the shape of the plant cell. This allows the plant to remain rigid and upright even if it grows to great heights.

### VISIT

Article and video on the solar powered sea slug, *Elysia chlorotica*.  
[bit.ly/17GrwmS](http://bit.ly/17GrwmS)

## Vacuoles

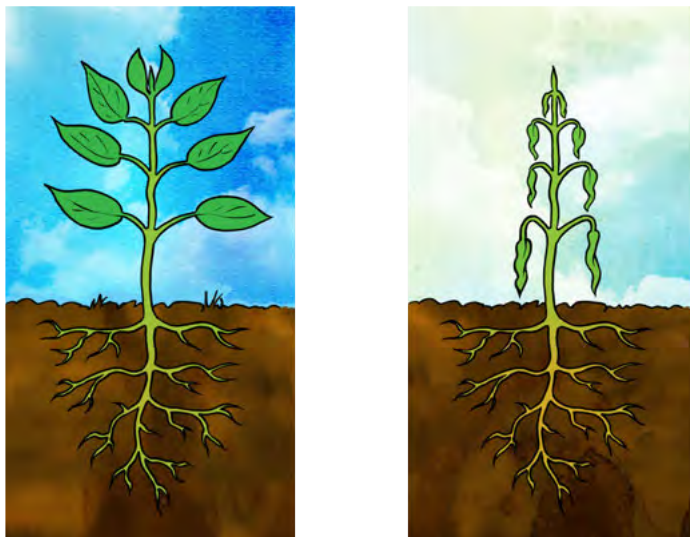
Does a plant have a skeleton? Turn to a friend and discuss what could possibly be used in a plant cell as a skeleton. Think for example of a blade of grass or a long stemmed rose.

### TEACHER'S NOTE

Plants have cell walls to provide support and some learners might remember the vacuoles.

**Vacuoles** in plant cells are usually quite large organelles that can occupy as much as 90% of the cell's volume. The liquid in the vacuole, called cell sap, helps to support the plant. The full vacuoles push out against the cell wall and make the cells, and therefore the plant, rigid. We say the cells are **turgid** in this condition. The opposite to turgid is **flaccid**.

You can easily see when a plant's vacuoles are full and when they are not. When the vacuoles are full the plant's stem and leaves will be held upright and firm. However, if the leaves and stem are drooping, the vacuoles might have lost a lot of water because the soil is too dry and the cell was forced to use up this water to survive.



*Left: A plant with turgid vacuoles is rigid and stands upright. Right: A plant with flaccid vacuoles droops (called wilting).*



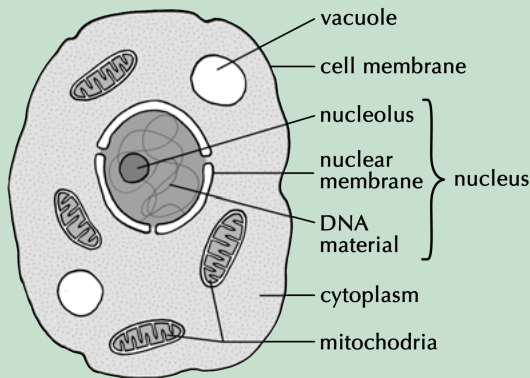
Vacuoles are only present in some animal cells and they are typically very small and have a short life-span.

## ACTIVITY: Comparing plant and animal cells

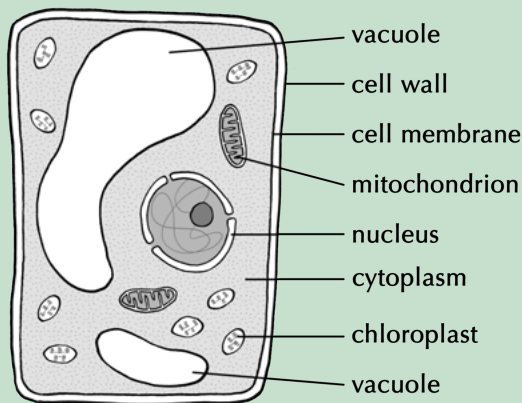
Study the two diagrams of plant and animal cells below.

1. Draw a table of differences between the two cell types in the space provided. Give your table a suitable heading.
2. Also provide labels for the different cell structures and organelles.

*Here are the labels for the animal and plant cell diagrams.*



*A typical animal cell.*



*A typical plant cell.*

*An example of the type of table that learners might produce is given below. Learners might present the information in a slightly different layout, which should be encouraged, if it is logical and legible. For example, they might not have the first column with the characteristic.*

*Table summarizing the differences between plant and animal cells*

<b>Characteristic</b>	<b>Animal cells</b>	<b>Plant cells</b>
Shape	Have an irregular shape	Have a rigid, regular shape
Cell wall	Do not have a cell wall, only a cell membrane	Have both a cell membrane and a cell wall.
Vacuoles	Have small vacuoles, which are often temporary or absent	Have large vacuoles
Chloroplasts	Do not have chloroplasts	Have chloroplasts to photosynthesise



### **ACTIVITY:** 3D model of a cell

In a 3D cell model, we will be making built models out of materials where we will use other objects to represent the actual parts of the cell.

#### **INSTRUCTIONS :**

1. You must create a 3D model of a cell.
2. You may use whatever materials or 'media' you choose to create your cell.
3. Your model must clearly show the following:
  - cell membrane
  - nucleus with nuclear membrane
  - cytoplasm
  - mitochondria
  - vacuoles
  - chloroplasts
  - Any other organelles that you might have learnt about

### TEACHER'S NOTE

This activity can be used as a project. Encourage learners to be creative when doing this task. They could make cell pizzas (with different toppings representing the organelles), cell jellies (with different fruits representing the organelles), or they may wish to use recycled items to represent the different functions of the organelles (such as batteries to represent mitochondria). The possibilities are endless.

Learners could create cell models out of playdough as an alternative option. Different colours can be created using different food colouring. The recipe for playdough is as follows:

- 1 cup plain flour
  - 1/2 cup of salt
  - 2 tablespoons of cream of tartar (optional)
  - 1 tablespoons of cooking oil
  - food colouring
  - 1 cup of boiling water
1. Add all the ingredients in a large bowl and mix together until it starts to bond together and becomes hard to mix.
  2. Take it out of the bowl and throw it on a board (or other surface for this purpose). (It will be hot when you take it out of the bowl so be careful.)
  3. Knead the dough until it takes on the look and consistency of play dough.
  4. Add the food colouring to get the colour you want.
  5. Keep the playdough in an airtight container in the fridge before use.

### Requirements for your cell model:

- Your model and the examples of the organelles need to show some resemblance to the real organelle that we have learnt about so far.
- Your model needs to be clearly marked with a heading and your name.
- Each organelle needs to be clearly labelled and with each label you need to add a description of the function of that particular organelle.
- You also need to make an accompanying drawing (at least the size of an A4 page) including the labels of the structure of a basic plant and animal cell.
- Your teacher will assess your model according to a rubric.

### TEACHER'S NOTE

Although there is a general assessment rubric for models supplied in the Appendix of the Teacher's Guide, here is a more detailed rubric that you can use to assess your learners' models out of 40 marks. You can photocopy this rubric if you wish to provide it to your learners so that they know how they will be assessed.

TOTAL [40 marks]

Aspect	4	3	2	1
Model construction	Materials carefully chosen and modified to resemble organelle	Materials were well chosen and tried to modify some to resemble organelle	Appropriate materials chosen and organelles and their functions were fairly accurately represented	Inappropriate materials chosen, model did not represent structure or function of the organelles
Model presentation	Model represented in creative, carefully planned way; headings and labels added; clearly and correctly presented and in 3D	Cell model is almost complete and mostly correctly presented; it is mostly 3D	Cell model is fairly correctly presented but not complete and missing more than 3 organelles; more than half is 3D	Cell model is missing more than 5 organelles; it is not 3D and is poorly presented
Representation of organelles	Organelles are the appropriate size in proportion to the rest of the cell structures. All 7 minimum organelles are present	1 or 2 organelles are not appropriately proportioned or do not have correct size or shape; Not all 7 minimum organelles present	3-6 organelles are not appropriately proportioned and incorrect size/shape used; 3-6 organelles missing from list	Representation seems careless and rushed; many organelles missing or incorrectly included; lacks planning
Labelling of organelles	Organelle flags or a key is used successfully and all organelles are clearly labelled	1-2 flags are missing or incorrectly placed; few spelling errors	3-6 flags are missing or incorrectly placed; many spelling errors	If flags are included they are incorrectly placed; many spelling errors
Understanding of organelles	Displays a clear understanding of all 7 organelles and their function(s) in the cell	Displays a good understanding of at least 5 cell organelles and their function(s)	Displays a fair understanding of at least 3 of the organelles and their function(s)	Displays very little understanding of organelles and their function(s)

Aspect	4	3	2	1
Class presentation	Presentation is well planned and confidently given; learner is an expert on the cell	Presentation is mostly clear displaying confidence; Not sure of 1-2 things	Presentation is at times unclear or unprepared; learner is unsure of most of the organelles and cell structure	Unclear or unprepared presentation; learner mostly unsure of organelles and cell structure
Drawing of cell	Cell is drawn accurately and neatly; excellent detail	Cell drawing is good and clear though missing 1-2 organelles; fairly neat. Includes 1-2 inaccuracies	Cell drawing is fairly good but missing 3-5 organelles and includes 3-5 inaccuracies	Very basic cell drawing showing very few organelles and many inaccuracies; untidy and poorly presented
Scientific method used to label drawing	Label lines are neatly drawn with a ruler; they do not cross and labels are grouped neatly on one side of the drawing; heading supplied; no spelling errors in labels	Label lines neatly drawn though not always with ruler; 1-2 cross; heading supplied but 1-2 spelling errors. Label lines not grouped on one side but placed around the drawing	Label lines either drawn by hand or missing; if included they cross; labels are placed all over the drawing, not neatly on one side	No lines included and no labels included
Rubric handed in with cell model and self-assessment completed	Rubric handed in; very good self-assessment and accurate grasp of their abilities and challenges	Rubric handed in with fairly good self-assessment completed. Fairly accurate assessment	Rubric handed in with some self-assessment done but it is unrealistic and a poor portrayal of their model	Learner handed in the rubric with the cell model but did not assess themselves on it
Handed in on time	Handed in on due date	Handed in one day after due date	Handed in two days after due date	Handed in three or more days after due date



### 1.3 Cells in tissues, organs and systems

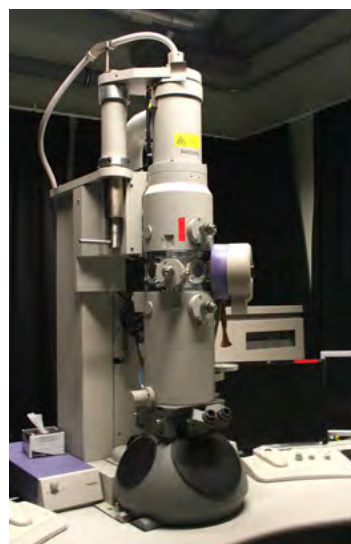
Now that you have learnt all about different cells, are you ready to see them for yourself?

#### Observing cells under a microscope

##### TEACHER'S NOTE

This section on microscopy is meant as an introduction as learners will need to be able to use microscopes later in this chapter, as well as if they carry on with Life Sciences in Gr. 10. Learning how to use an instrument is a very good skill. In Gr. 10 Life Sciences, learners will look at the different types of microscopes in more detail. Here, only light and electron microscopes are mentioned briefly.

Have you ever used a microscope before? Microscopes are instruments that are used to look at and study objects that are too small to be seen with the naked eye. Since the days of Hooke's observations, the development of microscopes has come a long way. Today we have incredibly powerful microscopes called electron microscopes which use electrons instead of light to observe very fine detail - even as small as a single column of atoms!



*A modern electron microscope*

##### TEACHER'S NOTE

Learners would have been introduced to the atom in Gr. 8 Matter and Materials and perhaps before. The atom is the building block of all matter. The ability to visualise columns of atoms under a transmission electron microscope indicates how extremely powerful and high resolution these instruments are. A useful site for information about microscopy:<sup>2</sup> [bit.ly/13ZkGaV](http://bit.ly/13ZkGaV)

##### VISIT

Citizen science: Help out in cancer research from your own home! [bit.ly/16DCU45](http://bit.ly/16DCU45)

##### TEACHER'S NOTE

If microscopes are not available in your school, try building one with the learners' help! If Robert Hooke could do it without the wonderful technological marvels we have in our lives today, so can we!<sup>3</sup> [bit.ly/19bsOcQ](http://bit.ly/19bsOcQ) or <sup>4</sup> [bit.ly/16IlkfZ](http://bit.ly/16IlkfZ)

Alternatively, organise to visit a school where microscopes are available and work alongside the learners at that school, or organise times when your school's

learners can use the equipment when the laboratory is not being used.

Before we start working with microscopes, let's have a look at the different parts of a basic light microscope and the safety precautions we need to follow when using these pieces of equipment.

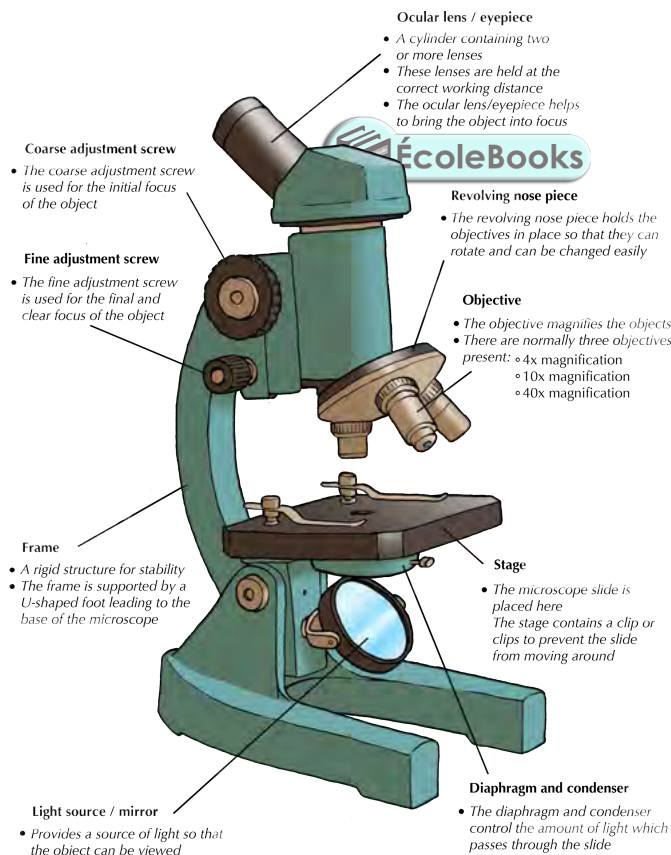


*A basic light microscope*

A microscope allows you to see detail in specimens that you cannot see with the naked eye. The image you see needs to be:

- well lit with enough light provided to see the specimen
- well focused
- contrasted with its surroundings to clearly see details

The next image explains the different parts of a light microscope and what they are used for.



When you use a microscope, make sure to follow these safety precautions:

1. There is a special way to carry the microscope: one hand supports the base and the other holds the frame of the microscope.
2. Put it down on a stable, horizontal, clear counter.

3. Before using the microscope, clean the lenses with proper lens paper. Do not touch the lenses with your fingers! Make sure the stage and slides are clean.
4. When handling the slides, do not use broken or cracked slides and handle cover slips by the edges.
5. When focusing with the objectives:
  - Focus smoothly and slowly
  - Be careful with the objectives and do not scratch them
6. When you are done:
  - Always turn the lowest magnification objective into place before storing the microscope.
  - Make sure that the stage and slides are clean before putting everything away.
  - Always store the microscope in a box or covered with a dust jacket to avoid dust from settling on the lenses.

To view cells under a microscope, we need to make and prepare something called a **specimen** on a **slide**.

A specimen is a small part or slice, or an example of an organism that we want to examine. When we view a specimen under a microscope it needs to let light pass through the specimen so we can see it. Therefore we need to prepare the specimen and cut extremely thin slices of less than 0.5 mm. Specimens are then placed on a glass slide.

We can prepare samples or specimens on a slide using these different techniques:

- **wet mount** - good for observing living organisms and is especially used for aquatic samples
- **dry mount** - good for observing hair, feathers, pollen grains or dust
- **smears** are often made of blood or slime that is smeared over the slide and allowed to dry before observing them.
- **stains** are added to wet or dry mounts by dropping colouring chemicals onto the specimens, like iodine solution, methylene blue or crystal violet. We use staining to improve the colour contrasts on the slide.

**VISIT**

Video on making a wet mount slide. [bit.ly/14znPSS](http://bit.ly/14znPSS)

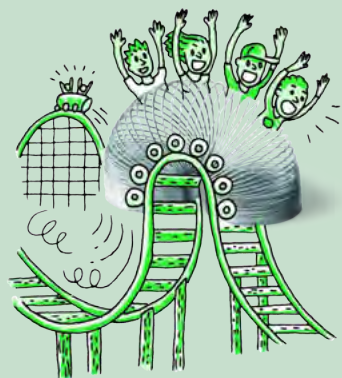
## ACTIVITY: Evaluating microscopic images

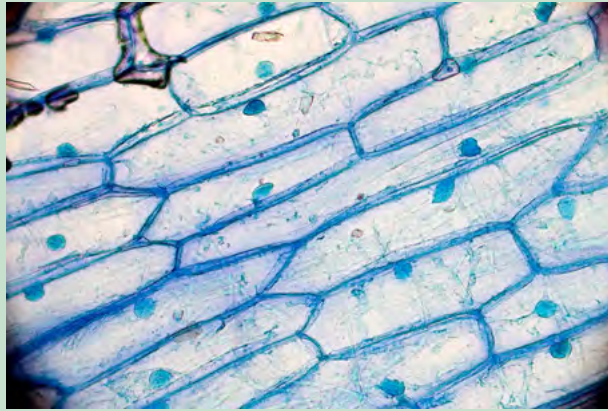
### TEACHER'S NOTE

This is an **extension activity**. It is optional and does not need to be done. However, if you do not have microscopes to work with at Gr. 9 level, this does provide an opportunity to get some experience with working with microscopes and troubleshooting problems, without actually using a real one.

### INSTRUCTIONS:

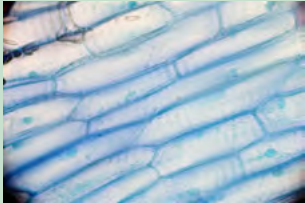
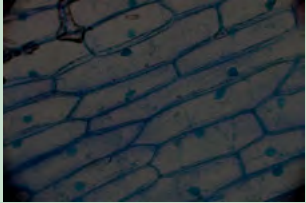
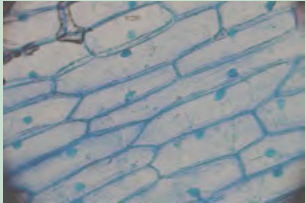
1. Carefully study this image of onion cells that have been stained blue. Evaluate this image in terms of the focus, light and contrast visible in the photo.





Learners need to explain that the image is sharp and in focus, that there is enough light shone on the specimen and that the contrast is clearly well achieved to show the structures of the cells.

2. These same onion cells were viewed under a microscope which had not been adjusted properly and the following photos were taken. Identify what is wrong with the photograph compared to the one above.

<b>Image</b>	<b>What is wrong with the image?</b>	<b>How could the image have been adjusted and corrected, using what part of the microscope?</b>
	<p>The image is fuzzy.</p>	<p>This image could have been focused using the fine and coarse adjustment screws.</p>
	<p>The image is very dark.</p>	<p>The brightness of the image could have been adjusted by changing the brightness of the lamp or moving the mirror to reflect more light onto the slide. The brightness can also be adjusted using the diaphragm and condenser apertures.</p>
	<p>This image has poor contrast.</p>	<p>The contrast of the image can also be adjusted by changing the intensity of the light and the diaphragm aperture.</p>

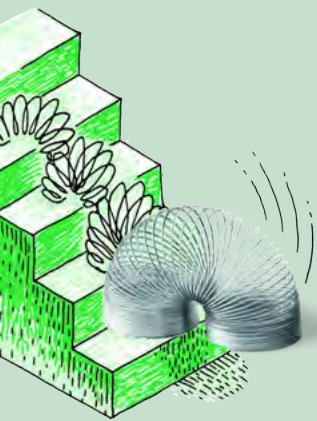
### TEACHER'S NOTE

Learners might battle with the last image about contrast as this is quite tricky to understand, so you might have to explain the answer to them. The difference between brightness and darkness is that brightness refers to how light or dark an image is, whereas contrast refers to the *difference* in lighting between different areas of the specimen.

### TEACHER'S NOTE

Before starting this activity, you could ask your learners why they think you are going to be making wet mounts, and not another type of mount, and what advantages using a liquid has. Have this as a class discussion and encourage your learners to take notes, either in a separate notebook or in the margin spaces within the workbook. We use liquid because:

- The liquid helps to support the specimen - remember, in our case it will only be a few cells so would be quite easily damaged.
- The slide will have a special glass coverslip on top of the specimen. When we use the liquid it fills the space between the specimen on the slide and the coverslip.
- The liquid allows light to pass through the glass slide and coverslip.
- The liquid prevents the specimens from drying out or blowing off the side.
- If we are using a stain instead of water, the stain lets the cell structures and organelles (the cell membranes and nuclei) stand out prominently allowing us to see it easily.



## ACTIVITY: Making a wet mount with onion and cheek cells

There is a very specific way to prepare slides for viewing under a microscope. You will use this technique very often in Life Sciences to study specimens.

### TEACHER'S NOTE

This activity will show learners how to prepare onion cells in a step-by-step manner, and will then challenge them to prepare their own cheek cells (using an ice cream stick or your own nail for collection) in order to study it under a microscope.

**Very important:** Make sure learners use clean, sterile sticks and that they do not re-use them and swap them.

If your class does not have access to a microscope, learners may still practice preparing a wet mount, and then examine the images at the end of the exercise.



## MATERIALS:

- onion
- scalpel or knife
- dissecting needle
- forceps
- microscope slides
- coverslips
- dropper
- tissue paper or filter paper
- distilled water
- iodine solution
- light microscope

### TEACHER'S NOTE

Risk assessment: Some people are allergic to iodine and/or shellfish. If any learners are allergic to iodine or shellfish DO NOT use the iodine solution to stain your specimens. Methylene blue and crystal violet are harmful and can be irritants. Avoid contact with the skin.

## INSTRUCTIONS:

**Step 1:** Prepare your microscope and slides as discussed in the safety methods above.

**Step 2:** Cut the onion into blocks of about 1 cm square with a sharp knife or scalpel.



*Cutting the onion to expose the layers.*

**Step 3:** Use forceps to pull or peel a small piece of the very thin membrane-like epidermis lining off one of the **inner** layers of the onion.



*Carefully pulling the lining off the onion layer.*

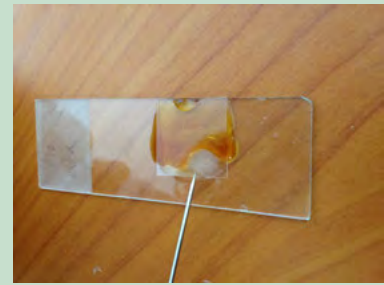
**Step 4:** Place a drop of iodine solution onto the slide.



### TAKE NOTE

You will need to work quite quickly as the onion cells will dry out!

**Step 5:** Place the membrane directly in the drop on the slide.



*Lowering the coverslip onto the specimen.*

**Step 6:** Gently lower a coverslip at an angle onto the onion cells. Hold the coverslip up with a dissection needle and gently lower the slip. This prevents air bubbles from getting trapped under the cover slip.

**TAKE NOTE**

If you accidentally trapped an air bubble, gently press on the middle of the coverslip to get rid of any trapped air using the dissection needle or drop some extra fluid right next to the edge of the coverslip.

**Step 7:** Wipe off excess fluid around the edge of the coverslip with tissue paper or filter paper.

**Step 8:** Make sure the lowest power objective lens (this is the shortest lens) is in line with the eyepiece. Switch on the lamp or use the mirror to reflect the light onto your stage. Place the prepared slide onto the stage and secure it with the stage clips.

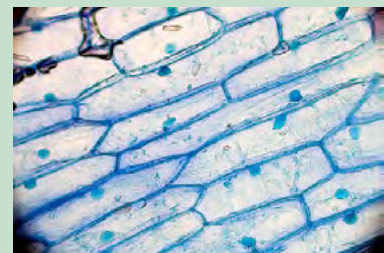


*The slide secured on the microscope stage.*

**Step 9:** While on the low power, look from the side and lower the objective lens to just above the coverslip. Then look through the eyepiece and use the fine focus to focus your image.

**Step 10:** Magnify your cells by swapping the objective lens to a higher powered lens. Only use the fine focus adjustment to focus clearly.

**Step 11:** Make careful drawings of your observations in the space below and remember to label what you see. Add a heading including the specimen, the stain used and the magnification.



*Onion cells.*

**TEACHER'S NOTE**

Learner-dependent answer

Now that you have prepared slides of onion cell specimens, use a toothpick to *gently* scrape the inside of your cheek to collect cheek cells using the side of the toothpick or ice cream stick. Follow the same instructions as above to prepare the cheek cell specimen and to view it under the microscope. Draw and label the cheek cells that you viewed under the microscope in the space below.

#### TEACHER'S NOTE

Learner-dependent answer

#### TEACHER'S NOTE

Learners must gently scratch the inside of their cheeks to collect some cheek cells and then wipe the toothpick on the slide and cover with a drop of water. (Please ensure that learners scrape with the broad side of the toothpick, slowly and gently, so that they do not injure themselves!) Alternatively, learners can use old wooden ice cream sticks. The water droplet will most likely contain several cheek cells. It is going to be near impossible to see the cheek cells in water. You should use a stain to colour contrast the cells, namely methylene blue or iodine solution. These cells are MUCH smaller than onion cells and the learners may battle to find them - look for tiny blue/yellow 'flakes' that are not lying on top of each other and magnify a small group of 3-4 cells.

Did you see something like this?



*Some cheek cells stained with methylene blue*

1. What are some of the differences and similarities you noted between the animal and cheek cells?

*Learners should be able to identify some of the following main differences and similarities between onion and cheek cells as:*

- *The onion cells have a thick cell wall and a cell membrane. The animal cells only have a cell membrane.*
- *The onion cells have a regular shape whereas the cheek cells have an irregular shape and seem more flimsy.*
- *In the onion cells they might notice a large vacuole which might not be as visible in the cheek cells. Cheek cells do not have vacuoles.*
- *Both onion and cheek cells have a nucleus and nuclear membrane.*
- *Both cells also have a cytoplasm and some might say that they see organelles inside this.*



**ACTIVITY:** Research the discovery of light and electron microscopes

**TEACHER'S NOTE**

This is an **optional activity** which learners can do outside of class if you have time.

The invention and improvement of microscopes has lead to incredible cellular discoveries (among others) in the last 400 years. Without microscopes, many of the microscopic organisms we know of today would never have been identified!

**INSTRUCTIONS:**

1. You can work individually or in groups for this task.
2. Research the history and discovery of the light and electron microscopes and how they are used today.
3. Design a brochure for the local Science museum where you tell visitors about the history of the development of microscopes.
4. Remember that a brochure must be informative, but not contain too much text.
5. Include some photographs or drawings.

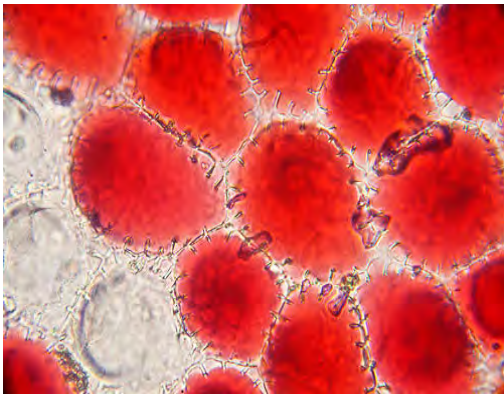


**Cells differ in shape and size**

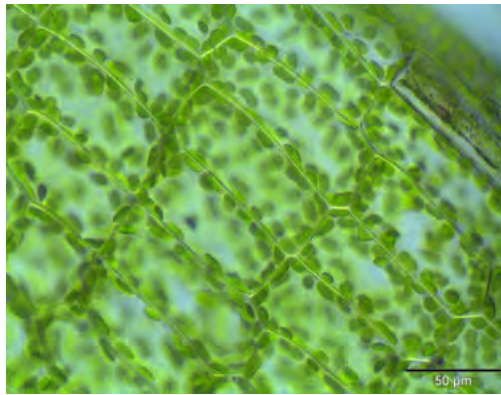
We looked at the basic differences between plant and animal cells. However, not all plant cells and not all animal cells are the same. Cells within an organism need to have different shapes and sizes because they fulfill different functions.

Look at the photo of the rose. Do you think the cells in the roots, stem, leaves, and petals of the rose all look the same?

The cells in the different parts of the rose all have to perform very specific functions and therefore have different sizes and shapes.








The rose's petals are red due to pigments in the vacuoles of the petal cells which are round.



Cells in the leaves are full of chloroplasts for photosynthesis. They are long and rectangular in shape.

Your body contains a great number of **specialised** cells, meaning they have different functions. They have differences in their structures allowing them to have different functions. We say they have **differentiated**.

Do you remember we spoke about nerve cells and red blood cells briefly in the beginning of the chapter? Some of them are summarised in the following table.

Specialised cell	Structure	Function
<b>Epithelial cells</b> - they are mostly flat	 	They cover the surface of the body for protection.
<b>Muscle cells</b> - some are long and spindle shaped		Muscle cells can contract and relax allowing for movement within your body
<b>Nerve cells</b> - they are very long and have branched ends		Nerve cells are specialised to carry messages that coordinate the functions of the body.
<b>Red blood cells</b> - Round and biconcave shape		Red blood cells carry carry oxygen and carbon dioxide throughout the body.



## Stem Cells

Stem cells are unspecialised cells which can divide and develop into many different types of specialised cells. Stem cells are quite amazing as they can divide and multiply while at the same time keeping their ability to develop into any other type of cell. Embryonic stem cells are the little ball of 50 -150 cells that forms 4-5 days after conception. Embryonic stem cells are very special as they can become absolutely any cell in the body, for example, blood cells, nerve cells, muscle cells or brain cells.

For this reason, scientists are using stem cells to conduct research. There are many benefits in doing this, but there are also many controversial and ethical issues surrounding stem cell research.

Are you curious about stem cell research? Find out more and discover the possibilities!

### TEACHER'S NOTE

The syllabus does not require great detail on stem cells, but this is an exciting field of science that is growing rapidly. The potential uses of stem cell technology may capture the imagination and inspire learners. As a possible extension activity, get learners to do some reading about the topic of stem cell research. Then they can write down some of the main points and also write about their own opinions and feelings about the topic. The last step is to have a class discussion. Encourage each learner to give their opinion. You could do this as a class debate and break learners up into groups, or else just go around the class and ask each learner for their opinion and why.

Alternatively, you may wish to share the following exciting possibilities with learners. In the future stem cell therapy may be able to treat many different diseases, such as:

- certain cancers (like leukemia, a cancer of the blood)
- diabetes mellitus (where cells that produce the hormone (insulin) that controls our blood sugar are destroyed and no longer work)
- spinal injuries and paralysis
- organ damage that requires organ transplants
- genetic diseases
- degenerative diseases (such as Parkinsons disease, where neurons in voluntary movement area of the brain die)

Alternatively, if resources cannot be found or if the terminology of stem cell research is too complex, this video on stem cells explains what the different stem cells are, what their normal role is in the normal body, and also explains some potential uses of stem cell technology <sup>5</sup> [bit.ly/15qjJHX](http://bit.ly/15qjJHX) .

## Microscopic and Macroscopic organisms

### TEACHER'S NOTE

Please ensure that learners understand the difference between microscopic and macroscopic and unicellular (single-celled) and multicellular (many-celled) organisms. Microscopic organisms are too small to be seen with the naked eye. Macroscopic organisms can be seen with the naked eye. Unicellular organisms

consist of one cell, multicellular organisms are made up of many cells. Learners can easily become confused and think that all microscopic organisms are unicellular, but this is not the case! There are many multicellular organisms that are too small to be seen.

We have just looked at specialised cells within organisms. The organisms that we discussed, plants and animals, consist of many, many cells. Your body has millions of cells! Did you know that there are some organisms which consist of only a single cell? We have many different specialised cells to perform the different functions within our body whereas in a single-celled organism, all the functions it performs are done in this one cell. We can make a distinction between organisms that are made of one cell (**unicellular**) and those that are made of many cells (**multicellular**).

### Microscopic organisms

We call one cell organisms that can only be seen with the help of a microscope **microscopic organisms**. There are many single-celled microscopic organisms. Have a look at the images.

#### TAKE NOTE

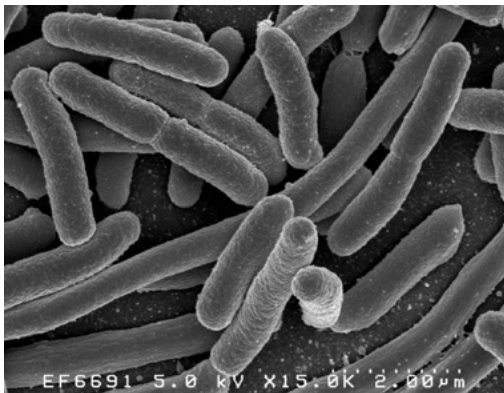
Microscopic and macroscopic describe whether an organism can be seen with the naked eye, while unicellular and multicellular refer to the number of cells an organism has.

#### VISIT

Take a virtual tour of the human body [bit.ly/14Fc3ZJ](http://bit.ly/14Fc3ZJ)

#### VISIT

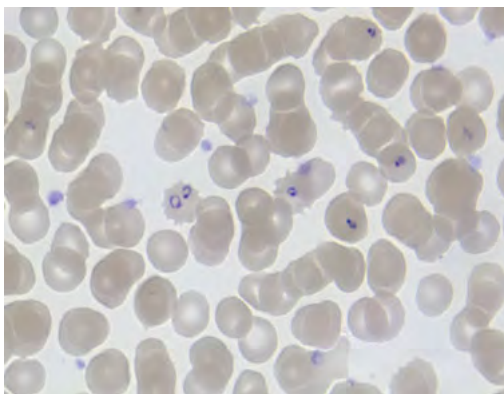
Fresh water amoebae  
[bit.ly/1cpzNnj](http://bit.ly/1cpzNnj) and  
[bit.ly/1bmfxyZ](http://bit.ly/1bmfxyZ)



A group of *Escherichia coli* bacteria which are found in the intestines of many animals.



An amoeba which is a single cell organism that lives in water.



Red blood cells showing some which have been infected with malaria (purple dots).



A single-celled algae called a desmid.

## Macroscopic organisms

In contrast to microscopic single-celled organisms, **macroscopic organisms** are visible to the naked eye and consist of many cells. Macroscopic organisms can have a few cells working together or trillions of cells that form larger organisms.

## Organisation of cells in macroscopic organisms

### TEACHER'S NOTE

In teaching this section, you may consider the example of the school as a 'living organism' in which:

- Each learner represents a single cell working on their own within a team.
- The classes are formed from groups of learners = tissues
- The grades are formed from groups of classes = organs
- The Gr. 7 - 9 and Gr. 10 - 12 are seen as the GET and FET phases, thus a phase = organ system
- All the phases working together in school = organism

In microscopic single-celled organisms, the individual cell has to perform all the life processes for that microscopic organism.

So what about the cells in macroscopic organisms that consist of many cells? We have already learnt about specialised cells in macroscopic organisms, so we know that not all cells perform all the processes - they are specialised to perform a specific function.

Specialised cells that perform a specific function, group together to form a **tissue**. For example, muscle cells will group together to form muscle tissue, epithelial cells will group together to form the skin, and nerve cells will group together to form the brain and nerves.

Groups of tissues that work together form **organs**. Think of the stomach for example - it is made of many different specialised cells that form muscle tissue to make it contract and epithelial tissue (made from specialised epithelial cells) which lines the inside of the stomach and produces mucus.

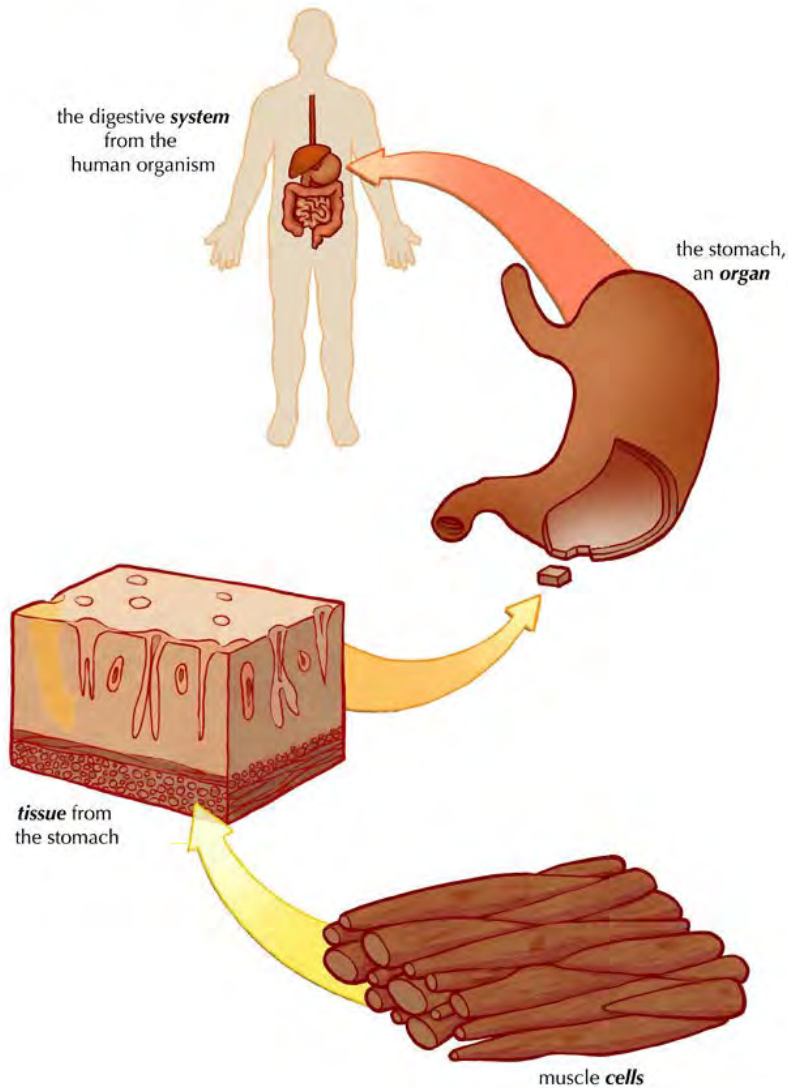
When organs work together we say they form **systems** or **organ systems**. There are many different systems in your body where specific organs work closely together to make your body function. Have a look at the following diagram which shows how cells are organised into tissues in the stomach which form part of the digestive system in a human (the organism).

#### VISIT

Learn more about your body  
at this interactive website

[bit.ly/14k53tH](http://bit.ly/14k53tH)

cells → tissues → organs → organisms

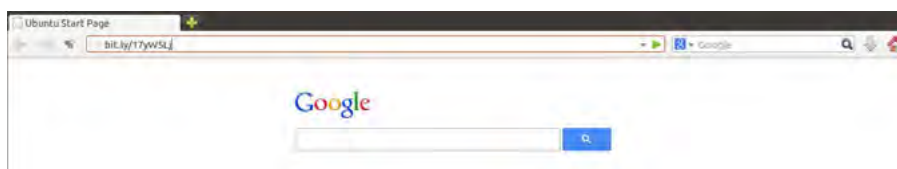


**VISIT**

Learn more about the different systems in your body [bit.ly/164zURJ](http://bit.ly/164zURJ)

All the systems work together to form an **organism**. We will be looking at some of these systems later on in the term.

Have you noticed the **VISIT** boxes in the margins which contain links? You simply need to type this whole link into the address bar in your internet browser, either on your PC, tablet or mobile phone, and press enter, like this:



It will direct you to our website where you can watch the video or visit the webpage online. **Be curious and discover more online on our website!**



### TEACHER'S NOTE

Throughout this year, we are going to develop the skill of designing and making **concept maps** in Natural Sciences. The "Key concepts" listed above is a summary written out in full sentences. A concept map provides another way of representing information (ideas and concepts) in a more visual way. The benefits of a concept map are that it allows one to show the linkages between different concepts. Often a concept map has a "focus question" around which the other concepts radiate. In these books the focus question will be the main topic for the chapter. The relationships between different concepts are shown using arrows with linking phrases, such as "results in", "includes", "can be", "used to", "depends on", etc.

As this year progresses, learners will have to start filling in more parts of the concept maps themselves, and then hopefully draw their own ones by the end of the year. This teacher's guide contains the full version of each concept map. Encourage your learners to study the concept maps and make sense of them at the end of each chapter before doing the revision questions. Help your learners to understand and "read" the concept maps by constructing sentences from them. For example in this case you could read: "Cells in plants have some differences as only plants have chloroplasts for photosynthesis".

**Learners need to learn how to learn!** This is one skill which might help them later in their school career where they have a lot more information to learn and make sense of. Concept mapping is one tool to use to summarise information and understand how different concepts link together. Real understanding and knowledge comes from grappling with the subject matter, and not just memorising facts.

To learn more about concept maps and how they encourage learner understanding, visit this site: <sup>6</sup> [bit.ly/17e2g7V](http://bit.ly/17e2g7V)

*"Knowledge is real knowledge only when it is acquired by the efforts of your intellect, not by memory."* - Henry David Thoreau



### SUMMARY:

#### Key Concepts

- Cells are the basic structural and functional units of all living organisms.
- Cells are microscopic and can only be seen under a microscope.
- Plant and animal cells have cell membranes, cytoplasm, a nucleus and organelles such as mitochondria and sometimes vacuoles.
- The cell membrane encloses the contents of the cell and separates it from its environment.
- Cell membranes are selectively permeable, which means they only allow certain substances to pass into and out of the cell.
- The cytoplasm includes the organelles and the cytosol. The cytosol is the jelly-like medium in which many chemical reactions take place in the cell. Everything inside the cell membrane, except the nucleus, is considered the cytoplasm.
- The nucleus in eukaryotic cells is enclosed by a nuclear membrane and contains the DNA.
- DNA contains inherited characteristics of an organism and controls the cell's activities. It is unique to each organism, resulting in variation within



- a species.
- Mitochondria are responsible for cellular respiration, which is the release of energy from food.
  - Plant cells have a cell wall around the cell membrane that is rigid and provides support and protection of the cell's content.
  - Plants have chloroplasts with the pigment chlorophyll to photosynthesise and produce glucose.
  - Plant cells also have large vacuoles to store water and glucose, and to provide support for the plant.
  - Vacuoles in animal cells are temporary (or absent) and much smaller.
  - Cells come in many different shapes and sizes.
  - Stem cells are cells that have the ability to divide and develop into many different cell types.
  - Microscopic organisms can only be seen under a microscope. All single-celled organisms, such as bacteria, are microscopic. However, some multicellular organisms such as dust mites are also too small to see with the naked eye.
  - Macroscopic organisms consist of many cells and can be seen with the naked eye.
  - Specialised cells perform special functions. Specialised cells that work together to perform a specific function form a tissue.
  - A group of different tissues makes up an organ.
  - Organs working together in groups form systems or organ systems.
  - Organ systems make up an organism, such as a human.

### **Concept Map**

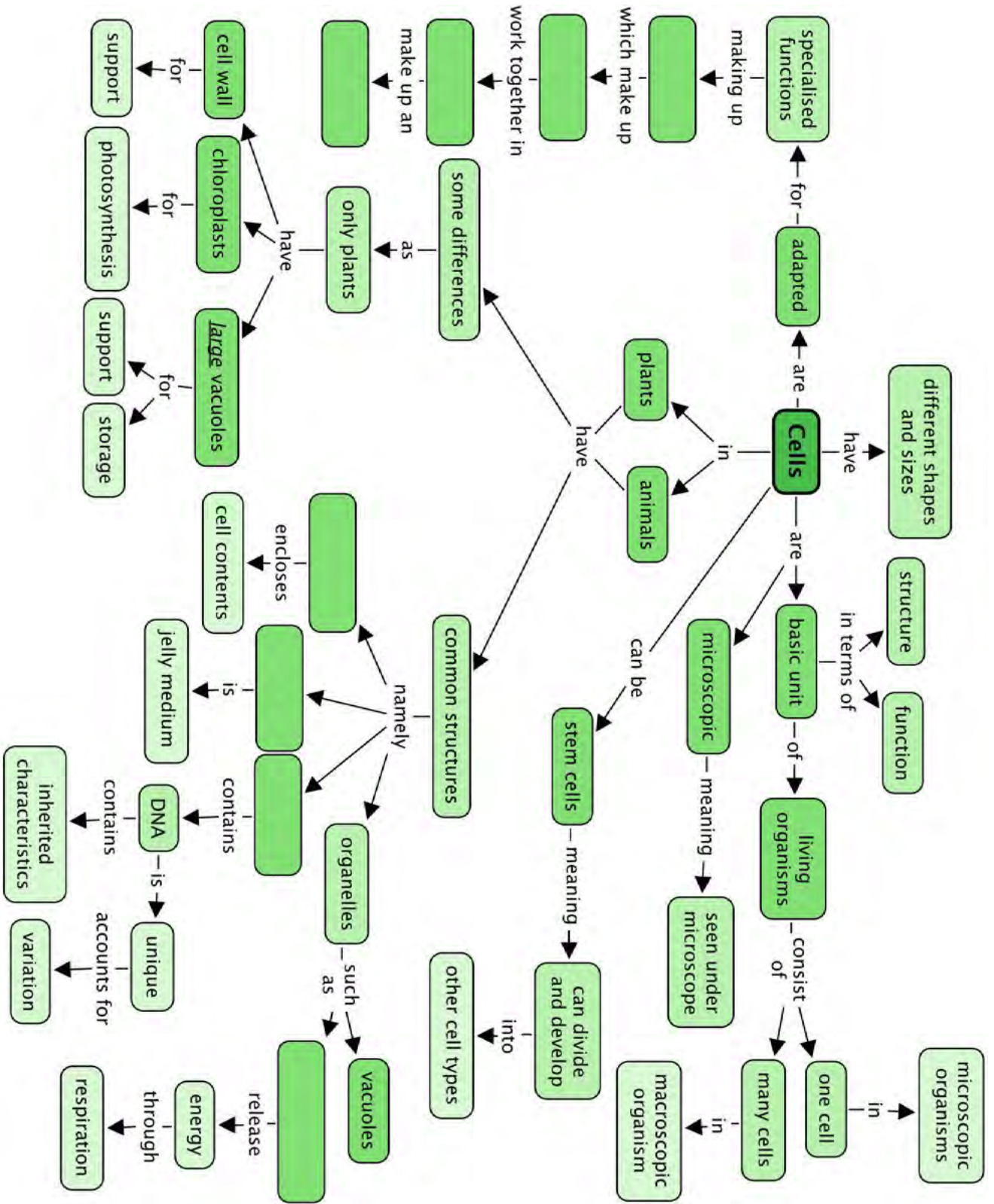
This year in Natural Sciences, we are going to learn more about how to make our own concept maps.

In the summary, we first have the "Key concepts" for this chapter. This is a written summary and the information from this chapter is summarised using words. We can also create a concept map of this chapter which is a map of how all the concepts (ideas and topics) in this chapter fit together and are linked to each other. A concept map gives us a more visual way of summarizing information.

Different people like to learn and study in different ways; some people like to make written summaries, whilst others like to draw their own concept maps when studying and learning. These are useful skills to have, especially for later in high school and after school!

Have a look at the concept map which shows what we have learned about the cell in this chapter and how these concepts link together. Can you see how the arrows show the direction in which you must "read" the concept map?

There are some empty spaces in the concept map that you need to fill in. For example, some of the common structures in cells have been left out. You need to look at the concepts linking from these bubbles to work out which structure goes where. For example, what structure in a cell encloses the cell contents? Write the answer in the correct space. On the left hand side of the concept map there are also empty spaces - can you see that this describes the hierarchy of how cells are organised into tissues, which are organised into organs, and so on? Fill in each level of organisation into the spaces.



## TEACHER'S NOTE

Teachers version

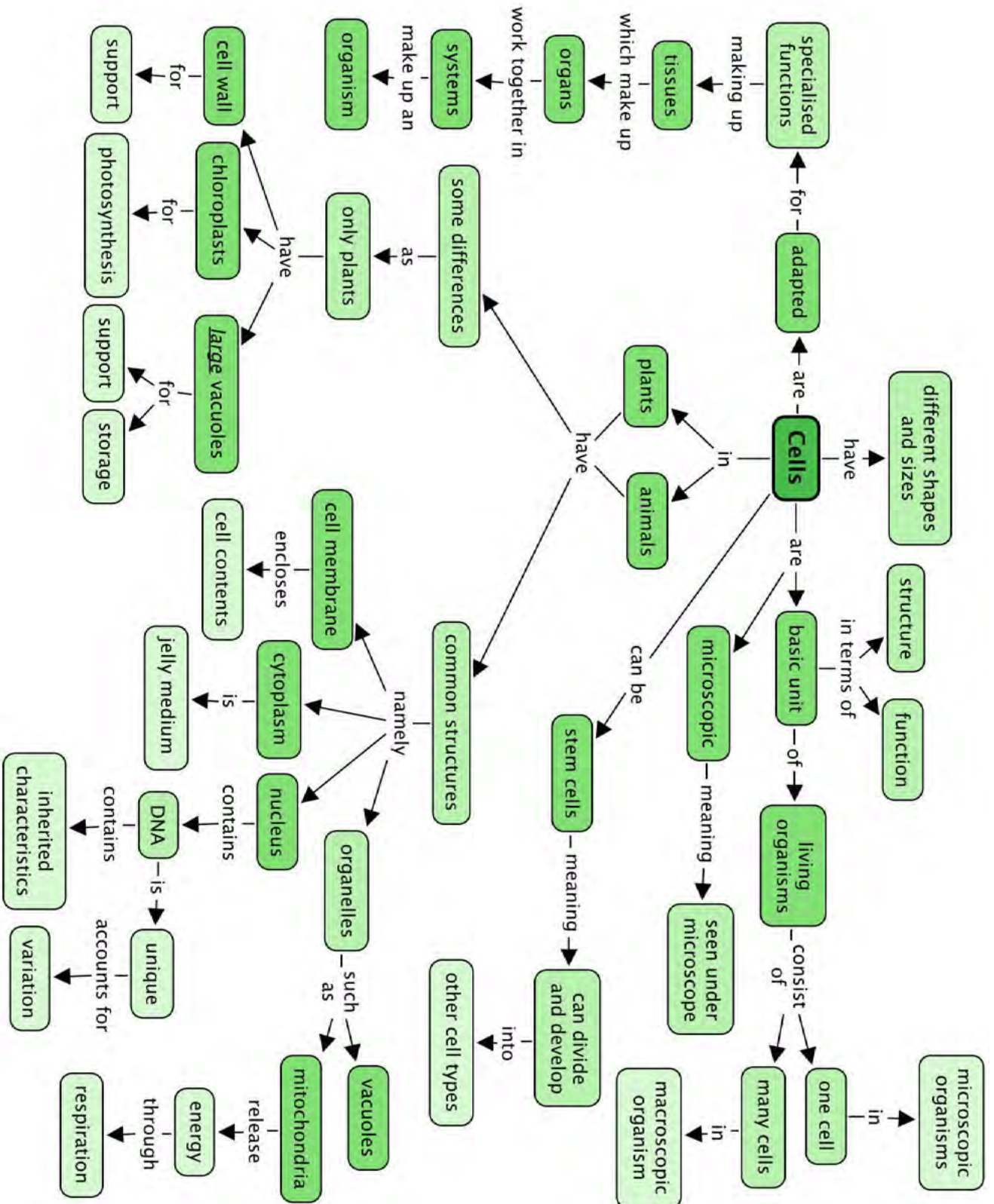
Below is the complete concept map with the answers filled in. Make sure your learners understand what a concept map is and that they have filled in the correct concepts into the empty spaces.

Remember that concept maps are different to mind maps in that concept maps have a hierarchical structure and show how concepts link together using arrows and linking words. Whereas mindmaps generally contain a central topic and individual branches coming out which do not necessarily link together.

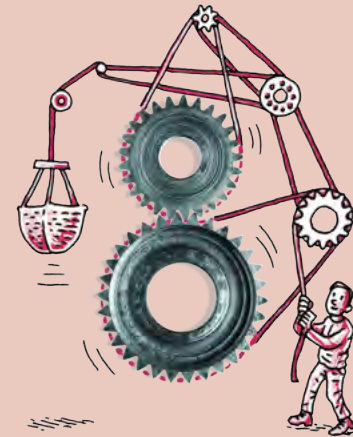
Mindmaps can also be a useful way of summarising information and studying, however, we are using concept maps as they help to show linkages, which is very important in science. Help your learners to "read" the concept map by showing them that the arrows show the direction in which concepts progress and are linked to each other.







## REVISION: Revision Questions



1. Why would you say cells are considered to be the smallest unit of life? [2 marks]  
*Learner-dependent answer. They should mention that cells are the smallest things that can live independently and are the most simple functional and structural unit that makes up all organisms.*
2. Explain what **selectively permeable** means when referring to the cell membrane. [1 mark]  
*Selectively permeable means the membrane only allows certain substances to pass into and out of the cell.*
3. Eukaryotic and prokaryotic cells differ. What is the main difference between these two types of cells? [2 marks]  
*Prokaryotic cells do not have a nucleus or membranes around the organelles, whereas eukaryotes have a nucleus and membrane bound organelles. May also refer to DNA being loose or enclosed in a membrane.*
4. What is the main function of the nucleus and what is the function of the DNA? [2 marks]  
*The nucleus controls all the processes inside the cell and the DNA carries the inherited characteristics of the organism.*
5. When a Gr. 9 learner labelled one of the cell organelles 'Powerhouse', their teacher marked it wrong. What should the learner rather have written? [1 mark]  
*mitochondrion*
6. A plant and an animal cell are similar in some ways yet very different in others. Compare the two types of cells in a paragraph. [10 marks]
  - *Both cells have a cell membrane, cytoplasm and a nucleus.*
  - *Plant cells have an additional cell wall that provides shape and rigidity to the cell.*
  - *Plant cells have large vacuoles and contain chloroplasts.*
  - *Animal cells do not have cell walls and have a more irregular shape.*
  - *Animal cells do not always have vacuoles and when these are present they are short-lived and much smaller than those in plant cells.*
7. Make two drawings to show the differences between plant and animal cells using the examples of plant and animal cells you studied under the microscope. Follow the drawing guidelines for making scientific drawings. [10 marks]  
*Learners should receive marks for following these drawing guidelines:*
  - *The drawing should be made with pencil and the labels should be added in pen.*
  - *The size of the drawing should be proportional*
  - *The title of the drawing should be clear and descriptive.*
  - *Lines used for labelling should end at or be just inside the feature being identified and should not use arrows.*
  - *Label lines should be drawn with a ruler and pen and should never cross.*
  - *Lines used for labelling should be parallel to the bottom of the page / horizontally and neatly spaced at the same vertical margin to the one side of the drawing.*
  - *The magnification, title and labels should be neatly written in print not cursive.*
  - *There should be no noticeable erasure marks left.*
  - *The drawings should be accurate and correctly labelled.*

8. There are different types of specialised cells and tissues in plants and animals that perform different functions. Match each function to the corresponding tissue. [3 marks]

Smooth muscle tissue	receives and sends messages and helps the body respond to stimuli
Nerve cell	carry oxygen around the body in mammals
Red blood cells	contracts and enables movement

- *smooth muscle tissue: contract and enables movement*
- *nerve cell: receives and helps the body respond to stimuli*
- *red blood cells: carry oxygen around the body in mammals*

9. Use words from this box to complete the sentences below. Write the sentences out in full. [4 marks]

- |   |
|---|
| <ul style="list-style-type: none"> <li>• organs</li> <li>• tissues</li> <li>• organ systems</li> <li>• specialised cells</li> </ul> |
|---|

Macroscopic organisms consist of many different \_\_\_\_\_ that are made of individual \_\_\_\_\_ that work together in a very particular way. These are formed from \_\_\_\_\_ that are in turned created when groups of \_\_\_\_\_ function together in a specific way.  
*Macroscopic organisms consist of many different organ systems that are made of individual organs that work together in a very particular way. These are formed from tissues that are in turned created when groups of specialised cells function together in a specific way.*

Total [35 marks]







**TEACHER'S NOTE****Chapter overview**

2 weeks.

This chapter is intended to give an overview of the main systems in the human body, and the basic structure and function of the associated organs. The focus in each system will be to look at the main **processes**, the main **components**, and then some of the potential **health issues** associated with the system.

## 2.1 Body systems (Introduction)

Tasks	Skills	Recommendation
Activity: Research and writing about health issues	Researching, summarising, describing, suggesting, writing, presenting	CAPS suggested

## 2.2 The digestive system (1 hour)

Tasks	Skills	Recommendation
Activity: Flow diagram of the digestive system	Summarising, describing, writing	Optional

## 2.3 The circulatory system (0.5 hours)

Tasks	Skills	Recommendation
Activity: Chart the circulatory system	Summarising, describing, writing	Optional

## 2.4 The respiratory system (0.5 hours)

Tasks	Skills	Recommendation
Summary Diagram	Summarising, describing, writing	Suggested

## 2.5 The musculoskeletal system ( 1 hour)

Tasks	Skills	Recommendation
Summary Diagram	Summarising, describing, writing	Suggested

## 2.6 The excretory system (1 hour)

Tasks	Skills	Recommendation
Activity: Differentiating between excretion and egestion	Comparing, identifying, describing	Optional
Summary Diagram	Summarising, describing, writing	Suggested

## 2.7 The nervous system (1 hour)

Tasks	Skills	Recommendation
Summary Diagram	Summarising, describing, writing	Suggested

## 2.8 The reproductive system (1 hour)

Tasks	Skills	Recommendation
Activity: Defining the main processes involved in reproduction	Identifying, writing	Optional

CAPS suggests that you make a large outline of the human body for this section and draw each system on to it as it is dealt with. You can do this by getting large sheets of recycled paper and tracing around one of the learners. A suggestion is to rather do one for each system and stick these up around the class.

Alternatively, provided here is a page which you can photocopy and each learner can do their own **summary after each system**. You can hand these out after each system and learners can do the following:

- Give the diagram a heading.
- Add a short description of the main purpose of the system.

- List the main processes that take place in the system.
- Make basic sketches in the correct places to show where the different organs and structures of the system are situated in the body.
- Add labels for each of the different structures in the system.
- Next to each structure's label write short bullet points to describe the function of that particular structure.
- Below the diagram list some of the health issues that relate to the system.

As this chapter is meant as an overview of the different body systems, we suggest doing this for the systems which will not be discussed in detail later, namely do it for:

- musculoskeletal system
- excretory system
- nervous system

The respiratory system also lacks an activity, so you may also wish to do a summary diagram for this section. You can also get learners to complete a summary diagram for each system as a homework exercise. But there is limited time for this chapter, and many systems to cover!

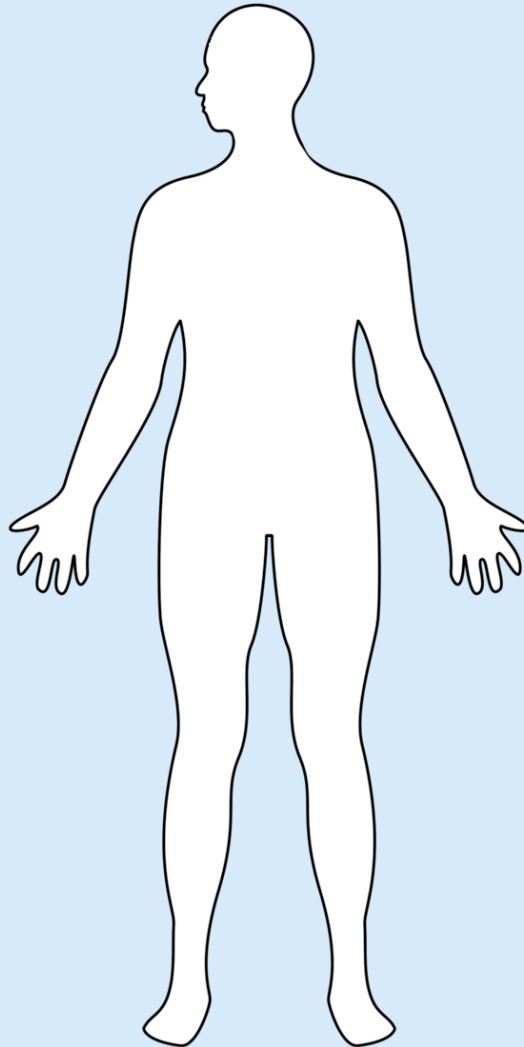
**The activities and summary diagrams you choose is your choice.**

Following is the page to photocopy for learners to summarise a system:

Heading: \_\_\_\_\_

Main purpose:

Main processes:



Health issues:





## KEY QUESTIONS:

- How does the body do the things it does, such as breathe, move and think?
- What happens when one of the systems in our bodies does not work properly and has a 'system error'?
- Is it possible to prevent ourselves from getting sick?
- How can you best look after your body?

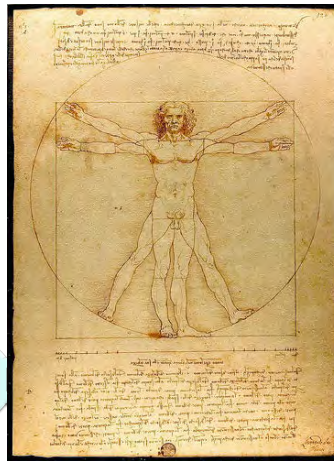


The human body has been studied by artists and scientists, mechanical engineers and medical practitioners throughout history. The mechanical beauty and operation of each and every part in the human body has fascinated human beings throughout history. Be curious and get ready to be fascinated!



### TAKE NOTE

If you want to check the definitions of a **New word**, check the glossary at the back of this strand.



*Leonardo da Vinci did many drawings and studies of the human body in the 1400's, such as this one called the 'Vitruvian Man.'*

## Body systems

The human body consists of several integrated systems that must work together for the body to function as a whole.

In the following pages we'll study seven of the main organ systems in our bodies. At the end of each organ system you will need to make a summary of that organ system to show:

- the main purpose or function of the system in the body;
- the main processes that take place in the system;
- the main components (organs) that make up the system; and
- the main health issues that relate to that particular system.

Therefore pay close attention and make notes as you study each organ system to help you with your summary.

## TEACHER'S NOTE

You could use the above criteria to draw up a large table to summarise all the organ systems as you work through them, perhaps on the one side of the board or on a large poster.

## **ACTIVITY:** Research and writing about health issues

### **TEACHER'S NOTE**

A suggestion is to assign different issues to different learners in your class so that you get a range of research posters to stick up. This can be done at the end of this section, but has been included here so that learners are aware of it. You may choose to use this poster and presentation for an informal assessment mark.



### **INSTRUCTIONS:**

1. You are going to learn about many of the health issues related to each of the different systems. Choose one of these health issues to research.
2. You will need to:
  - a) Consult at least 3 different resources to find out more about that particular health issue.
  - b) Suggest ways that this health issue may be prevented (if this is possible).
  - c) Suggest treatment for the health issue in question.
3. Present your findings on an A3 poster as part of an oral presentation (of 3 - 4 minutes) to the class.

## **2.1 The digestive system**

Our cells need **protein, carbohydrates, fats, vitamins** and **minerals** to function. Yet we eat large pieces of food that are too big to pass through the selectively permeable cell membranes. So how does the food we eat eventually get to our cells in a small enough form to be absorbed?

### **Purpose of the digestive system**

#### **TEACHER'S NOTE**

After learners have done this initial thought exercise, a fun suggestion to introduce the digestive system is to bring out a tube (either a hosepipe, or even a piece of rope, but a tube is ideal), that is 9m long to represent the digestive system. Explain to learners that the digestive system is like one long tube of different organs and this is all coiled up inside of you. Along this tube different processes occur to digest the food we eat (namely ingestion, digestion, absorption and egestion). Then explain to learners that we will be looking at what happens along this tube. You can even drape the tube up over the board in the front of the classroom for the rest of this section.

Our digestive system is responsible for breaking down the food that we eat into small particles that can be **absorbed** into the bloodstream. They are then **transported** to the cells throughout our body.

The digestive system is made up of the different parts of the **alimentary canal**. This canal is a long, twisting pipe-like structure (about 9 meters in total) that starts at the mouth and ends at the anus. Along the way the food is broken down from chunks into molecules small enough to pass through cell membranes and supply energy to cells.

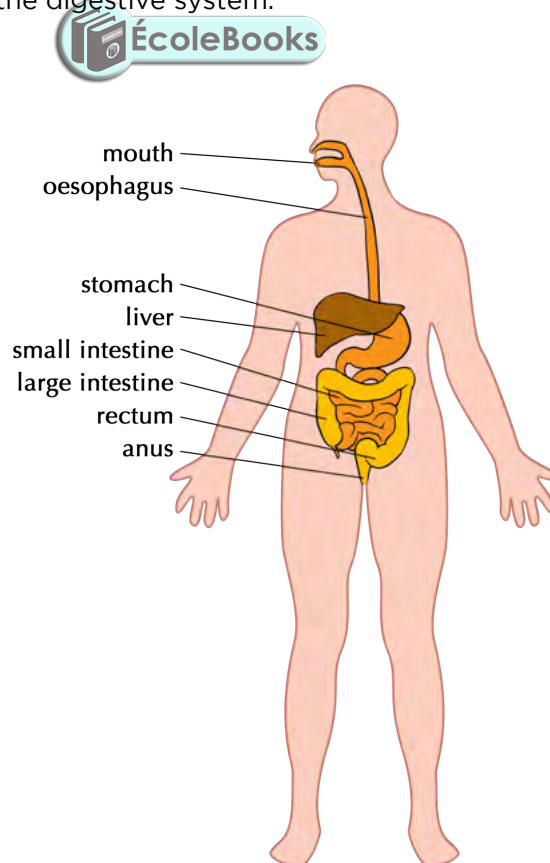
### Main processes in the digestive system

There are four main processes that occur in the digestive system at different parts along the alimentary canal. They are:

- **Ingestion:** This occurs when you take food into your body through your mouth by eating or drinking it.
- **Digestion:** This is the process of breaking down large food pieces into particles that are small enough to be absorbed and pass through cell membranes.
- **Absorption:** This is when the digested particles move into the cells of the digestive tract (they are absorbed) and move to the bloodstream from where they are carried to all the cells in the body.
- **Egestion:** Any undigested or unwanted particles that travel through the digestive tract are later passed out as faeces. This process is known as egestion.

### Components of the digestive system

Have a look at the following diagram which gives an overview of the different parts making up the digestive system.



## 1. The mouth and oesophagus

Digestion starts in the mouth as food is chewed and mixed with saliva. It then travels down the oesophagus when you swallow.

## 2. Stomach

The chewed food enters the stomach and is further digested. The stomach has substances called enzymes to help digest the food. The stomach also contracts to break the food down further into a liquid.

## 3. Small intestine

Most of the digestion takes place in the small intestine. Absorption of the food particles also takes place in the small intestine.

## 4. Large intestine (or colon)

By the time the food reaches the large intestine, most of the nutrients have been absorbed. What is left is water, salts and indigestible fibre. The water that is left is absorbed in the large intestine.

## 5. Rectum and Anus

The remaining substances (called faeces) are passed into the rectum and then out through the anus. This is called egestion.

### TAKE NOTE

There is a difference between egestion and excretion. Egestion is when undigested particles are passed out as faeces. Excretion is when the body gets rid of metabolic waste formed from chemical reactions taking place in the body.

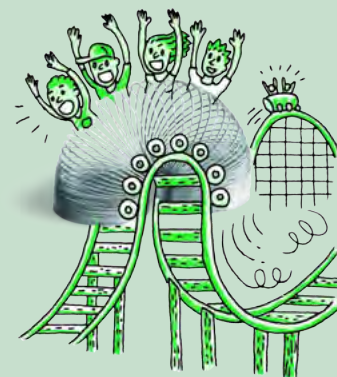
## ACTIVITY: Flow diagram of the digestive system

Flow diagrams are diagrams that show how the different sets of a process fit together in a sequence. They show the direction (flow) by using arrows. These are important tools to help you think about processes in Science.

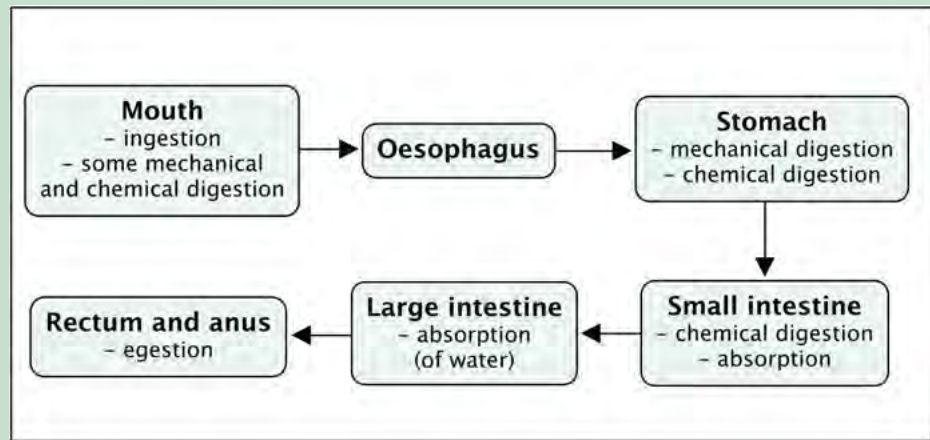
### INSTRUCTIONS:

1. Draw a flow diagram to represent the passage of food from the time it is taken into the body to the time it is egested from the body.
1. The blocks must show the main components involved in digestion, listed in order with arrows in between. Under each component include the main processes that occur at each of these stages.

*The learners' flow diagrams could look something like this one below. An idea is to draw this up on the board and get learners to swap books with each other to check if they produced something similar and logical.*







## Health issues involving the digestive system

**Common diseases of the digestive system include :**

**Ulcers:** Sometimes open sores or ulcers develop on the lining of the mouth, oesophagus, stomach or upper portions of the small intestine. Ulcers can be very painful. They are generally caused by bacterial infections and some medications.

**Anorexia nervosa:** This is one of many eating disorders. People who suffer from this eating disorder have an abnormal fear of gaining weight and therefore starve themselves on purpose. This can lead to many health issues such as bone thinning, kidney damage, heart problems and even death.

**Diarrhoea:** Someone who passes very frequent, loose, watery stools has diarrhoea. Many diseases cause undigested food to pass through the large intestines too quickly for water to be absorbed and cause diarrhoea.



*Do not forget to wash your hands with lots of soap and water!*

### TAKE NOTE

It is good to know the dangers and health consequences of an unhealthy lifestyle.

**Liver cirrhosis:** This disease slowly replaces healthy liver tissue with scar tissue and eventually prevents the liver from functioning properly. Alcohol abuse and fatty liver caused by obesity and diabetes are the most common causes of liver cirrhosis.

## 2.2 The circulatory system

Did you know that the blood moving throughout your body forms a system? To "circulate" means to move around, and so we have the circulatory system within the human body which transports blood.

### TEACHER'S NOTE

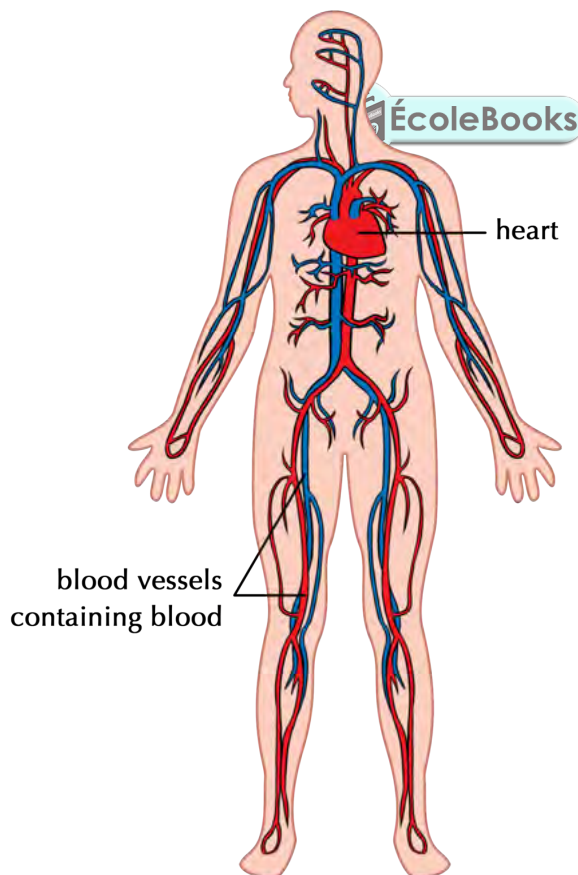
The circulatory system includes blood as well as lymph, however at this level, only the blood circulatory system will be dealt with.

### Purpose of the circulatory system

The circulatory system is responsible for transporting blood with oxygen ( $O_2$ ) from the lungs to cells and then transporting blood with carbon dioxide ( $CO_2$ ) back to the lungs. It also has to distribute nutrients from the digestive system to the cells in the body and remove waste products to be excreted.

### Components of the circulatory system:

The circulatory system is composed of the heart and a system of blood vessels, including arteries, veins and capillaries.



*The circulatory system is composed of the heart and blood vessels*

## 1. Heart

The heart is a very strong muscle and pumps blood throughout the body. There are four chambers in the heart that receive and send blood to all parts of the body. The top two chambers are called *atria* (singular= atrium) and the bottom two chambers are called *ventricles*.

## 2. Blood vessels

There are various blood vessels which carry the blood throughout the body. These are:

- arteries
- capillaries
- veins

## 3. Blood

The blood is transported throughout your body and carries various substances. The substances can be dissolved in the blood liquid (plasma), such as carbon dioxide, nutrients and waste products, or else within red blood cells, such as oxygen.

## Main processes in the circulatory system

Our circulatory system is actually made up of two systems that function together:

- a short system that circulates blood between the lungs and the heart; and
- a much longer system that circulates blood from the heart throughout the body and back again.

This process occurs as follows:

- Blood is circulated from the heart to the lungs. At the lungs, carbon dioxide (CO<sub>2</sub>) leaves the blood and oxygen (O<sub>2</sub>) enters the blood. This process is known as **gaseous exchange**. Since the blood now contains more oxygen than carbon dioxide, we say it is **oxygenated**. This oxygenated blood returns back to the heart again.
- Once in the heart the oxygenated blood is then circulated to deliver the oxygen to all the cells in the body before returning back to the heart. At the same times as it delivers oxygen, the blood also collects carbon dioxide from the cells. This blood has more CO<sub>2</sub> than O<sub>2</sub>, so it is **deoxygenated** blood. The carbon dioxide is excreted when it next returns to the lungs.

This process occurs over and over again throughout your life, thousands of times a day!

### VISIT

Watch a video that shows the direction of blood flow through the four chambers of the heart. [bit.ly/14Fccfa](http://bit.ly/14Fccfa)

Watch a video on the circulatory system. [bit.ly/19Wf2Od](http://bit.ly/19Wf2Od)

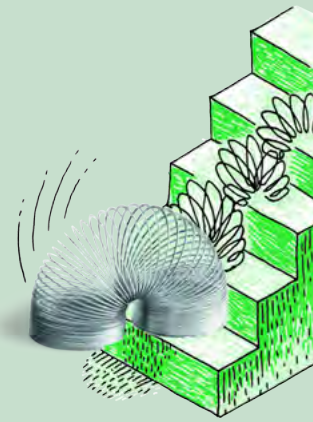
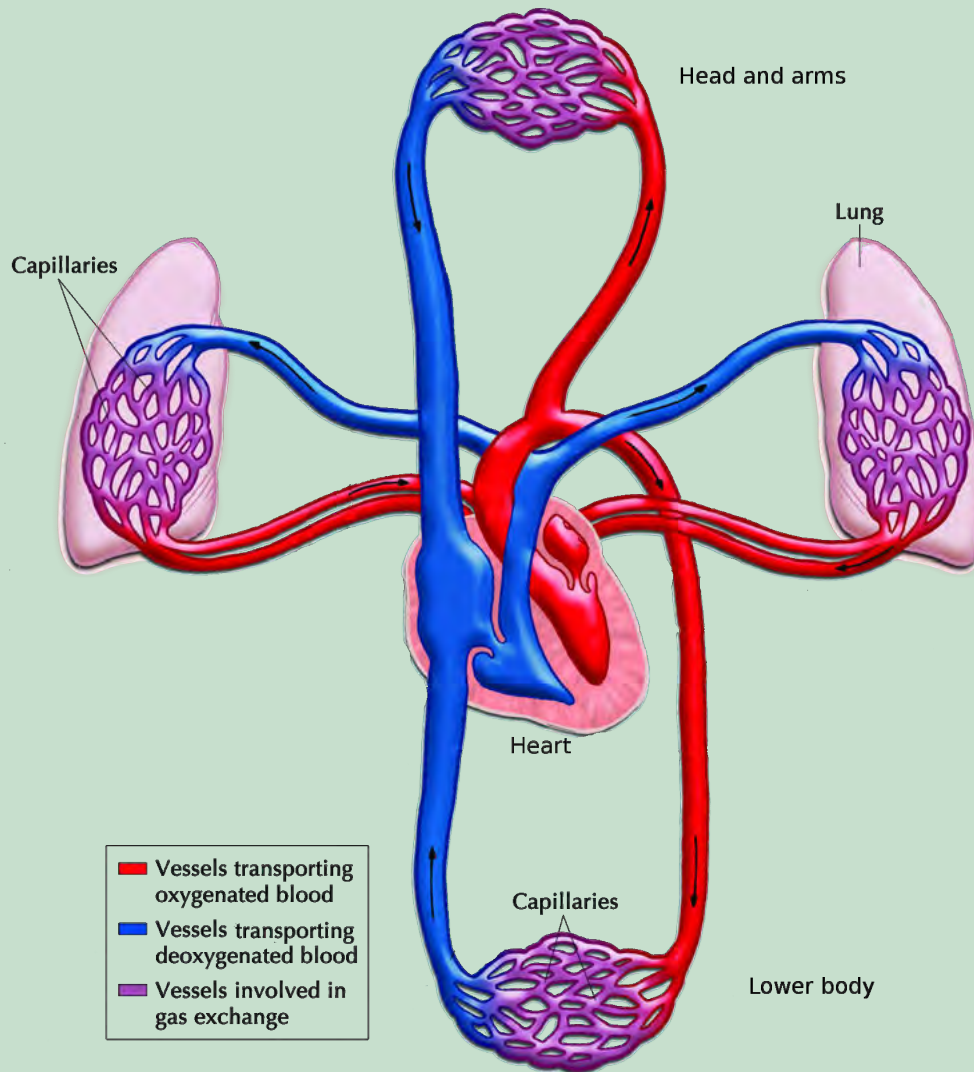
### TEACHER'S NOTE

Why not play one of the videos in class like this one [bit.ly/16IIBPU](http://bit.ly/16IIBPU) while the learners are working on their activities in order to help them remember important terminology.

## ACTIVITY: Chart the circulatory system

### INSTRUCTIONS :

- Study the diagram below that explains the circulatory process.



### TAKE NOTE

In diagrams we generally use red to indicate blood vessels that contain oxygenated blood and blue to show blood vessels with deoxygenated blood.

- Use the diagram above to draw a circular diagram in the space provided to show how blood travels through the circulatory system (composed of two systems).
- Your circular diagram will form a complete circle.



**TEACHER'S NOTE**

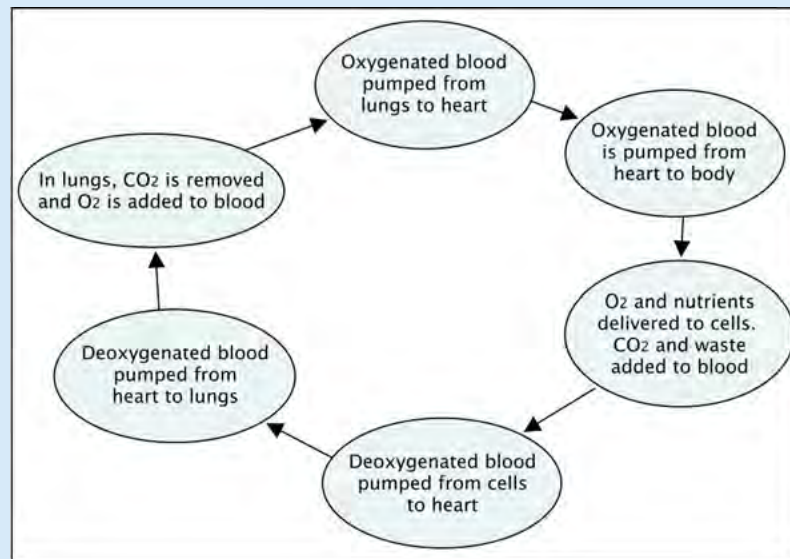
There is a difference between a flow chart and a circular diagram: a flow chart shows a process from beginning to end and arrows start at one point and end at another. A circular diagram shows a process that occurs over and over again, which forms a cycle.

- Add arrows to show the direction the process occurs in.

**TEACHER'S NOTE**

Learner-dependent answer

A flow chart could look like the one below. Perhaps let your learners try it themselves first and then draw one on the board. Do not just draw it on the board for them to copy - they must first try it themselves.



**TAKE NOTE**

You can find out lots more online by visiting the links provided in the **Visit** boxes. Be curious and discover the possibilities!

**Health issues involving the circulatory system**

Common diseases of the circulatory system include:

**High Blood Pressure:** This occurs when the force with which the blood pushes against the walls of the blood vessels is too high and can cause damage to the capillaries and several organs.

**Heart Attacks:** Occur when a narrowing or blood clot develops in one of the blood vessels that supplies the heart muscle with blood. If the narrowing or blood clot is big enough it can stop the blood flow to the heart muscle and can stop the heart from pumping which is called a heart attack. The person can die.

**Strokes:** Occur when cells in your brain are deprived of oxygen. This often occurs as a result of a blockage in the blood vessels leading to the brain, or when one of these vessels rupture (break or burst open).

## 2.3 The respiratory system

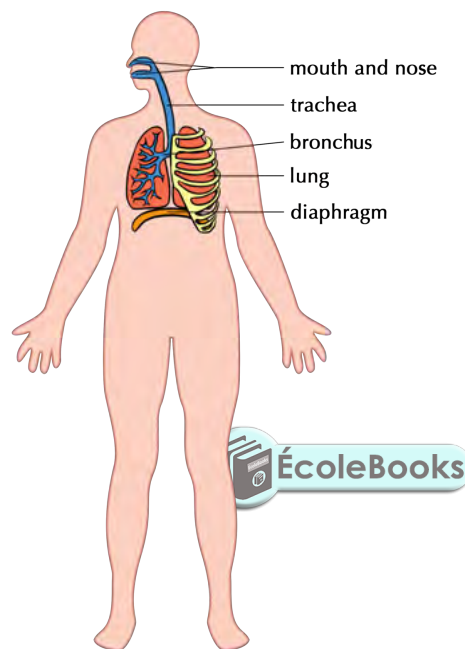
Closely linked to the circulatory system is the respiratory system. The circulatory system maintains the circulation of blood in the body while the respiratory system deals with the exchange of gases in your body.

### Purpose of the respiratory system

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

### Components of the respiratory system:

Various organs play a vital role in the respiratory system.



*A diagram of the structures that make up the respiratory system*

#### 1. Mouth and nose

Oxygen rich air enters the body through the mouth and nose where it is warmed.

#### 2. Trachea (also called the windpipe)

The trachea is a tube that enters the chest and allows air to flow from the mouth into the bronchi and from there into the lungs. It is kept open by cartilage rings. When dust particles and germs in the air enter the trachea during inhalation, the mucus lining the trachea traps these particles and the **cilia** work together to move them out of the body. When you sneeze or cough you expel the mucus and foreign particles from your body.

#### 3. Bronchi

The trachea splits into two air tubes, called bronchi that connect to each of the lungs. These tubes divide even further into smaller and smaller tubes that connect with the tiny air bags (alveoli) of the lungs.

#### 4. Lungs

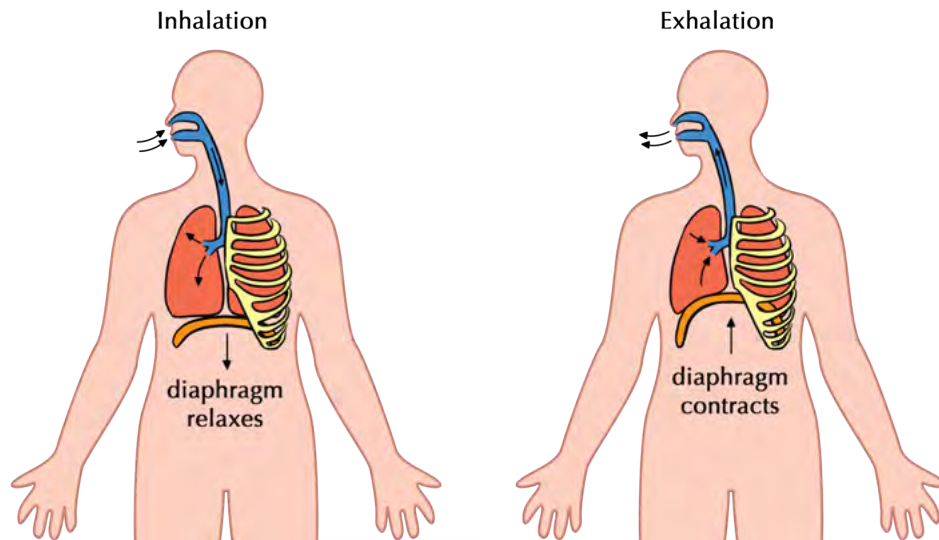
The main organs of the respiratory system are the lungs. The tiny alveoli or air bags in the lung are surrounded by small capillaries where gaseous exchange takes place.

#### VISIT

Visit this animation and watch how the ribcage changes shape and size during inhalation and exhalation [bit.ly/11WaP8h](http://bit.ly/11WaP8h)

#### 5. Diaphragm

This dome shaped muscle below the lungs enables you to breathe. When it contracts, it moves downwards and your lungs fill with air. When it relaxes again it moves upwards and forces the air out of your lungs. This is the main muscle used for breathing.



This diagram helps us to understand how breathing occurs showing how the diaphragm contracts and relaxes.

#### Main processes in the respiratory system

Three distinct processes occur in the respiratory system:

- **Breathing** occurs when we take oxygen into the body (lungs) and push carbon dioxide out of the body. Breathing therefore occurs in two phases:
  - Inhalation - drawing air in
  - Exhalation - pushing air out
- **Gaseous exchange** takes place at two locations by a process called **diffusion**:
  - in the alveoli, oxygen diffuses into the blood from the lungs and carbon dioxide diffuses from the blood back into the lungs
  - at the body tissues oxygen diffuses from the blood into the cells and carbon dioxide from the cells diffuses into the blood
- **Cellular respiration** occurs within the mitochondria of cells to release the chemical energy in food.

#### TAKE NOTE

People often confuse respiration with breathing. Breathing is taking air into the body through the lungs. Respiration or cellular respiration takes place inside the cells to release energy when oxygen is combined with glucose and other nutrients.

## Health issues involving the respiratory system

Some common health issues of the respiratory system are:

- **Asthma:** caused by allergies that inflame and narrow the airways
- **Lung cancer:** a disease that mostly results from smoking or severe air pollution
- **Bronchitis:** swelling of the lining of the bronchi due to infection which causes coughing and makes it difficult to get air into their lungs
- **Pneumonia:** an infection in the lungs where the alveoli fill with fluid
- **TB (Tuberculosis):** an infectious disease caused by the bacteria, *Mycobacterium*

### VISIT

To learn more about lung cancer, watch this video on how this disease affects your body [bit.ly/17gAxnF](https://bit.ly/17gAxnF)

## 2.4 The musculoskeletal system

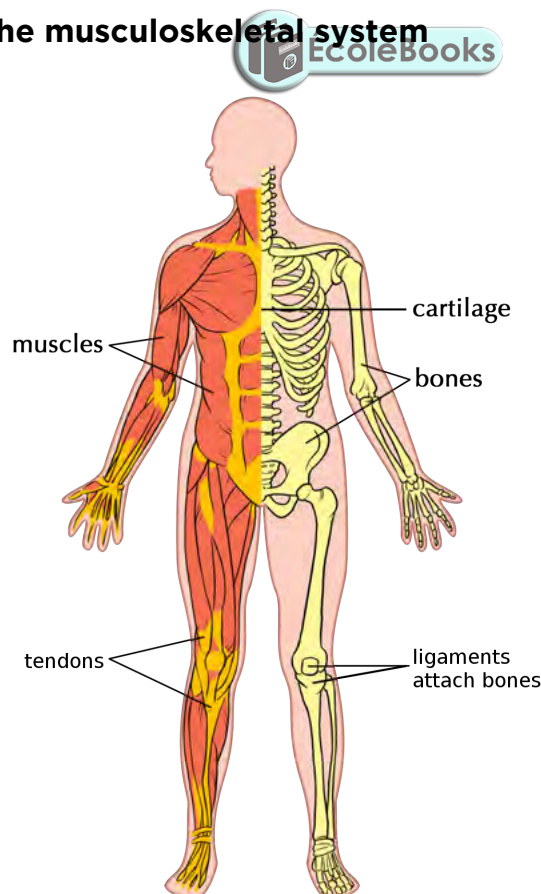
All the movements that your body performs rely on a system of muscles, tendons, ligaments, bones and joints that work together. These are the components of your musculoskeletal system.

### Purpose of the musculoskeletal system

Muscle tissue is responsible for producing movement in the body, however muscles need to be attached to a frame structure to produce movement.

The bones of the skeleton provide a frame for muscles to attach to, so that movement is possible. The skeleton also protects the body, especially the soft, fragile organs like the heart, lungs and brain.

### Components of the musculoskeletal system



*The components of the musculoskeletal system help bring about movement.*



**VISIT**

A video on muscle contraction and relaxation in the arm. [bit.ly/13ZIIUd](http://bit.ly/13ZIIUd)

The components of the musculoskeletal system include the following:

**1. Muscles**

Muscles allow us to move because they are able to contract (become shorter) and relax (become longer).

**2. Bones**

Bones provide support and help to form the shape of the body. The place where bones meet is called a joint - think of your knee or elbow joint, or your finger and toe joints.

**3. Cartilage**

Cartilage is stiff yet flexible and is found between bones in joints and between the ribs and breastbone (as indicated in the diagram). It also forms the ears, nose and bronchial tubes, and forms discs between the bones of the spinal column.

**4. Tendons**

Your muscles attach to the bone with strong cords called tendons. You can feel some of the tendons in your body, for example behind your ankle (called the Achilles tendon).

**5. Ligaments**

Ligaments occur between bones at joints and hold bones together within the joint. Ligaments are extremely strong.

**Main processes in the musculoskeletal system**

We can move our entire bodies from one place to another through self-propulsion. This is called **locomotion**. Locomotion is different to movement. Movement is the change in shape, direction, position or size of a part of the body. Animals show movement and locomotion. What about plants? Do you think plants show movement and locomotion?

**TEACHER'S NOTE**

Ask your learners this question to get their answers. The answer is that plants only have movement as they are able to change shape and grow, and even change direction in response to a light or water source, but they are rooted to one place - they cannot locomote (move from place to place). Encourage learners to take notes on this discussion either in a separate notebook or in the margins of the workbook.

**VISIT**

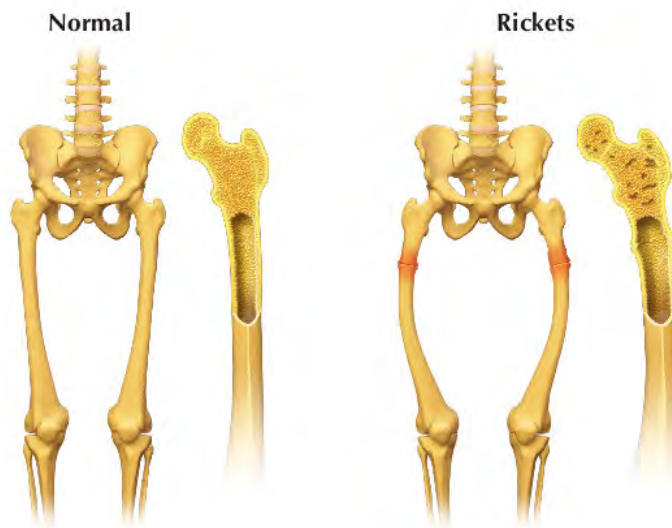
An innovative use of 3D printers to help repair fractures in bones! [bit.ly/13Q6hBw](http://bit.ly/13Q6hBw)

Locomotion and movement are made possible through the contraction and relaxation of muscles. Muscles are stimulated by nerves to contract.

**Health issues involving the musculoskeletal system**

Common disorders of the musculoskeletal system include:

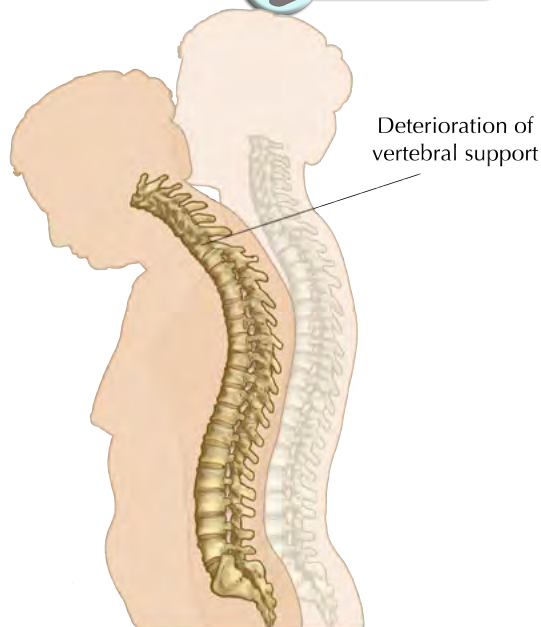
**Rickets:** This disorder is caused by a lack of vitamin D, calcium or phosphate which results in soft, weak bones. A typical symptom in children who have rickets is a bowing (bending outwards) of the bones of the legs.



*Can you see how the shape of the bones changes when a person has rickets?*

**Arthritis:** This is a condition where the joints in the body become inflamed, painful and swollen. The cartilage between the joints breaks down causing the bones to rub against each other which is very painful.

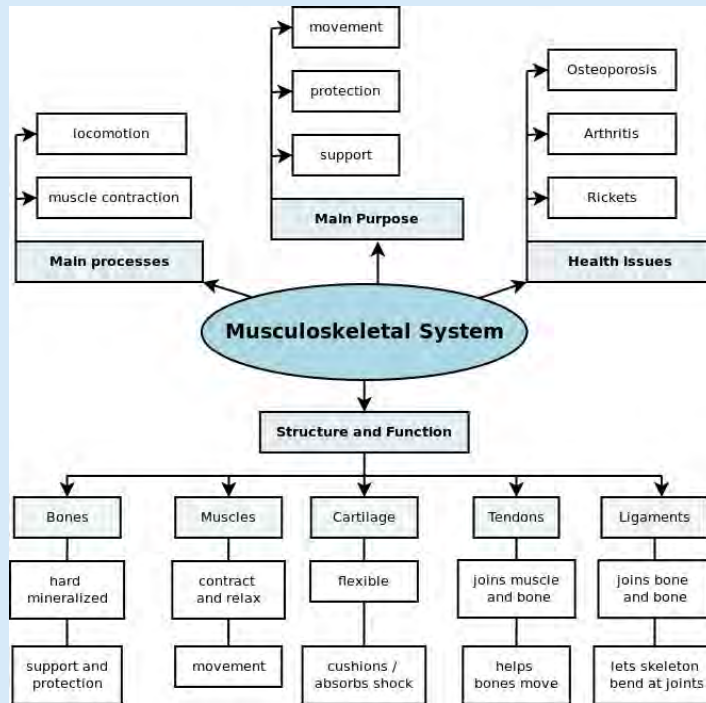
**Osteoporosis:** This occurs when the bone tissue becomes brittle, thin and spongy. These fragile bones can break easily, and they start to crumble and collapse. Although osteoporosis is common in older people (especially older women), teenagers and young adults may also develop it.



*As this woman got older, she developed osteoporosis causing her vertebral column to crumble and collapse and so she now stoops over.*

**TEACHER'S NOTE**

An alternative to doing the summary diagram with the human body outline at the end of this system, is to get learners to produce a mind map. It is important that learners are exposed to and get experience with different techniques to summarise information and help them study or learn. This is crucial for later grades. Below is an example of a mind map that a learner may construct:



**2.5 The excretory system**

We will now be looking at the excretory system. This is often confused with egestion, which we previously learned about.

**ACTIVITY:** Differentiating between excretion and egestion

Do you remember learning about the difference between excretion and egestion? Explain what you understand the difference between these terms are.

1. Egestion is...  
*Egestion is the removal of undigested material (solid waste) from the digestive tract via the anus.*
2. Excretion is ...  
*Excretion is the removal of metabolic waste products from the metabolism which takes place in cells in the form of urine and sweat and exhalation*



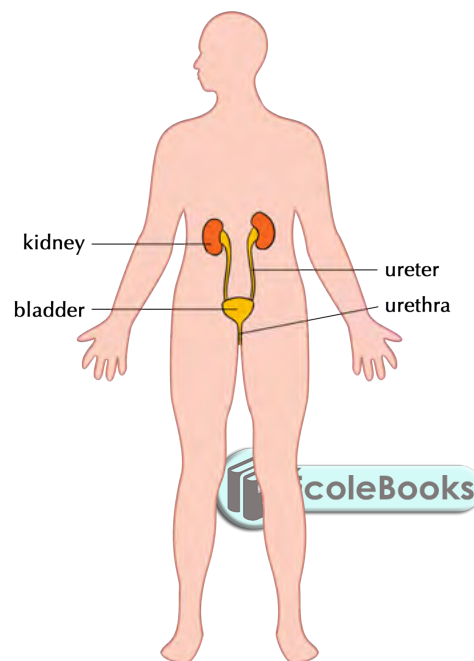
## Purpose of the excretory system

Our cells use oxygen and nutrients to function and in the process also produce various metabolic waste products including:

- **urea:** a substance that is formed when protein is broken down in the liver
- **carbon dioxide:** a by-product of cellular respiration

The organs of the excretory system are responsible for removing these harmful metabolic waste products from the blood so that they do not build up to high concentrations. But, in the process, they have to retain the nutrients and water for the body to function. One of the main functions of the excretory system is to prevent too much or too little water in the body.

## Components of the excretory system



*The excretory system is responsible for removing metabolic waste products from the blood*

We already know that the lungs excrete carbon dioxide (CO<sub>2</sub>) when you exhale. Another organ that excretes waste is the skin. When you sweat, your skin excretes excess water, salts and a small percentage of urea. In this section, however, we will focus on the excretory system to remove metabolic waste from our blood in the form of urine.

To do this, the body uses the urinary system that consists of four main parts.

### 1. Kidneys

The kidneys filter all the blood in your body to remove urea from the blood. You have two kidneys, each about the size of your fist and bean-shaped. Your kidneys produce urine which is a combination of excess water and waste products.

### 2. Ureters

There are two ureters (thin tubes) which connect each kidney with the bladder and carry the urine from the kidney to the bladder.



### 3. Bladder

The bladder is a balloon-like organ that collects the urine before excreting it during urination.

### 4. Urethra

The urethra is a tube that connects the bladder to the outside of the human body through which the urine is excreted.

## Main processes in the excretory system

There are four main processes discussed below.

**1. Filtration:** All the blood in the body passes through the kidneys as part of the circulatory system. The kidneys filter the blood to remove unwanted minerals and urea, and also excess water. Some water is removed so that the metabolic waste products can be excreted in solution in the liquid urine.

**2. Absorption:** Once the blood is filtered by the kidneys, the substances that the body needs are re-absorbed back into the blood so that they are not lost in the urine.

**3. Diffusion:** The substances are transported into and out of the specialised cells of the kidney through the process of diffusion.

**4. Excretion:** The kidneys funnel the liquid urine through the ureters to the bladder where it is stored. When the bladder has filled up, it uses muscles to force the urine out of the body through the urethra. This is called excretion.

## Health issues involving the excretory system

Common diseases of the excretory system include:



*A patient receiving dialysis to filter his blood because the kidneys are not working as they should.*

**Kidney Failure:** When this happens the kidney loses its ability to properly filter and remove metabolic waste which allows this waste to build up in the body. This is very harmful and may be fatal. In such cases the patient needs to undergo very regular kidney dialysis. Dialysis involves using a machine which filters the blood for the patient to remove waste products.

#### VISIT

A summary video of the excretory system.

[bit.ly/160u9IA](http://bit.ly/160u9IA)

**Kidney Stones:** Kidney stones form when fluid intake is too low, resulting in the concentration of solutes (salts and minerals) in the kidney becoming too high. This can result in a small crystal (stone) forming. The kidney stone may stay in the kidney or move down the ureter to be excreted in the urine. A larger stone may however cause severe pain along the urinary tract and may even get stuck, blocking the flow of urine and causing severe pain or bleeding.



*A kidney stone which is about 4.5 mm in diameter.*

**Bladder infection:** This is one of the most common infections in women but is quite rare in men. Bacteria can enter the bladder and cause an infection. This causes swelling and pain when urinating.

## 2.6 The nervous system

### TEACHER'S NOTE

A fun idea is to play the song of the nervous system in the visit box as learners come into the class and sit down.

### VISIT

A song about the nervous system. [bit.ly/13ZsGIR](https://bit.ly/13ZsGIR)

### Purpose of the nervous system

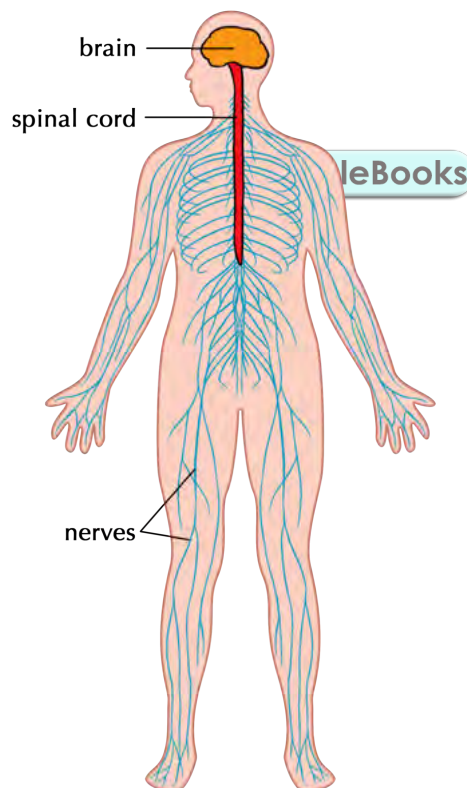
Our nervous system is a complex network that transmits nerve impulses between different parts of the body. The nerves in our body receive **stimuli** from inside the body or from the environment (from the ears, eyes, skin or tongue for instance). These are turned into **impulses** to the brain and spinal cord.

### TAKE NOTE

Stimuli is the plural form of the word stimulus.

### Components of the nervous system

The nervous system consists of various parts.

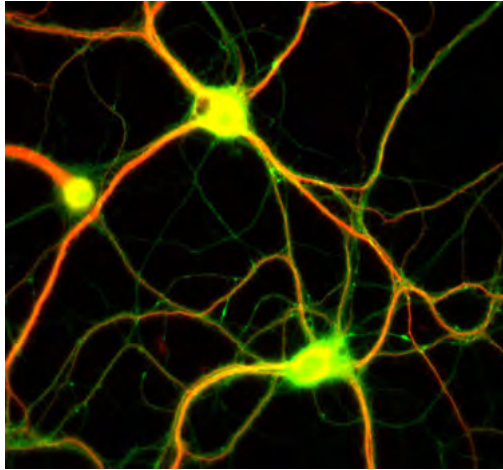


#### 1. Nerves

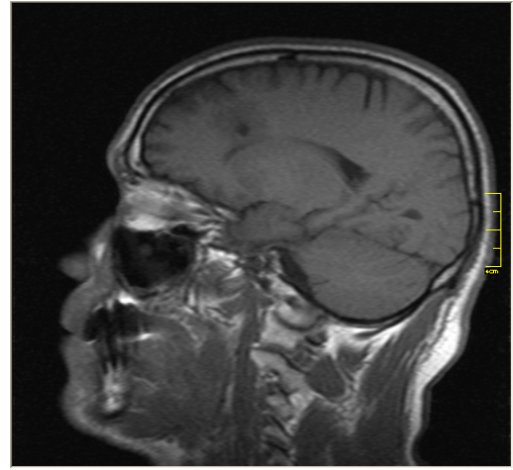
Nerves are the long fibres which transmit messages from the brain and spinal cord to the rest of the body and back. Each nerve is actually an enclosed bundle of nerve cells, called neurons. The nerves work together to carry messages throughout the body. They make up the nerve tissue in the nervous system.

## 2. Brain

Your brain is located inside your skull. The brain is part of your central nervous system and sends messages to the rest of your body. There are different areas in the brain that have different functions. All these different areas also communicate with each other.



*This fluorescent image shows nerve cells from a rat brain which were grown in the laboratory.*



*A MRI (magnetic resonance imaging) scan of a person's head showing the position of the brain within the skull.*

### VISIT

Citizen science: Play a game to help MIT map the brain! [bit.ly/160udlh](http://bit.ly/160udlh)  
Learn more about the brain and participate in the interactive activities to stimulate the brain [bit.ly/13stpSU](http://bit.ly/13stpSU)

### TAKE NOTE

"Peripheral" means on the outside. So the peripheral nervous system is on the outside of the central nervous system.

## 3. Spinal cord

The spinal cord runs from the brain through your spine, protected by your vertebral column. The spinal cord is a bundle of nervous tissue and other support cells. Together with the brain, the spinal cord also forms part of your central nervous system.

## 4. Sensory organs

We have mentioned that there is a central nervous system (made up of the brain and spinal cord). The second part of the nervous system within our bodies is the peripheral nervous system.

The peripheral nervous system connects the central nervous system to the muscles and organs. Various sensory organs are responsible for collecting information and sending it via sensory nerves to the central nervous system.

Our sensory organs are our:

- ears
- nose
- eyes
- skin
- tongue

## Main processes in the nervous system

The nervous system is responsible for key processes in the body. These are discussed next.

**Sending and receiving impulses:** Nerve cells in the brain send and receive multiple messages from multiple sources at any given moment. These are transmitted as electrical impulses.

The central nervous system interprets these signals and this is how we sense the world around us. These processes are:

- **Hearing:** In the ear, sound waves are transformed into electrical signals that travel along the auditory nerve to the brain. This allows us to understand what we are hearing.
- **Seeing:** Seeing and understanding what you see are complex processes. Light enters your eye and stimulates specialised cells within your eye. These cells transmit signals to the brain along the optic nerve, where they are interpreted as sight.
- **Feeling:** The skin allows us to feel and experience the world around us through touch. Millions of nerve endings in the skin, called receptors, cover the skin, muscles, bones and joints, as well as internal organs and the circulatory system. These receptors respond to pressure, pain, temperature and movement.
- **Tasting:** Taste buds in your tongue and parts of your mouth can distinguish between the different flavours: sweet, sour, bitter, salty. These receptors work very closely with the receptors in the nose. Together the taste and odour of food is sent to the brain where it is processed and interpreted.
- **Smelling:** Nerve cells in the lining of your nose respond to molecules in the air. They send messages to the brain which interprets the smell accordingly and recognises any one of about 10 000 different smells!

**VISIT**

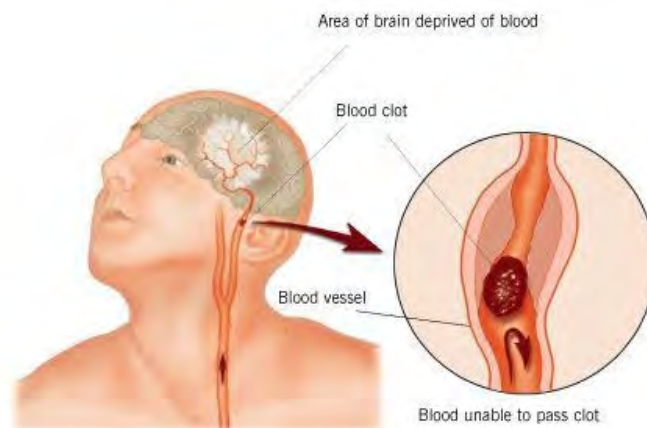
Want to learn more about  
the eye and sight?  
[bit.ly/16IRhU](https://bit.ly/16IRhU)

**Regulating:** An important part of the nervous system is to maintain a balance within the human body. This includes regulating our body temperature. Our bodies need to be kept at about 37°C to work effectively. If the body is too hot the brain might try and cool the body through increased sweating. If you are very cold, your body will start to shiver to generate heat energy. These responses to changes in body temperature are controlled by your nervous system.

## Health issues involving the nervous system

**Trauma and injuries to brain and spinal cord:** Any damage to the brain or spinal cord can have devastating effects on the human body. For example, people who break their necks in an accident, often damage their spinal cord. This prevents the brain from sending and receiving messages to the body and the person can become paralysed.

**Stroke:** If blood flow to the brain is stopped, brain cells begin to die, even after just a few minutes without blood or oxygen. This can lead to a stroke where a part of the brain function is lost.



*When the brain is deprived of blood and oxygen due to a blood clot, the person may suffer from a stroke.*

**Degenerative disorders:** There are several problems associated with the nervous system that cause a gradual loss of function over time (degenerative). These conditions include Alzheimer's Disease, Parkinson's Disease and Multiple Sclerosis.

**Mental health problems:** Examples include depression, anxiety disorder and personality disorders.

**Sensory organ problems:** We have discussed the various sensory organs that are associated with the nervous system. These organs can also have problems, such as:

- Deafness
- Blindness
- Short sightedness

**Effects of drug and alcohol on the brain:** Different types of drugs target different areas in the brain and it is mostly the brain's reaction(s) that make people want to take drugs and/or alcohol.

#### TEACHER'S NOTE

Teachers may want to use this opportunity to discuss the topic of drug abuse. If you would like to explain some of the effects of drugs and alcohol on the brain to your learners, here are some:

- Drugs like methamphetamines (tik) and cocaine make the user feel a huge sense of reward causing these drugs to become addictive.
- People also use drugs as a stimulant - using caffeine, cocaine and amphetamines to speed up their reactions.
- Alcohol and marijuana (dagga) have the opposite effect on the brain and slow it down - these are called sedatives and hypnotics.
- Hallucinogens like LSD and Ecstasy, and also more recently the drugs Woonga and Nyaope, make you see things that are not real.
- Morphine and heroin are used to relieve severe pain and when misused slow down the user's reactions.

It may be useful to explain to learners that the same drug may be useful and beneficial when used properly and at the correct dosage, or abused when it is used inappropriately, or in excessive amounts.

#### VISIT

The effects of drug and alcohol on the adolescent brain [bit.ly/14k6icr](http://bit.ly/14k6icr)

Alcohol and drug abuse can cause irreversible brain damage, a loss of memory, decreased learning capability, an increased risk of strokes and heart attacks, and a variety of emotional and mental health problems.

## 2.7 The reproductive system

### Purpose of the reproductive system

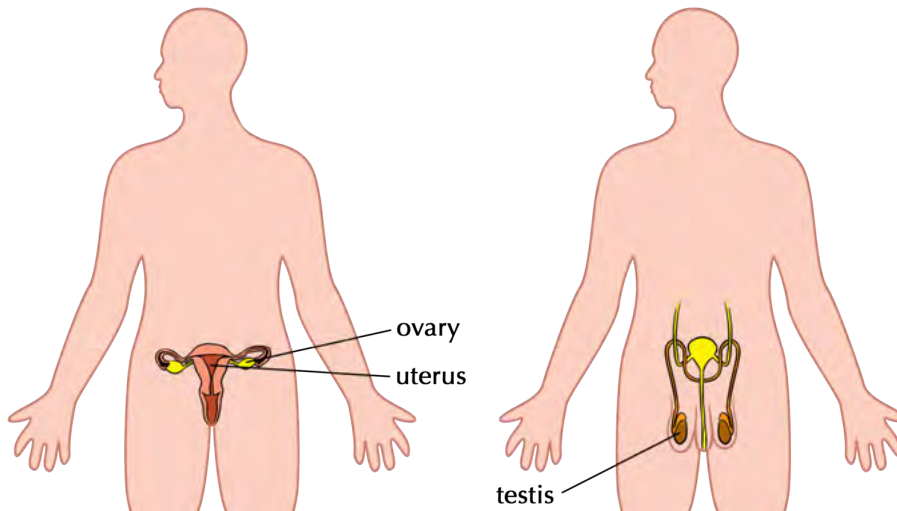
In humans, as in other eukaryotic organisms, the main purpose of the reproductive system is to produce sex cells to ensure the continuation of the species.

### Components of the reproductive system

We will be looking at the reproductive organs in more detail in the next chapter. For now, let's get an overview of the main components in the reproductive system.



The female (left) and male (right) reproductive organs differ:



### 1. Ovaries

The ovaries are located inside the female's body in the lower abdomen and produce mature egg cells (ova).

### 2. Uterus

The uterus (also known as the womb) is present in females. It has a thick lining and muscular wall. This is where a fertilised egg will implant and develop during pregnancy.

### 3. Testes



The sex organs in males are located in the scrotum, a pouch of skin that hangs between the legs. During puberty the testes start to produce sperm cells.

## Main processes in the reproductive system

During sexual reproduction, the egg and sperm have to combine to form a new individual. Let's do an activity to find out about the main processes in the reproductive system.

### TEACHER'S NOTE

As this will be dealt with in the next chapter, a simple activity can be done now for learners to look up these new terms and write down definitions.



## **ACTIVITY:** Defining the main processes involved in reproduction

### **INSTRUCTIONS :**

- Below is a list of the main processes involved in the reproductive system.
- Look up each term, either in your dictionary or on the internet and write a brief description on the lines provided.
- The first three have been done for you.
- Growth

Growth is the increase in size and mass of an organism as it develops over time.

- Cell division

Cell division is the process when a parent cell divides into two daughter cells. In the reproductive system, cell division occurs within the ovaries and testes to produce gametes (sperm and egg cells)

- Maturation

Maturation is the process of becoming mature. In humans, this refers to puberty where sexual organs mature so that they are able to reproduce.

### **TEACHER'S NOTE**

The muscles in the uterus are some of the strongest in the human body. This is because they need to be able to grow and contract to contain a growing foetus and to push the foetus out during labour.

#### 1. Copulation

*Copulation is the act of sexual intercourse (procreation) when a man inserts his penis into a woman's vagina.*

#### 2. Ejaculation

*This is the release of the sperm into the woman's cervix during sexual intercourse.*

#### 3. Ovulation

*This is when a mature ovum (female egg cell) is released from the ovary once a month.*

#### 4. Menstruation

*If the ovum is not fertilised, the lining of the uterus is shed during menstruation.*

#### 5. Fertilisation

*When a male (sperm cell) and female (egg cell) gamete fuse (come together) during copulation.*

#### 6. Implantation

*In the reproductive system, this refers to the process when the fertilised egg implants (attaches firmly into) the uterus lining.*



## Health issues involving the reproductive system

**Infertility:** About 10% of heterosexual couples have problems falling pregnant and may even be completely unable to sexually reproduce. This is infertility and it affects both men and women.

**Foetal Alcohol Syndrome:** When a pregnant mother drinks alcohol during her pregnancy, the alcohol may cause serious birth defects in the unborn baby. This will affect the child throughout their entire life and in most cases cannot be reversed.

### TEACHER'S NOTE

Additional information on foetal alcohol syndrome can be viewed at this link: [bit.ly/14k6k4f](http://bit.ly/14k6k4f)

### VISIT

Learn more about STDs and sexual health: [bit.ly/1cEtUlc](http://bit.ly/1cEtUlc)

**Sexually Transmitted Diseases (STDs):** Many life-threatening diseases such as HIV/AIDS, syphilis and gonorrhoea can be transferred during sexual intercourse.



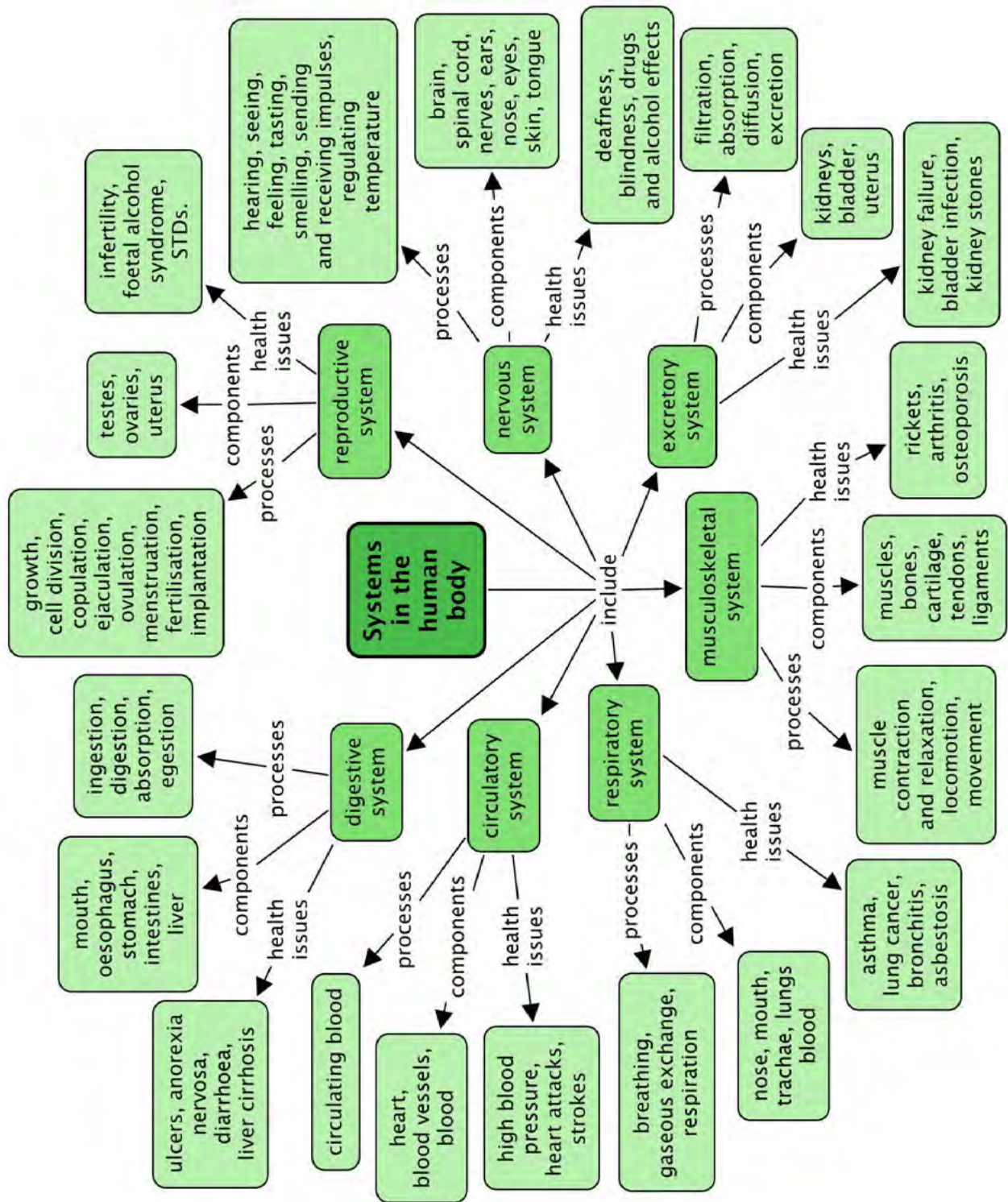
## SUMMARY:

### Key Concepts

- There are many complex systems functioning in our bodies.
- Each system has very specific organs and tissues that are key components in making the system function optimally.
- Different processes take place that are dependent on the key components in each system.
- There are various health issues that affect the systems of the body and that can often be prevented with a healthy lifestyle and wise (informed) life choices.

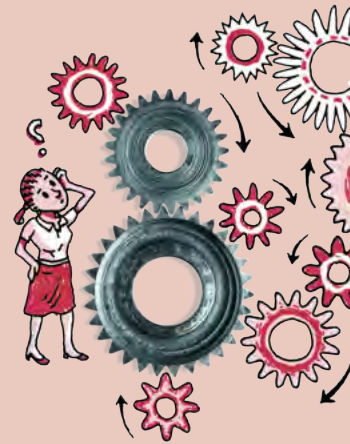
### Concept Map







## REVISION:



1. What does digestion mean? [4 marks]  
*Breaking food into small soluble parts that can be transported in the blood and absorbed by the cells.*
2. List the four main processes involved in the digestive system. [4 marks]  
*Ingestion, Digestion, Absorption and Egestion.*
3. Describe the different components of the digestive system and their function. [15 marks]
  - **Mouth and oesophagus:** food is chewed in the mouth and passed through the oesophagus to the stomach
  - **Stomach:** bolus enters the stomach where it is mechanically digested through churning and chemically digested by gastric juices in the stomach.
  - **Small intestine:** most of the chemical digestion and absorption takes place in the small intestine where food is chemically broken into tiny pieces to be absorbed by the walls of the small intestine and transported in the blood to the cells.
  - **Large intestine:** water that is left after digestion in the small intestines are absorbed in the large intestine and indigestible fibre is left to pass through and faeces are formed.
  - **Rectum and anus:** undigested fibre and substances (faeces) passes from the large intestine to the rectum and anus from where it is egested.
4. Diarrhoea is can be very dangerous in babies. Why do you think this is so? How it can be prevented? [3 marks]  
*Babies who have diarrhoea lose large quantities of undigested nutrients and water in this way. Their bodies quickly dehydrate and they become too listless to feed or drink, dehydrating their bodies even further. If they do not get medical attention they may die. This can be prevented by sterilising their bottles and feeding equipment to prevent the transfer of the bacteria that cause diarrhoea.*
5. Distinguish between inhalation and exhalation. [2 marks]  
*Inhalation: breathing in; exhalation: breathing out.*
6. Is carbon dioxide in your body excreted or egested? Explain why you say so. [3 marks]  
*Egestion is the removal of undigested substances and fibre from the body; Excretion is the removal of waste products of metabolism, including cellular respiration. Since carbon dioxide is a waste product of cellular respiration it is **excreted**.*
7. Draw a simple diagram to show how blood is circulated around the body in a closed system. [10 marks]  
*Learner-dependent answer*
8. What is the difference between breathing and respiration? [5 marks]  
*Breathing: taking air into and out of the body through the mouth, trachea, bronchi and lungs.*  
*Respiration: occurs at the cellular level when oxygen is taken into the cells where it is used to release energy from food; carbon dioxide is a by-product of this and it is returned to the blood and sent to the lungs to be exhaled.*
9. Give two parts of your musculoskeletal system you use when you have to climb stairs. [3 marks]  
*Muscles contract and relax to move the bones at the joints and allow for locomotion. Tendons and ligaments are also used.*



10. What are the functions of the bones in the skeleton? [2 marks]

*Bones are an attachment place for muscles and provide protection and support.*

11. Drugs and alcohol have various negative effects on the body. List at least 3. [3 marks]

*Learners were exposed to various negative effects and should refer to these in this answer. These may include any of the following among others:*

- *Dependence on the drug / alcohol make it almost impossible to withstand cravings and the addict will do almost anything to get money to buy more.*
- *Organ damage and ultimately organ failure and death.*
- *Reduced brain activity and harm to brain cells, leading to seizures, impaired vision and motor coordination, blackouts, etc.*
- *If using intravenously the user stands a big chance of infection by HIV and other infectious diseases.*
- *Stimulant drugs like nicotine and cocaine affect the respiratory system.*
- *Smoking also affect almost every other system in the body - vascular, skin, etc*
- *etc*

12. Explain why it is so dangerous for a pregnant woman to drink alcohol during pregnancy. [2 marks]

*If a pregnant woman used alcohol during the pregnancy, this may cause deficiencies, Foetal Alcohol Syndrome and physical and central nervous system abnormalities in the baby. These effects are permanent and irreversible.*

Total [56 marks]





**TEACHER'S NOTE****Chapter overview**

2 weeks

After looking at several of the organ systems within the human body in overview in Chapter 2, the next three chapters will now look at some of these systems in more detail.

This chapter on "Human reproduction" starts off by looking at the purpose of reproduction and how humans mature during puberty in order to be able to reproduce. This will be very relevant to your learners as they are in this stage in their lives at the moment.

Be aware that learners might not feel comfortable discussing reproduction in the classroom, and older teens might laugh or make inappropriate jokes to conceal their own discomfort.

**Some tips for when teaching human reproduction:**

1. Respect your learners' questions and concerns. Some of them may not have had an opportunity before to ask questions about reproduction, especially if their parents did not feel comfortable discussing this with them. This is a sensitive topic, and learners might be embarrassed to ask questions. Encourage your learners to ask questions and not be embarrassed. Learners must be told to phrase their questions carefully and to use scientific words, with no vulgar expressions. You yourself, as the teacher, must only use scientific terms.
2. Discuss processes openly so that learners are comfortable within the classroom environment to talk and learn about reproduction and how it influences their lives. Discourage and discipline any laughing or disrespectful behaviour from other students.
3. Possibly bring in a guest speaker. Learners might feel more comfortable asking a stranger questions. Also, if you bring in an expert, such as a gynaecologist or midwife, learners might take the subject more seriously. If necessary, you can separate boys and girls. For example, if you are showing a graphic video about the female reproductive organs, it might be useful to have the boys watch a similar video in another room that explains the male reproductive organs.
4. Avoid portraying the reproductive system in a negative light or as "forbidden" as this will only add to some of the discomfort that learners might already feel. At this stage in their lives, learners are already very interested in reproduction and the changes that their bodies are going through. This is natural and should be embraced so that they are educated and can make informed choices about their sexual health going forward.
5. Here is a website to do some further reading: [bit.ly/1cfWcTS](http://bit.ly/1cfWcTS)

### 3.1 Purpose and puberty (2 hours)

Tasks	Skills	Recommendation
Activity: Reflecting on population growth	Identifying, predicting, writing	Optional

### 3.2 Reproductive organs (1 hour)

Tasks	Skills	Recommendation
Activity: Identify the role of the male and female bodies in reproduction	Identifying, writing	Suggested
Activity: Identify structure and function	Identifying, describing, explaining, writing	CAPS suggested
Activity: Comparing the reproductive organs	Comparing, summarising, writing	Suggested

### 3.3 Stages of reproduction (3 hours)

Tasks	Skills	Recommendation
Activity: Flow diagram of the pathway of sperm	Summarising, describing	CAPS suggested
Activity: Comparing fertilisation and menstruation	Comparing, summarising, drawing	Suggested
Activity: Debate Surrogacy	Working in groups, discussing, debating, presenting, writing	CAPS suggested
Activity: Describing different contraceptives	Identifying, describing	Optional
Activity: Forum discussion	Working in groups, discussing, debating, presenting, writing	Optional



## KEY QUESTIONS:

- What is puberty and what does it mean when we "reach puberty"?
- Why do we all go through puberty at different times and rates?
- What changes take place inside our bodies during puberty?
- What do our reproductive organs look like when they are mature?
- How does reproduction occur?
- What is menstruation and why does it occur once a month?
- How does a baby grow inside a woman's uterus?
- Are there ways to prevent pregnancy and the transmission of STDs?



At this stage in your life, your body is probably going through all sorts of changes as it grows, develops and matures. In this chapter we will learn more about these changes and why they occur.

### 3.1 Purpose and puberty

#### The purpose of reproduction

You have previously learnt that reproduction is one of the seven life processes, and like all organisms, humans need to reproduce to ensure the survival of the species.

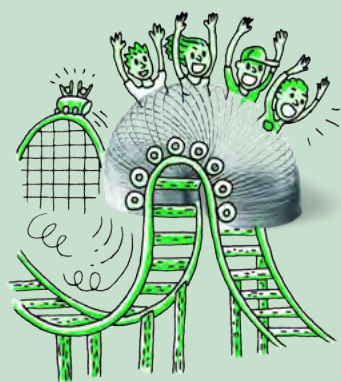
#### ACTIVITY: Reflecting on population growth

##### TEACHER'S NOTE

You can use this section to open up discussion about population growth and population control. At the end of the chapter there is a debate regarding contraceptives but teachers may choose to include a discussion on the different ethical points of view regarding contraceptives at this point already.

Have a look at the website link provided in the visit box about our "Breathing Earth". This will give you an idea about how our population is growing.

In 2011 the world's population grew to 7 billion people, one billion more since 1999. Medical advances and increases in agricultural production (food) allow more and more people to live longer lives.





### TEACHER'S NOTE

An interesting suggestion if you have an internet connection and a projector or smartboard to display a website, is to open up the link provided here in the visit box on our "Breathing Earth". This simulation very clearly shows how our population is growing. You can open up the link at the start of the lesson and leave it running for the duration. Then at the end of the lesson, you can see how much the population of the world has grown during your one lesson.

Alternatively, if you do not have an internet connection in your classroom, ask some of your learners to take out their mobile phones and go to the site. Even if you only have a few mobile phones within the classroom, you can get learners to each take a look at the site at the start and end of the lesson. Do not be afraid to embrace the technology that your learners are using on a daily basis! They most likely have their cellphones in their pockets in class anyway, unless they have been banned during school hours.

In ancient times, countries such as India, Rome and Greece, saw a large population as a source of power. The Romans even made laws about how many babies a couple could have and punished those who did not follow the rules. Yet Confucius (551-478 BC) thought that too many people was a problem, as there wouldn't be enough food to feed everyone, leading to war and famine and various other problems. Today in China this philosophy still applies and couples are only allowed one baby and are heavily taxed if they have more than one.

South Africa's population grew by 15,5%, or almost 7-million people, in the space of 10 years to reach a total of 51.7-million in 2011. This is according to the country's latest national census which took place in 2011. The last census took place 10 years previously in 2001.

### QUESTIONS:

### TEACHER'S NOTE

These questions are meant to stimulate discussion within your class. You can go through these as a class or learners can then do them individually and then discuss their answers.

1. List any possible reasons why you think South Africa would want to have a large population.

*Learner-dependent answer. Might include: more people so more manpower and more taxes; might include religious or cultural bias; etc.*

2. What are some advantages and disadvantages to the country in which the number of children per couple is limited so that the population growth is limited?

*Advantages: lower population growth; lower pressure on the country's resources; lower drain on resources, particularly on the education resources; higher standard of living for families*

*Disadvantages: fewer people to pay taxes; religious or cultural non-compliance might lead to revolt*

3. Predict what possible long-term problems might arise if the population in South Africa continues to grow at the fast rate at which it is currently growing.

### VISIT

Video on our world population growth.

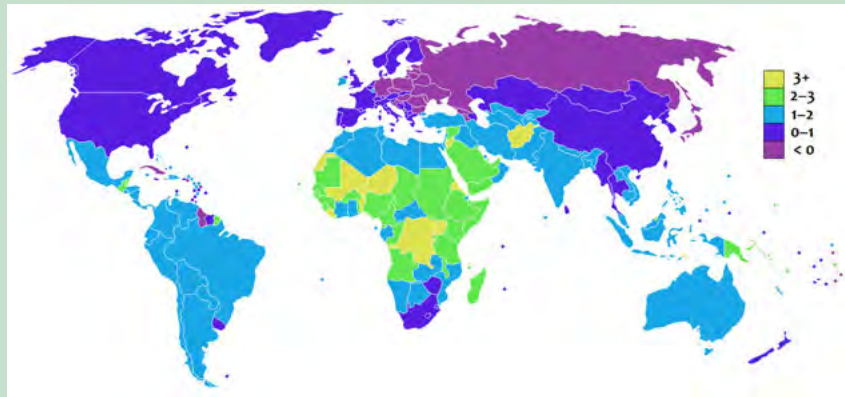
[bit.ly/16DDipB](http://bit.ly/16DDipB)

A simulation to show population growth

[bit.ly/19kSnvE](http://bit.ly/19kSnvE)

*With fewer resources to go around many might starve and since they might not have work or social grants to support them. Unemployment would increase even more. This might also lead to increased crime as people try to provide for themselves and their children, as well as drug and alcohol abuse as a coping mechanism.*

- Have a look at the following diagram which shows the percentage growth a country's population in a year. The different colours give an indication of the growth rate, as shown in the key. For example, countries which are colour coded yellow, have an annual growth rate of 3%. This means their population increase by 3% each year. Answer the questions which follow.



*Percentage growth rate of each country.*

**VISIT**

The science of overpopulation (video).  
[bit.ly/13Q6VPn](http://bit.ly/13Q6VPn)

- Which continent would you say has the largest percentage growth rate each year? Justify your answer.  
*Africa has the largest population growth rate. This can be seen as it has the largest number of countries which are coloured green and yellow which shows the highest annual percentage growth rate.*
- Many countries in Europe are coloured light purple in the diagram. What does this mean?  
*Learners need to look at the legend to see that light purple means a growth rate of "< 3%". This means the growth rate is negative which means the population size is decreasing each year.*
- Various population control methods are put in place around the world - contraceptives to stop women from falling pregnant, abortion clinics, large tax incentives to convince people not to want more children, and others. What is your opinion about population control methods and do you think they should be allowed in modern society?  
*Learner-dependent answer.*

**What is the purpose of puberty?**

The human body is geared towards reproduction to ensure the survival of the species. Men have to produce sperm and ensure that they come into contact with a female egg cell. Women have to produce (and store) egg cells that can be fertilised by a male sperm cell.

Children's bodies and sexual organs are not mature and cannot yet perform the reproductive function. Puberty is therefore the time when a child's body develops and changes. The sexual organs mature to enable the body to produce sex cells. These sex cells are called **gametes**.

## How does puberty just "start"?

Puberty is the stage in the life cycle of humans when we become capable of sexual reproduction. Girls and boys do not, generally, go through puberty at exactly the same time. So how does puberty "start"?

Many of the complex actions that take place in our bodies are controlled by chemical messengers called hormones. Hormones are produced by different glands in our bodies. The pituitary gland is an important gland which controls most of the body's hormones and hormonal activities. It is about the size of a pea and located at the base of the brain.

Puberty is brought on when the pituitary gland releases specific hormones into the bloodstream. These hormones then travel to the immature sex organs and signal the hormones in these to be released.

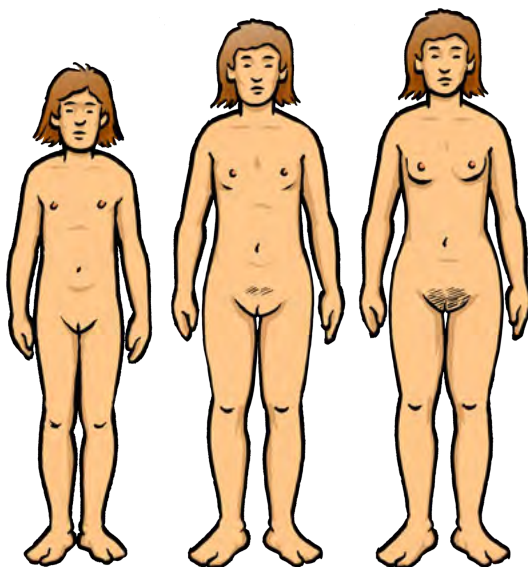
In girls, the ovaries are stimulated by hormones released by the pituitary gland to release the hormone **oestrogen**. In males, the testes are stimulated to release the hormone **testosterone**. These hormones initiate all the bodily changes that you experience during puberty.

## What changes during puberty?

The main purpose of puberty is for the sexual organs to mature. However, the hormones which are released from the reproductive organs also start a number of other changes in the human body. We call these **secondary sexual characteristics**.

Puberty brings about the following secondary changes in females:

- **Breasts** start to develop that may be used for breastfeeding a baby after childbirth.
- **Pubic hair** starts to grow at the onset of puberty. Underarm hair also starts to grow.
- **Menstruation** occurs in girls in a monthly cycle once they reach puberty.
- **Body shape** also changes due to the rising levels of oestrogen in the body.
- **Body odour and acne** develop as more oil is secreted and the smell of sweat in the body changes.



### VISIT

Visit this interactive site to explore the changes that occur during puberty  
[bit.ly/1cpBnFl](http://bit.ly/1cpBnFl)

### VISIT

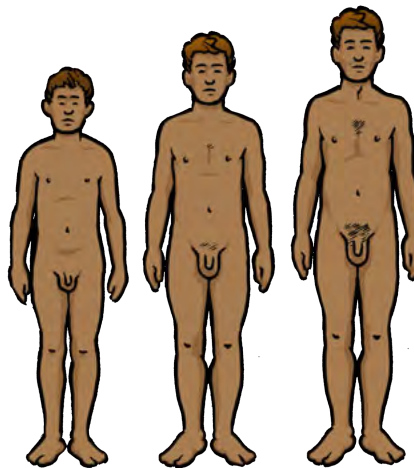
This animation shows the position of the pituitary gland (the pink gland)  
[bit.ly/15qfVXa](http://bit.ly/15qfVXa)

**TAKE NOTE**

Testes is plural and testis is singular.

At the start of puberty boys are, on average, 2 cm shorter than girls, yet adult men are approximately 13 cm taller than adult women. Puberty brings about the following secondary changes in males' bodies:

- **Testicle and penis size** increases.
- **Hair** starts to grow on the pubic areas, the limbs, chest and the face.
- **Voice** becomes deeper as the larynx (voice box in your throat) grows.
- **Body shape** changes occur as the skeletal muscle and bones increase in size and shape.
- **Body odour and acne** start to develop, as with females.

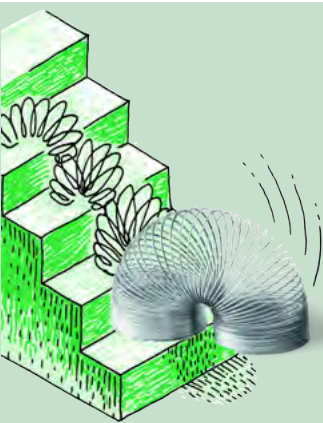


Let's take a look at the reproductive organs.



### 3.2 Reproductive organs

Let's take a closer look at the male and female reproductive organs to see how they are structured and what functions they perform.



#### ACTIVITY: Identify the role of the male and female bodies in reproduction

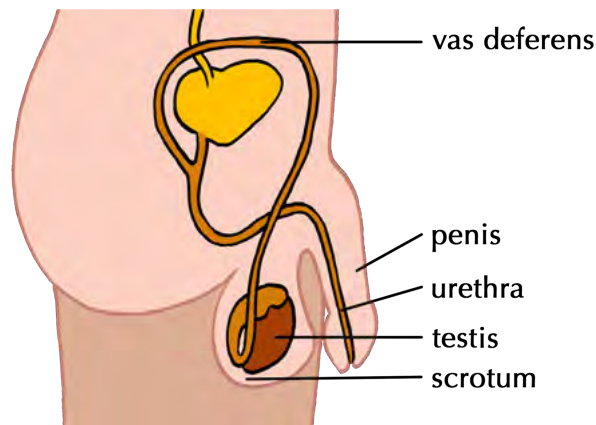
In the space below, explain what you think the role of the male and female bodies are in reproduction.

1. The male body has to ...  
*The male body has to produce sperm and deliver this sperm to the female body in order for it to come into contact with the female egg (ovum).*
2. The female body has to...  
*The female body has to produce ova (egg cells). Once a month, one egg cell is released and if a sperm cell penetrates the outer layer of the egg cell, fertilisation can take place. This may then lead to pregnancy and the female body adapts to provide for all the needs of the unborn baby before giving birth.*



## Male reproductive organs

The male reproductive organs include:



### TAKE NOTE

As you learn about the reproductive organs, think carefully about their **structure** and how their structure is **adapted** to their **function**.

### 1. Testes and scrotum

Males are born with their two testes hanging outside their bodies. The testes in young boys do not produce sperm. During puberty the two testes release testosterone which then triggers the production of sperm.

The two testes are each contained in a pouch of skin called the scrotum. The scrotum ensures that the testes are kept at a constant temperature of 35°C which is the temperature at which sperm is produced.

### 2. Sperm duct (vas deferens)



Different tubes (ducts) carry the semen from the testes to the penis. The sperm duct carries the sperm from the testes to the urethra in the penis.

### 3. The penis

The penis is the external sex organ. The head is often covered by a loose fold of skin called the foreskin. The penis needs to be erect (stiff and hard) to be able to go into the vagina to deliver the sperm to the cervix during ejaculation.

### 4. Urethra

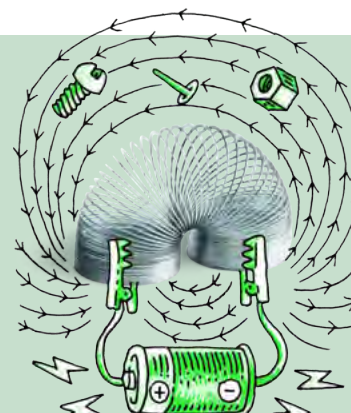
The semen moves through the urethra to the outside during ejaculation. The urine passes through the urethra during urination, but the semen and urine do not move through the urethra at the same time.

### TAKE NOTE

Some cultures have the foreskin removed, called circumcision. This is done when the boy is a baby or at puberty.

## ACTIVITY: Identify structure and function

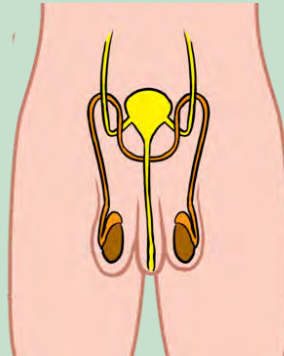
1. Study the diagram of the male reproductive system. Label each part using its correct scientific name.
2. In the table, identify the function(s) of the male reproductive organs mentioned.
3. In the last column, suggest how you think the structure of the organ is adapted to perform the function most effectively.





**TEACHER'S NOTE**

This question starts to delve into the relationship of structures that are adapted to function. Learners need to LINK structure to function when examining any organ. This is an extension activity and requires learners to apply the knowledge they have just learnt.

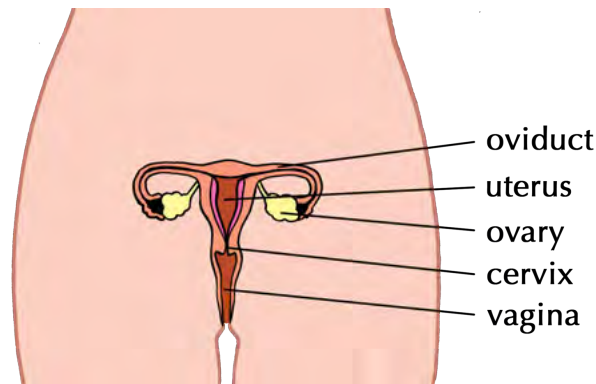


**TEACHER'S NOTE**

Reproductive Organ	Function	Adaptation
Penis	During sexual intercourse, the penis becomes erect and delivers the sperm into the cervix of the vagina.	The penis is on the outside of the male body, and it is elongated so that it can insert into the vagina and deliver the sperm into cervix. The penis contains the urethra and becomes erect so that it can insert into the vagina.
Testes and scrotum	The testes produce the sperm and the scrotum hold the testes outside of the body.	The testes need to be at 35 °C, which is lower than body temperature, in order to produce sperm. The testes are therefore outside of the male body and hang in the scrotum, which can adjust the temperature of the testes so that the right temperature is maintained in order to produce sperm.

## Female reproductive organs

The female reproductive organs include:



### 1. Vagina

The vagina is a tube that connects the uterus with the outside of the body. During intercourse the vagina acts as a canal for the penis to fit into to deliver sperm. Once a month, during menstruation, the menstrual blood leaves the body through the vagina. It is also the birth canal during childbirth when it stretches to allow the baby to pass through.

### 2. Uterus

The uterus is hollow with extremely strong muscular walls that can carry and protect a baby. Two oviducts (Fallopian tubes) at the top of the uterus, connect it to the ovaries. The bottom neck of the uterus is called the cervix, which is tightly closed to protect the inside of the uterus.

### 3. Ovaries

There are two ovaries on either side of the uterus. They produce oestrogen and contain the ova. Each month the ovaries take turns to produce a mature ovum. This is called **ovulation**.

#### TAKE NOTE

The plural of ovum is ova.

### 4. Oviducts (Fallopian tubes)

The uterus and ovaries are connected through a pair of muscular tubes called the oviducts or Fallopian tubes. The mature ovum travels into these tubes to the uterus. Fertilisation occurs in the oviduct.

## ACTIVITY: Comparing the reproductive organs

1. Explain how the structures of the vagina, cervix and uterus are specially adapted to fulfil their functions.

*The vagina is elastic and muscular so it can contain the penis during intercourse to prevent the sperm from running out. The cervix is situated at the top of the vagina approximately where the penis' ejaculated sperm will be. It is tightly closed to protect the uterus. It carries the sperm into the uterus which has a thick, blood-rich lining, ready for the implantation of the fertilised egg.*



**VISIT**

Learn more about the female reproductive system at this site: [bit.ly/1cWaGpM](http://bit.ly/1cWaGpM)

- Provide at least 2 reasons why the uterus needs to have strong muscular walls.  
*The uterus needs to protect and carry the unborn child during pregnancy and it needs to contract and push out the baby during childbirth.*
- Compare the position and functions of the ovaries with that of the testes. Create a table to show these differences.  
*A possible table that learners might produce:*

**TEACHER'S NOTE**

Differences between the female ovaries and the male testes

Characteristic	Ovaries	Testes
Position	Inside the body	Outside the body
Hormones produced	Oestrogen	Testosterone
When gametes are produced	Females are born with ova in their ovaries which mature once puberty is reached	Males only start to produce sperm once they reach puberty
Number of gametes released/produced	Release one ovum per month	Produce thousands of sperm daily
Hormone influence	Hormones in the ovaries stimulate the ovum which are already present so that they mature	Only start to produce sperm under the influence of the hormones

### 3.3 Stages of reproduction

We have already mentioned most of the processes that take place during reproduction. These processes occur in stages. Let's first have a look at the female reproductive cycle.

#### The reproductive cycle

The female reproductive cycle repeats every 28-30 days to release an egg cell to be fertilised if sperm are present. This cycle will repeat for many years from puberty to **menopause** (when the reproductive cycle comes to an end).

The processes that occur will differ depending on whether the ovum is fertilised or not. After ovulation, if fertilisation does not occur, the reproductive organs 'reset' through menstruation to start the process again.

## Ovulation

Once a month, one of the ovaries releases one mature ovum into the oviduct.. This process is called ovulation. At the same time the uterus wall thickens and develops extra blood vessels. This is in preparation for the *possible* implantation of a fertilised egg.

## Menstruation

When there is no fertilised egg cell (**zygote**) to implant in the uterus, the thick layer of blood and tissue is no longer needed. It is passed out through the vagina during menstruation. The entire process is called the menstrual cycle and it normally repeats every 28-30 days.

## Fertilisation

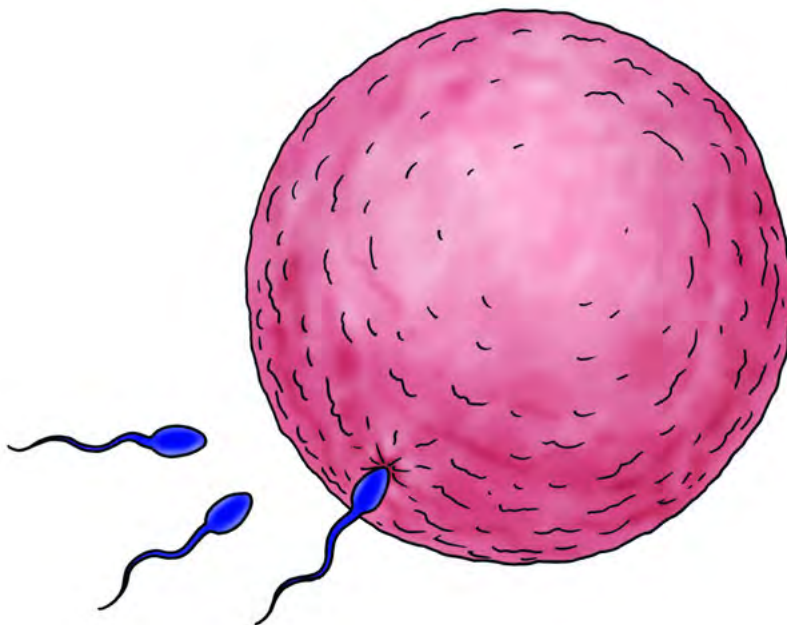
During sexual intercourse the erect male penis enters the female vagina. This is called **copulation**.

The male penis deposits sperm into the female vagina through **ejaculation**. There can be millions of sperm cells in one ejaculation, but only one will be able to penetrate the outer membrane of the ovum.

After ejaculation into the vagina, the sperm swim into the cervix and through the uterus to the oviducts. Once inside the oviducts, the sperm swim to meet the mature egg that was released from the ovaries and is now travelling towards the uterus.

One sperm cell burrows into the surface of the ovum. Only the sperm's head enters, the tail stays outside. As soon as one has penetrated the outer layer, the surface of the ovum changes and no more sperm will be allowed to enter.

This process is called **fertilisation** and it takes place in the outer part of the oviduct, and not in the uterus or vagina.



*Once the sperm on the right has entered the outer layer of the ovum, no more sperm will be able to penetrate.*

### VISIT

Learn how to create an ovulation calendar to keep track of a menstrual cycle. [bit.ly/19WfMCU](http://bit.ly/19WfMCU)

Learn more about the menstrual cycle: [bit.ly/14k7tc2](http://bit.ly/14k7tc2)

### TAKE NOTE

There are times in the menstruation cycle near to ovulation when there is a high chance of becoming pregnant. All girls need to be aware of where they are in their own menstrual cycle as each cycle differs slightly.



## **ACTIVITY:** Comparing fertilisation and menstruation

### **INSTRUCTIONS:**

1. Use the following diagram to compare what happens when an egg is fertilised compared to when it is not fertilised. You can even use coloured pens if you have.
2. Use labels and arrows to illustrate on the left hand side what happens to the ovum if it is fertilised by a sperm cell.
3. Use arrows and labels to illustrate on the right hand side what happens if the ovum is not fertilised and the woman subsequently menstruates.

#### **VISIT**

Video on fertilisation and early development.

[bit.ly/11WbMNR](http://bit.ly/11WbMNR)

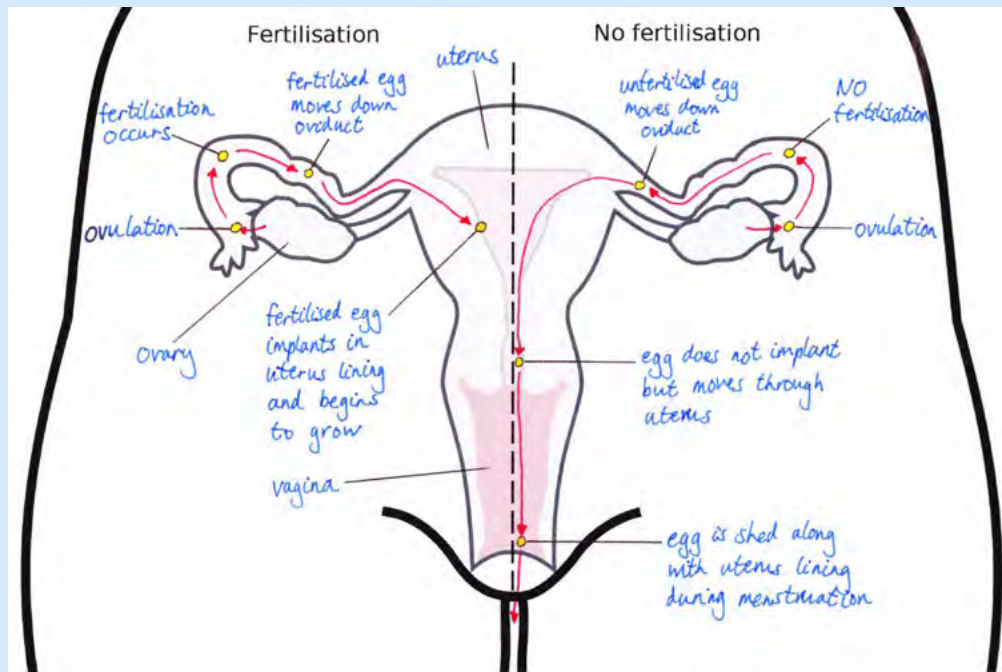


#### **TEACHER'S NOTE**

The following diagram shows an example of something that the learners might produce. Learners might battle to do this. A suggestion is to produce a sketch on the board and go through it with them, filling in the annotations. Do not simply draw it up and get learners to copy down the answers. Ask for their input and possibly get different learners to come up to the board to draw in different stages.



## TEACHER'S NOTE

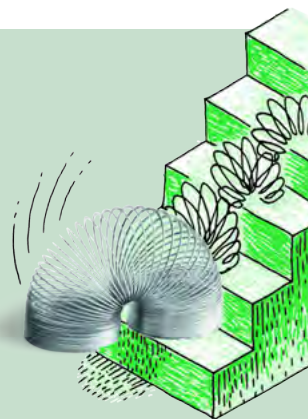


## ACTIVITY: Flow diagram of the pathway of sperm

### INSTRUCTIONS:

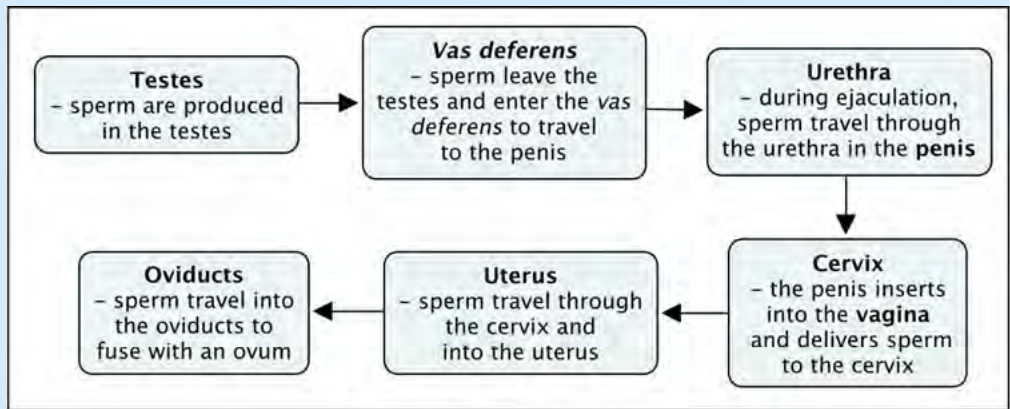
1. Use a flow chart to track the progress of a sperm cell from the testes in the male body to the ovum in the female body.
2. Use the space below to draw your flow diagram. Remember to draw arrows.
3. Use the following terms in your flow chart, in the correct order.

- a) Cervix
- b) Uterus
- c) Urethra
- d) Penis
- e) Testes
- f) Sperm duct
- g) Oviduct/Fallopian Tube
- h) Vagina



**TEACHER'S NOTE**

The following flow chart can be used as a reference for learners' flow charts:



**Pregnancy and birth**

Pregnancy begins the moment the female egg cell is fertilised by the male sperm cell. This is then called a **zygote**.



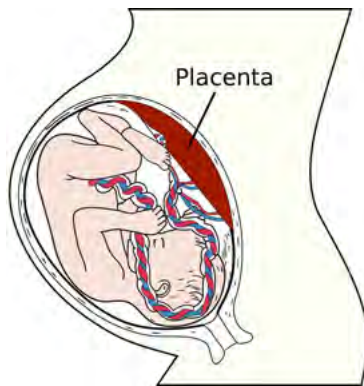
The zygote will then start to divide and grow as it moves down the oviduct. It will then implant in the uterus lining, where it will continue to grow. The fertilised egg is now called an **embryo** and undergoes cell division over and over again. This forms a cluster of cells with the different cells differentiating to become the specialised cells, tissues and organs that make up the human body.



*An 8-cell human embryo on day 3 after fertilisation.*

**VISIT**  
This video shows the development of a baby from fertilisation to birth  
[bit.ly/14Fd57z](http://bit.ly/14Fd57z)

Where the embryo implants into the spongy, blood-vessel rich lining of the uterus, some of the cluster of cells that formed after fertilisation form the placenta. The placenta is partly formed by the mother and partly by the embryo. The embryo develops an umbilical cord to attach itself to the placenta. The embryo can receive food and oxygen and remove its wastes through the umbilical cord and placenta.



The foetus is attached to the placenta by the umbilical cord.

**VISIT**

Video on fertilisation and early pregnancy.  
[bit.ly/19Wfv9m](https://bit.ly/19Wfv9m)



A newborn baby.

In humans, pregnancy is about 40 weeks (9 months). We call this the **gestation period**. Towards the end of the pregnancy, the uterus starts to contract. This pushes the head of the foetus into the vagina (birth canal). After the head has appeared the rest of the body comes out quite quickly. The last to come out is the placenta.

## ACTIVITY: Debate Surrogacy

### TEACHER'S NOTE

This is an **optional activity**, depending on your class.

Many couples, for various reasons, are unable to fall pregnant. A surrogate mother can be impregnated with the couple's fertilised embryos and can therefore carry the couple's baby to full term. South African law only allows certain individuals to do this, it is not just available to anybody.

### INSTRUCTIONS:

1. Work in groups of 6.
2. Debate the issue of surrogacy in your group. Base your debate on the ethical concerns below or any others you may think of.
3. Appoint a spokesperson for the group.
4. Each of the groups' spokesperson must then share their groups points of view with the class.
5. Debate these issues in the class.

There are many ethical issues concerning surrogacy:



- In many cases, the surrogate mother is paid to grow the baby inside her body. Often it is women who are poor that agree to be surrogate mothers and it is suggested that people who pay them to carry their babies are exploiting them. Should women be paid to be pregnant and deliver babies?
- In certain religions, surrogacy (including the donation of sperm and ova) is seen as "highly immoral" because it involves the intrusion of a third person on a couple's relationship. Should religious institutions be allowed to prevent surrogacy in this way?

1. Use the following lines to write down some notes on any other points your group discusses:

*Learner-dependent answer*



### **Influences on the unborn baby**

During pregnancy, what the mother eats, drinks and takes into her body has been shown to directly affect the unborn child. Other substances like smoking, alcohol and drugs have a negative influence on an unborn baby.

The placenta transports nutrients and oxygen to the foetus, and removes metabolic waste products and carbon dioxide. However, it cannot differentiate between nutrients and harmful products, such as nicotine, alcohol or drugs. If the mother uses these substances during pregnancy, they will most likely pass through the placenta to the foetus causing great harm to the unborn child.

Pregnant mothers who drink alcohol during pregnancy may cause irreversible birth defects in their unborn babies. This is called Foetal Alcohol Syndrome.

### **Prevention of pregnancy and contraceptives**

Anyone who is sexually active and who wants to prevent an unwanted or unplanned pregnancy can take certain precautions.

There are a range of different contraceptives that can be used to prevent pregnancy. There are four different types of contraceptives:

1. **barrier** - physically prevent sperm from reaching uterus
2. **hormonal** - prevent ovulation and fertilisation in the female using hormones
3. **intra-uterine devices** - prevent the embryo implanting
4. **sterilisation** - by surgery in men and women which is permanent and not reversible

**VISIT**  
The University of  
Stellenbosch has a website  
on FAS [bit.ly/16DEdQk](http://bit.ly/16DEdQk)

## ACTIVITY: Describing different contraceptives



### TEACHER'S NOTE

It may be possible to get examples of these different types of contraceptives for the learners to have a look at. Many clinics will have samples that can be used for educational purposes. They are normally very willing to hand out stock that has passed its expiry date and is **only** to be used for educational purposes.


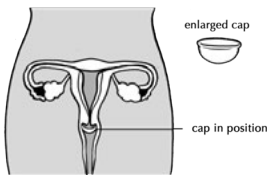
### INSTRUCTIONS:

- In the following table, several different types of contraceptives have been listed, along with a picture and description.
- You need to read the information, look at the images and classify the types of contraceptive as one of the following:
  - barrier
  - hormonal
  - intra-uterine device
  - sterilisation

### TAKE NOTE

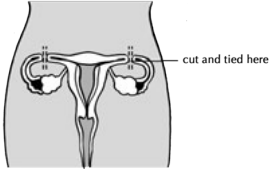
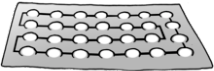
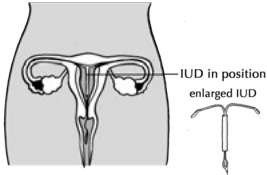
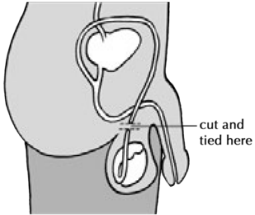
'Contra-' means against, so  
'contra-ception' means  
against conception.

### TEACHER'S NOTE

Contraceptive	Description	Classification
<p>Male condoms</p> 	<p>These thin sheaths of rubber are placed over the erect penis before inserting it into the vagina. When the male ejaculates the sperm and seminal fluid is caught in the condom and cannot enter the cervix.</p>	Barrier
<p>Diaphragm</p> 	<p>The diaphragm is a small rubber cap that is placed at the entrance to the uterus before sexual intercourse to create a seal and prevent sperm from entering the uterus.</p>	Barrier



**TEACHER'S NOTE**

Contraceptive	Description	Classification
<p>Tubal ligation in women</p> 	<p>A surgical procedure in women in which the the oviducts are cut and tied which prevents mature eggs from reaching the uterus for fertilisation.</p>	<p>Sterilisation</p>
<p>Oral contraceptive pill</p> 	<p>Often referred to as "the Pill", it is taken every day by mouth. It contains a combination of female hormones which prevents ovulation each month.</p>	<p>Hormonal</p>
<p>Female intra-uterine device (IUD)</p> 	<p>A small 'T'-shaped device is inserted into the uterus and prevent fertilisation. It is a long-acting, reversible contraception as the device may be removed again. It is not suitable for women who have not yet had a baby and must be inserted by a doctor.</p>	<p>Intra-uterine device</p>
<p>Vasectomy</p> 	<p>A surgical procedure in males in which the vas deferens is cut and tied. Sperm are therefore prevented from becoming part of the ejaculate.</p>	<p>Sterilisation</p>

### TEACHER'S NOTE

Some intra-uterine devices can also be classified as hormonal as they contain progesterone. The progesterone also prevents fertilisation, by increasing the cervical mucus, suppressing the endometrium and sometimes also inhibiting ovulation. The IUDs with copper are non-hormonal and also prevent fertilisation as the copper acts as a natural spermicide within the uterus.

Sexual intercourse with many different partners is very risky behaviour as there are many diseases that are transmitted through the fluids involved in the sexual act. We call these **Sexually Transmitted Diseases** (STDs). There are many different STDs, for example; HIV/AIDS, Herpes virus, Syphilis, Gonorrhoea and genital warts.

Being faithful to one partner limits your chances of contracting STDs. If you know that your partner has an STD he or she can either get medical treatment for this and/or you can take the necessary precautions to prevent contracting the disease. One of the most popular precautions to prevent the transmission of STDs is for the male partner to wear a condom. However, condoms can break and this can expose you to an STD, so you still have to be careful.

#### VISIT

Need to know more about STDs? [bit.ly/19kSRSg](http://bit.ly/19kSRSg) or [bit.ly/14Fd9Ex](http://bit.ly/14Fd9Ex)

### Choices regarding unwanted pregnancies

Many women who become pregnant might feel that they do not want or cannot care sufficiently for their unborn baby. Some may feel that they do not have the money to support another baby if they already have other children. When teenage girls become pregnant, many might feel that they would still like to complete their schooling and could not also raise a child. Other women might not want the baby as it might possibly be a result of rape or incest. Many women have many different reasons why they do not want to be pregnant or raise a child.

There are of course various choices that they can make in such a situation.

- **Adoption** - where the baby is given to another family who want to adopt him or her.
- **Leaving the baby in a place of safety** while remaining anonymous. The baby will then be put forward for adoption.
- **Parenting** - keeping the baby with the support of the extended family.
- **Abortion** - terminating the pregnancy by removing the embryo from the mother's uterus.

### TEACHER'S NOTE

The following activity will require learners to do some research and interviews and then come back into class to hold a forum discussion. A suggestion is to get learners to start doing some research and thinking about the topics in the days leading up to this lesson. Below is some more information on each of the types of choices a woman is faced with when she experiences an unwanted pregnancy. Read through this first so that you are familiar with the choices before the lesson so that you can help learners with their forum discussions.

- **Adoption:** Many couples in South Africa cannot have children of their own for different reasons and therefore choose to adopt children as their own. There are different organisations that help pregnant mothers who want to give their unborn children up for adoption. The Department of Social Services also helps pregnant mothers in the process of adoption. Adoptive parents typically have to go through a very strict screening process to make sure that they will be fit to raise a young child. When a mother (and where possible the father) signs that their baby will be given up for adoption, they have 60 days in which to change their minds before the adoption goes through. During this time, the baby will be placed in special foster care facilities or with foster families who will care for him or her until they can go to their adoptive parents.
- **Leaving the baby in a place of safety:** Sometimes the parents of a newborn baby, for various reasons, want to get rid of the baby. As a result, many babies are found abandoned. Many organisations in South Africa are trying to provide a safe haven for unwanted babies. One way they approach this, is to provide a baby-safe drop off site where the mother and/or father can place their unwanted baby in a special window with a safety flap on the outside. However, this option has many legal complications. Legally, the babies cannot easily be adopted because they do not often have birth certificates. Since the parents usually cannot be found, they cannot sign adoption papers. Although social workers will try and find the parents to get them to sign the adoption papers, after a few months they may put the baby forward for adoption without the parents' signatures. The best option is therefore to go to a social worker and ask them to help organise the adoption. This also protects the rights of the child.
- **Parenting:** Often when a woman (or teenage girl) realises that she is pregnant, many thoughts rush through her head. If it is an unwanted or unplanned pregnancy she is often filled with feelings of panic, anxiety and fear for the future - for her and her unborn child. She may fear that her parents or partner will abandon her and that she will then be on her own and will have to care for the baby on her own. However, if she is able to talk to her parents and partner, they may be able to find a solution to the situation that will enable her to keep her baby. She may be able to raise her child with the help of her or her partner's extended family. The most important thing is to face her fear and discuss the situation to reach a suitable decision.
- **Abortion:** Some women choose to have an abortion to end their pregnancies. During an abortion, the developing embryo is removed from the mother's womb. Chemical or physical processes can be used, depending on the age of the embryo. Abortions can be risky, especially if they are performed by untrained, unqualified abortionists. During an abortion the mother may lose a lot of blood. Her cervix may also be damaged or torn, or the uterus itself may be damaged during the procedure. These complications are not common when the abortion is performed by properly trained and qualified doctors and nurses in a clean, sterile medical facility. However, sometimes pregnant woman go to places where unqualified or untrained people perform the abortions. They are typically performed in unclean, unhygienic conditions by people without the proper medical training to know what to do in case of an emergency.

Complications are very common here, with many of the woman experiencing infections due to the dirty, unsterilised equipment. If someone is considering an abortion, it is therefore very important that they go to a professional abortion clinic that meets very high medical standards of cleanliness and well-trained staff. They should also speak to a caring professional first, as aborting a child may have long term effects, like feelings of guilt.

## **ACTIVITY:** Forum discussion

### **TEACHER'S NOTE**

This activity relates to Life Orientation. This activity was specifically included at the end of the section to allow for research to occur before the forum discussion. Break the class up into groups of 6 and allow them to move into different areas of the classroom, or perhaps even move outside if space permits. Each group must then conduct their forum discussion according to the instructions and guidelines below.

You, the teacher, can spend a little time with each group to make sure they are on track and discussing the topic. Use the notes provided on the different options for an unwanted pregnancy if you need to provide a group with some background information or some guidelines about what to discuss. Encourage learners to express their points of view and why they believe something.

### **TEACHER'S NOTE**

An alternative is to have one discussion forum in the front of the class and give different learners the chance to sit up front on the panel, and you can be the moderator.

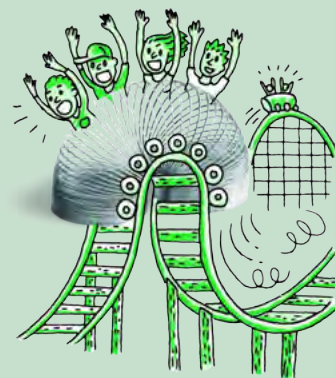
This activity does not need to be assessed and is more for personal education, and a chance for learners to practise debating.

Hold a forum discussion regarding the choices women have when they do not want to be pregnant or raise a child. Before the discussion, do research and interviews with your parents or caregivers, with health professionals or ask your Life Orientation teacher.

### **How to hold a forum discussion:**

In a forum discussion, experts are asked to sit on a panel and give their opinion about a particular topic. There are specific roles in a forum discussion:

- **Moderator:** This person keeps the discussion focused and on track.
- **Participants:** The experts. This will be you, the learners, after you have conducted your research.



1. Work in groups of 6.
2. Choose a moderator.
3. Discuss the different choices that women have regarding unwanted pregnancies using the information you obtained from the interviews you conducted.

**Rules for a forum discussion:**

1. The speakers need to take turns to give their opinions.
2. Treat everyone with dignity and respect. Speak politely.
3. Use the correct scientific terminology.

**Record your findings:**

Use the space below to record the findings from the forum discussion explaining what choices women have when faced with an unwanted pregnancy.

**TEACHER'S NOTE**

Learner-dependent answer







## SUMMARY:

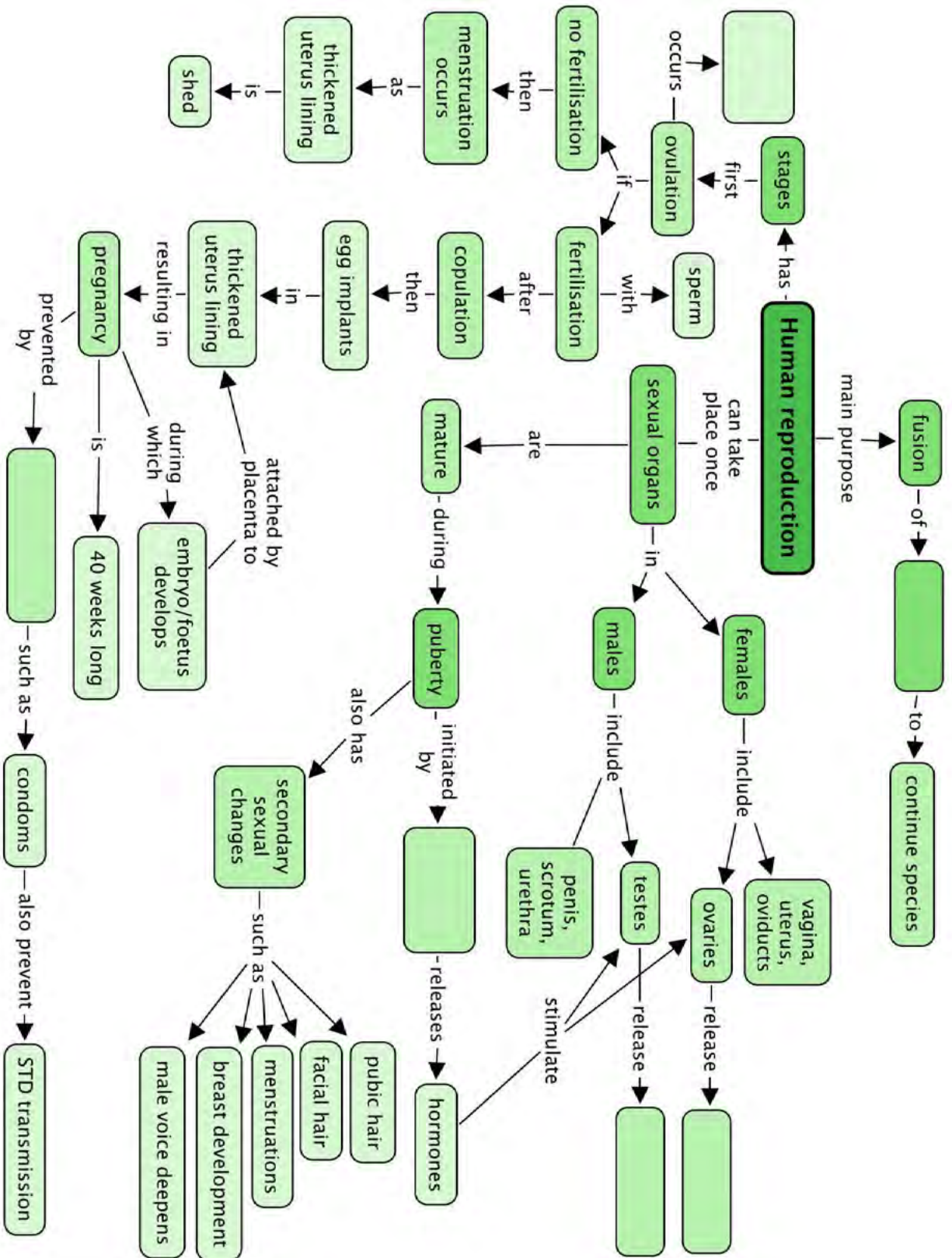
### Key Concepts

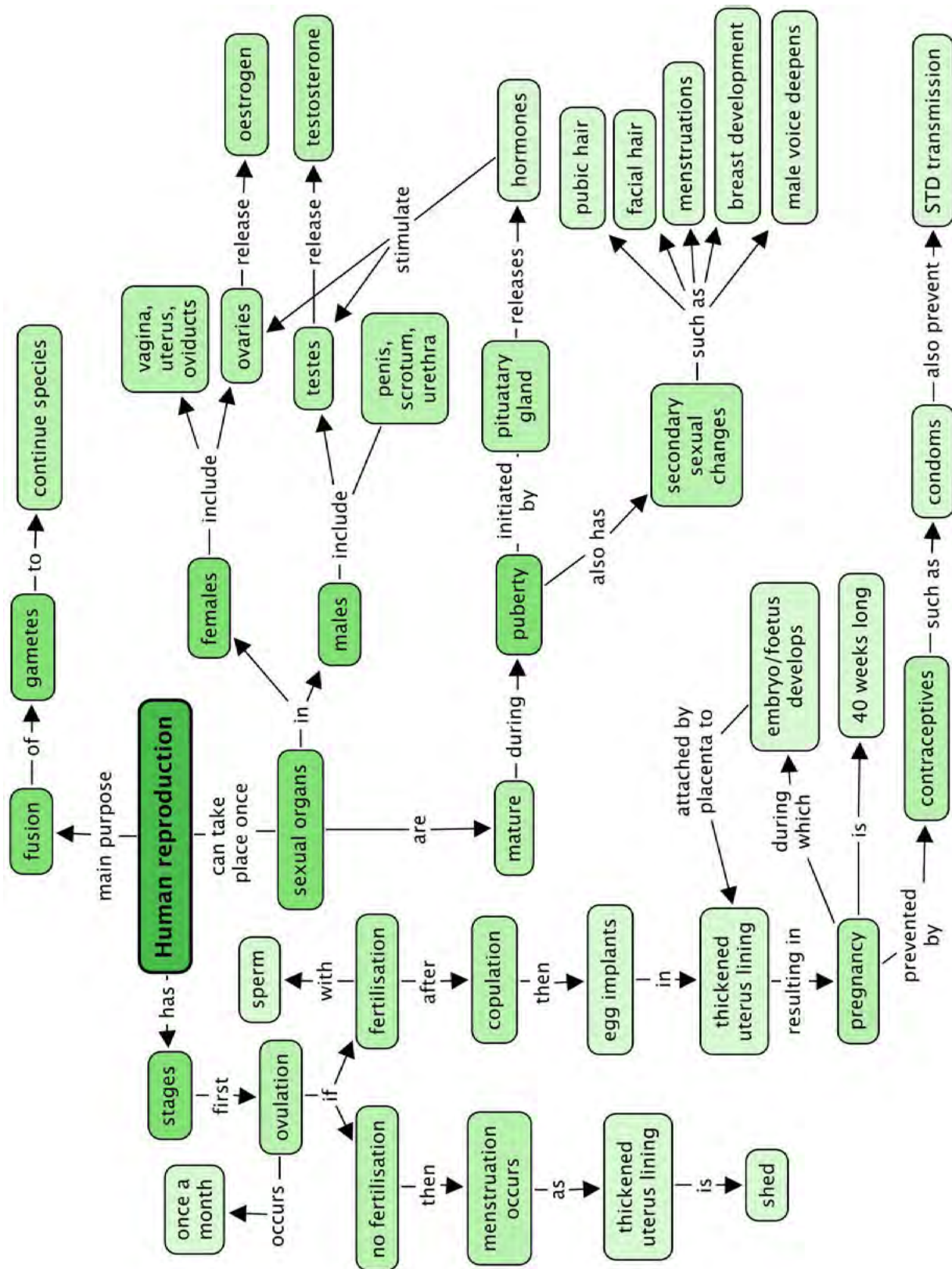
- The main aim of human reproduction is to produce babies to continue the species.
- In human reproduction, two gametes (the sperm and egg cell) fuse during conception to form a zygote, that will eventually become a new baby.
- Puberty is the stage in the human life cycle when the sexual organs mature and prepare for reproduction.
- The pituitary gland below the brain releases hormones that stimulate the testes and ovaries to release hormones that will start the production of sperm in the male and the maturation of ova (egg cells) in the female.
  - In males, the hormone testosterone stimulates the testes to produce sperm.
  - In females, the hormone oestrogen stimulates the ovaries to produce mature ova.
- Testosterone and oestrogen cause different secondary changes in the body.
  - Females begin to menstruate, grow breasts and grow pubic and underarm hair, and may experience acne.
  - Males grow hair on the pubic area, on the face, chest and underarms, develop a deep voice and may develop acne.
- The male reproductive organs are: penis, sperm duct (vas deferens), testes, scrotum and urethra. Sperm is produced in the testes.
- The female reproductive organs are: vagina, cervix, uterus, oviducts (Fallopian tubes) and the ovaries. Ova are produced in the ovaries.
- Stages in the reproductive cycle include: ovulation → copulation → fertilisation → embryo implants in uterus → results in pregnancy → gestation lasts 40 weeks → childbirth
- Pregnancy can be prevented by using contraceptives. Condoms prevent the sperm from reaching the ovum and also prevent the spread of STDs.
- Pregnant women have various options if they do not want to keep their babies. Very early in the pregnancy they can undergo an abortion. They may also give the baby up for adoption.

### Concept Map

This concept map shows all that we have learned about reproduction in humans. Complete it by filling in the blank spaces. You might find this quite tricky, but you need to learn to "read" a concept map by constructing sentences. For example, "**Human reproduction** can take place once **sexual organs** are **mature**. They mature during **puberty** which is initiated by ..... The ..... releases **hormones** which stimulate the **ovaries** and **testes**." What is this gland which initiates puberty and releases hormones, and which hormones do the ovaries and testes release? Fill this in below.











## REVISION:

1. Explain the changes that occur to the male and female body during puberty. [10 marks]  
*For females, these include: breasts develop, pubic hair starts to grow, underarm hair grows, body shape changes, ovaries mature, acne develops in some individuals. For males, these include: penis grows and becomes larger, testes mature, pubic hair starts to grow, facial hair grows, underarm, chest and back hair grows, voice deepens, acne develops in some individuals.*
2. Describe the hormonal control of the start of puberty. Name the organs involved and the hormones. [5 marks]  
*At the onset of puberty, hormones are released into the blood (these hormones were not specifically named at this level). These hormones travel in the blood and stimulate the reproductive organs. In females, the ovaries are stimulated to produce oestrogen and in males, the testes are stimulated to produce testosterone.*
3. At what stage of the reproductive cycle can one say that a woman is pregnant? [1 mark]  
*When the egg has been fertilised by a sperm (ie fertilisation), the woman is now pregnant.*
4. There is a urban legend or myth that says that a girl cannot fall pregnant the first time she has sexual intercourse. Think carefully about everything you have learnt about conception and fertilisation, and discuss whether this myth is true or false. [2 marks]  
*It can be true if the girl has sex before her reproductive organs have matured and therefore before she is able to ovulate. In this instance she will not be able to fall pregnant. If the woman's reproductive organs have matured and she has started to menstruate and ovulate, then she can fall pregnant after sexual intercourse, even if it is the first time. Thus in this instance the myth is not true.*
5. Explain why you think it is important for someone who considers becoming sexually active to know how reproduction occurs in humans. [1 mark]  
*Learners need to indicate that once someone knows the facts about conception they will be able to take (realistic) precautions to avoid unwanted pregnancies and disease. They will also not believe all the myths and make sensible decisions.*
6. Imagine someone who has many sexual partners asks you for advice on which contraceptive to use. What advice would you give them? [3 marks]  
*Someone who has many sexual partners stands a high risk of contracting an STD. To prevent this and to prevent an unwanted pregnancy learners should be able to say that they should use a condom during intercourse. They could also possibly suggest that the person limits the number of sexual partners that they have, and if they are in a relationship, then both of them should remain faithful to one partner. Alternatively, if they do continue with many partners, the person should try establish the status of these partners before intercourse, and still use a condom. The person should also be advised to have regular check ups to know their status.*
7. Some people have religious reasons for not using contraceptives. Decide whether you agree with them or not and why. Write a short letter to the editor of local newspaper expressing your concerns about contraceptives from this specific point of view. [6 marks]  
*Learner-dependent answer*

### TEACHER'S NOTE

Learners should be able to see the different points of view regarding this issue and reference the debate on this topic that was held earlier in this chapter. There is no right answer, rather the focus should be on the fact that learners can justify their opinions and express themselves. They should draw on this and write their letter in this frame of reference. NB: Learners are not criticising anyone's religion or culture in this activity.

8. Do you think schools should teach learners about different contraceptives? Why do you say so? [3 marks]

*Learner-dependent answer. Check that learners are able to justify their answer and provide a reason for what they think.*

9. During pregnancy the pregnant mother needs to take care of herself in order to provide a healthy and safe environment for the unborn child. Your local clinic has asked you to produce a brochure that they can display in their waiting room for first-time mothers. Write a detailed list of instructions for a pregnant woman explaining what she needs to do to keep herself and her unborn baby healthy. You can choose how you want to do this - perhaps a list of "Do's" and "Don't's", or else provide some headings under which you can list some instructions such as "Diet" , "Lifestyle", etc. [6 marks]

*Learners should refer to the diet and lifestyle choices of the pregnant mother, specifically noting that pregnant mothers who consume drugs and alcohol, also pass these on to the unborn baby through the placenta, resulting in irreversible damage to the unborn child. The mother should therefore avoid these during pregnancy.*

### TEACHER'S NOTE

this last question does not need to be assessed.

Total [37 marks]





**TEACHER'S NOTE****Chapter overview**

1.5 weeks

Learners would have already had an overview of the circulatory and respiratory systems in chapter 2. However, the overview introduced them in isolation, whereas these two systems are very tightly integrated. This chapter will look at these processes and associated organs in more detail and how the two systems are linked.

## 4.1 Breathing (1 hour)

Tasks	Skills	Recommendation
Activity: Main components in the circulatory and respiratory systems	Identifying	CAPS suggested
Activity: Summarise breathing using a flow chart	Summarising, explaining	Suggested

## 4.2 Gaseous exchange (1.5 hours)

Tasks	Skills	Recommendation
Activity: Lung dissection	Dissecting, observing, describing, interpreting, explaining	CAPS suggested
Activity: Drawing gaseous exchange in the alveoli	Drawing, summarising	Suggested

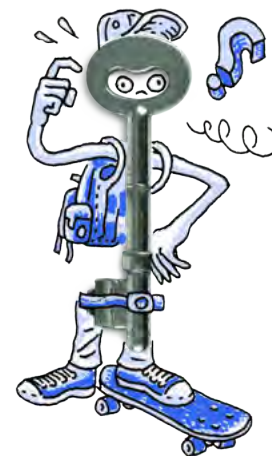
### 4.3 Circulation and Respiration (2 hours)

Tasks	Skills	Recommendation
Activity: Heart dissection	Dissecting, observing, describing, interpreting, explaining	CAPS suggested
Activity: Feel your blood rushing through your body!	Measuring, calculating	Suggested
Activity: Tabulating differences between the blood vessels	Comparing, describing, summarising, interpreting,	CAPS suggested
Activity: A circulation simulation!	Working in groups	Optional
Activity: Homework activity to measure your resting heart rate	Measuring, calculating	Suggested
Investigation: Measuring and comparing heart rates before and after exercise	Planning, investigating, predicting, measuring, comparing, tabulating, constructing graphs, summarising, interpreting, writing	CAPS suggested

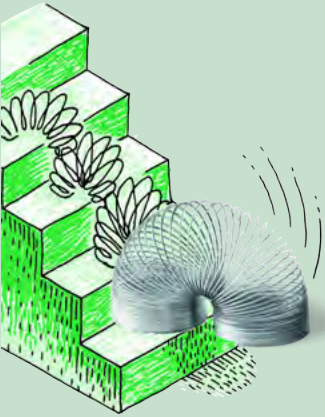


#### KEY QUESTIONS:

- Why do we have to breathe?
- Are our lungs like big balloons in our chest, or what do they look like?
- How does the oxygen in the air that we breathe in pass from our lungs into our blood?
- How does blood move around our bodies and get to each cell to deliver oxygen?
- We know that carbon dioxide is produced as a waste product in cellular respiration, so how is it removed from our bodies?
- How are the circulatory and respiratory systems linked?



If we do not get oxygen for a few minutes, humans get permanent brain damage and may die. Cell respiration needs a constant oxygen supply to provide us with enough energy, so we constantly need to breathe and keep blood circulation going to deliver this oxygen and remove the carbon dioxide. The respiratory and circulatory systems need to work together. Let's briefly revise the main components involved.



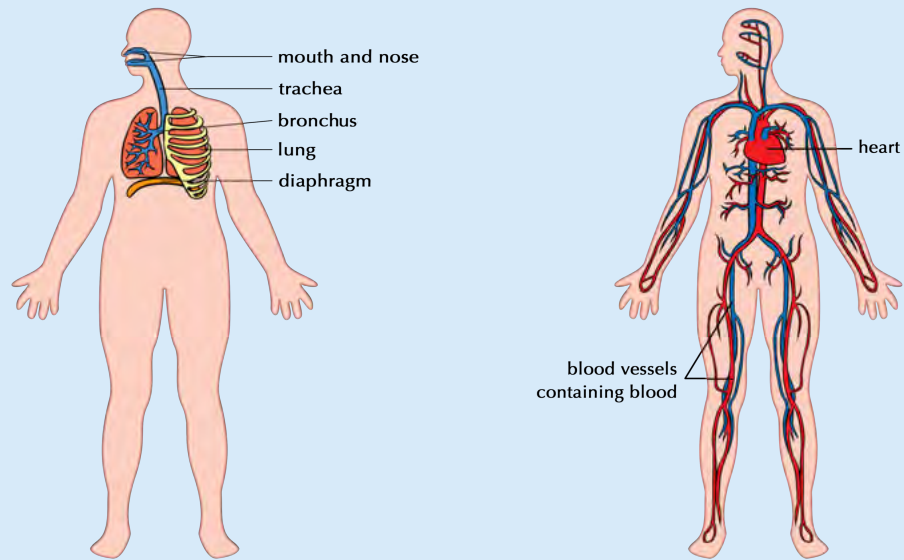
## **ACTIVITY:** Main components in the circulatory and respiratory systems

### **INSTRUCTIONS:**

1. Study the diagrams below.
2. Label the different components that form part of the respiratory and circulatory system.

### **TEACHER'S NOTE**

The labels for the diagrams should be as follows:



We will now look at these two systems under the following processes:

- breathing
- gaseous exchange
- circulation and respiration

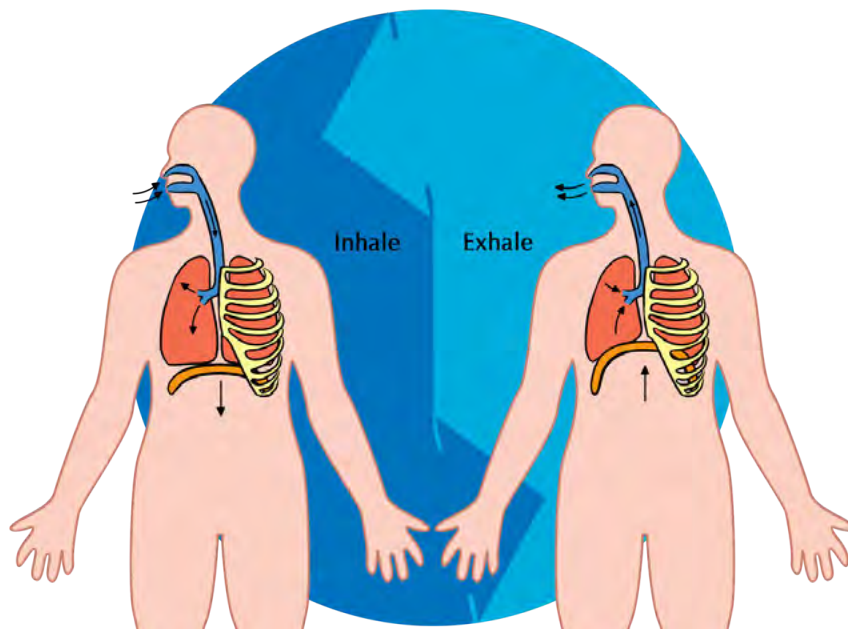
## **4.1 Breathing**

We already learnt in Chapter 2 that breathing consists of two processes:

1. inhalation
2. exhalation

When we inhale we take in air with a high concentration of oxygen and when we exhale we breathe out air that has more carbon dioxide in it. These processes

take place in a continuous cycle.



#### TEACHER'S NOTE

Teachers should try and make sure the learners understand the concept that the volume of the chest cavity changes the air pressure in the lungs and results in inhalation and exhalation. During inhalation, the chest cavity expands (gets bigger). When this happens the air pressure inside the lung decreases (because there is the same amount of air in a bigger space). In order to equalise with the air outside, air rushes in to the lungs. Similarly, when the chest cavity contracts (becomes smaller) during exhalation, the air pressure inside increases, and the air is pushed out to equalise with the atmosphere.

In order to explain this concept to learners you can use the example of a syringe. (**NB:** Remove the needles from the syringes beforehand.) Air acts like the liquid in this case. If you pull back on a syringe you increase the volume in the syringe, and liquid moves into the syringe. If you push back on the syringe to decrease the volume, you will push the liquid out. The syringe example may help learners to understand that air is "sucked in" and "pushed out" by the changes in volume.

During **inhalation** the following takes place:

- The rib cage moves upwards and outwards.
- The diaphragm contracts and flattens causing it to move downwards.
- This causes the chest volume to increase and the pressure decreases.
- As a result the lungs are also pulled to become bigger.
- This allows the air to be pulled into the extra space inside the lungs.

During **exhalation** the following takes place:

- The rib cage moves downwards and inwards.
- The diaphragm also relaxes, causing it to become more dome-shaped
- This causes the chest volume to decrease and the pressure increases.
- As a result the lungs are squeezed smaller
- This forces the air out of the lungs.



**ACTIVITY:** Summarise breathing using a flow chart

A flow chart allows us to write short summaries of processes that take place. When you study for a test or exam you can picture the flow chart in your head, which often helps to trigger memories of what you learnt.

Use a flowchart to show how breathing (inhalation and exhalation) takes place. You may chose your own design for the flow chart but it needs to show that inhalation and exhalation occur in a cycle.

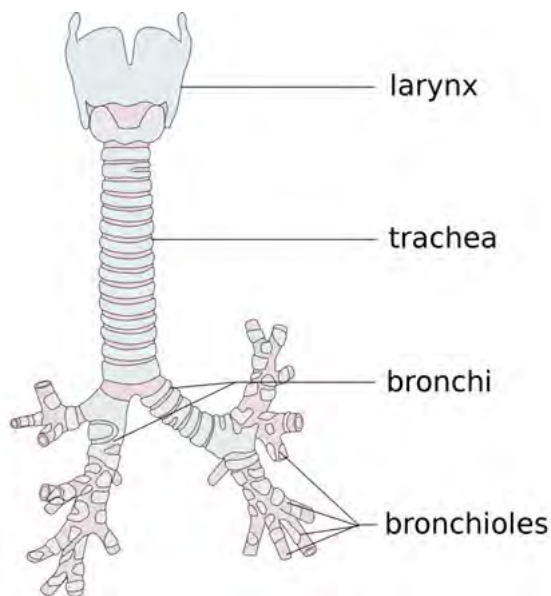
**TEACHER'S NOTE**

Learners should show the following in a cycle: Rib muscles contract → rib cage moves up and out → diaphragm contracts → diaphragm moves downwards (flattens) → rib cage volume increases → lungs expand → take in more oxygen → rib muscles relax → rib cage moves downwards and inwards → diaphragm relaxes → rib cage volume decreases → this pushes out the air from the lungs.

**TAKE NOTE**

The two tubes that branch from the trachea are called bronchi (plural) or a bronchus (singular).

During inhalation, air travels to the two bronchi - tubes that lead to each lung. The bronchi are themselves branched (divided) into thousands of tiny bronchioles. During exhalation, the reverse takes place as air leaves the lungs and body.



*This image shows how the larynx joins the trachea which branches into the bronchi within the lungs.*

What happens to the air within the lungs?

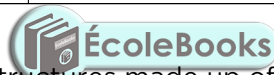
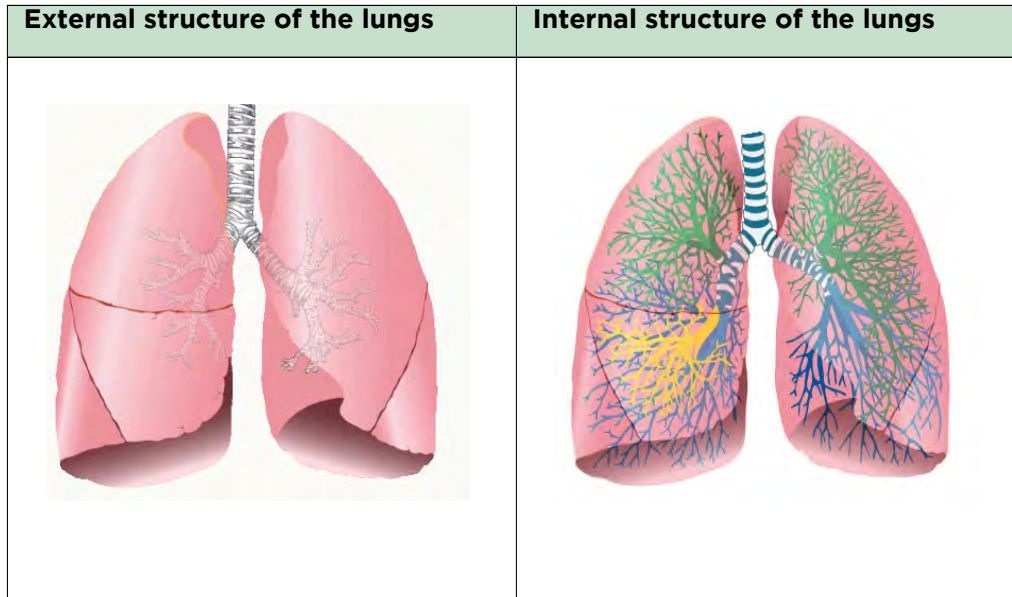


## 4.2 Gaseous exchange in the lungs

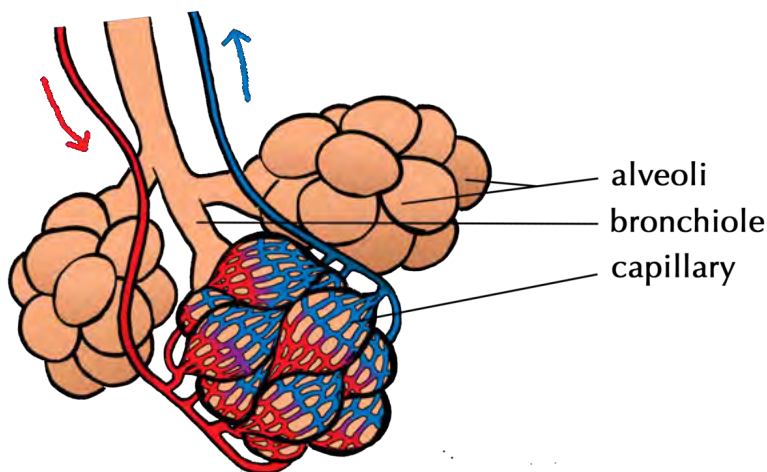
**Gaseous exchange** takes place in the lungs and in the cells of the body. The structure of the lung is adapted to fulfil the function of gaseous exchange.

### Structure of the lung

Although the lungs inflate during inhalation and deflate during exhalation, they are not hollow. The lungs in a healthy individual are soft, pink and *spongy*.



The alveoli look like small grape-like structures made up of many individual air sacs. A big network of capillaries surrounds each alveolus. Have a look at the following image showing this.



An alveolus is one air sac but a group together (plural) is called alveoli.

#### VISIT

A video on gaseous exchange. [bit.ly/13Znipl](https://bit.ly/13Znipl)

#### TAKE NOTE

The colours of the different bronchioles in the diagram indicate air travelling to different parts of the lungs.

#### VISIT

Watch a video that shows how gases are exchanged at the alveoli [bit.ly/14FdiI2](https://bit.ly/14FdiI2) and [bit.ly/11WcfzA](https://bit.ly/11WcfzA)



## **ACTIVITY:** Lung dissection

If you are not able to do this in class, you can watch some of the videos showing a lung dissection.

### **TEACHER'S NOTE**

It is possible to learn about the function of lungs from the diagrams and pictures supplied in the workbook. However, dissecting the real organ is hugely beneficial to the learners and will help them to understand the structure of the lungs and how this relates to their function. If however, you are not able to do the dissection, you can watch some of the videos supplied.

### **MATERIALS:**

### **TEACHER'S NOTE**

This will depend on how many lungs you are able to obtain and how many learners are willing to do the dissecting. A suggestion is to break learners up into groups, or else do the dissection as a demonstration in front of the class, especially if you have a big class or many Gr. 8 classes. The following materials are required for each dissection, whether in a group or to be done as a demonstration.

- lung
- tray
- scalpel
- dissecting scissors
- rubber tubing (for example the Bunsen burner tubing) or hose pipe
- ruler
- beaker of water
- water and soap for washing hands
- disinfectant

### **TEACHER'S NOTE**

Sometimes the main sections of lung tissue are cut into at the abattoir (as part of the inspection process). You can approach the butcher well in advance and discuss what you need so that they can limit damage to the material and provide lungs as whole as possible. Butchers often refer to it as 'pluck' which contains the lungs and part of the heart.

#### **VISIT**

Watch this video that shows the structure of the lungs  
[bit.ly/17gByw6](http://bit.ly/17gByw6)

### **Health and safety tips:**

1. The lungs may carry some bacteria. It is not necessary to wear gloves, as we do not wear gloves when preparing meat in a kitchen, but you must wash your hands thoroughly.
2. Clean all equipment and your work surface with disinfectant after the dissection.

3. Be careful when handling sharp equipment, such as the scalpel.
4. Decide how you are going to dispose of the lungs.

### TEACHER'S NOTE

#### Ethical issues

Before starting this lesson, find out if any learners are sensitive to the use of animal products in this way, or even to the fact that animals are farmed for human consumption. Some learners may also have religious or cultural objections to the dissection and handling of animal parts, especially cows and pigs. You need to be aware of these issues and be sensitive to them.

#### INSTRUCTIONS:

##### Part 1: Preparation:

1. Place the lung on the tray on your workbench.
2. Make sure all your dissecting instruments have been disinfected and are sharp. Lay them out next to your tray.
3. Make sure you have access to a first aid kit if necessary.

##### Part 2: External structure

1. Take note of the external structure of the lung. Look at the general shape, colour and texture.
2. If you have access to a scale, measure the mass of the lung.
3. Use your ruler to measure the length of the lung.
4. Identify the following parts of the lung
  - a) The **trachea** (wind pipe) which is the main tube bringing air into and out of the lungs
  - b) The **hard rings** in the trachea. What do you think these rings are for?

### TEACHER'S NOTE

These hard rings are made of cartilage and keep the trachea open so air can move freely. Encourage learners to make notes of their observations throughout the dissection.

5. The **bronchi**. There are two bronchi that branch off from the trachea - one to each lung.
6. See if you can identify the first bronchioles branching off from the bronchi.
7. Are there any **blood vessels** visible that are attached to your lung? If so, feel these vessels and describe what you feel.
8. Use the rubber tubing or straw or hose pipe and insert this into the tube leading into the lung and hold the trachea tightly closed around the pipe. Blow on the end of this tube to see if you can inflate the lung. Do not breathe the air back into your own lungs!

##### Part 3: Internal structure

1. Using the scalpel and dissecting scissors, cut down into the lung.
2. Observe the inner tissue of the lung and think how you would describe it. Discuss this with your group.
3. Cut out a piece of the lung tissue and feel for tiny bronchioles (they feel like little hard lumps in the soft lung tissue). Place this piece of lung tissue into a beaker of water. Observe the piece of lung tissue. Does it float or sink?

#### VISIT

Visit this animation that shows how air is taken into the lungs and then gases are exchanged at the alveoli  
[bit.ly/14Fdeb8](http://bit.ly/14Fdeb8)

### QUESTIONS:

1. Write a description of the look, feel and colour of the lung you observed. If you were able to measure the mass, write it down, and include the length of the lung in centimeters.  
*Learner-dependent answer.*
2. What structures made the trachea stay open, but still able to bend?  
*The semicircular rings of cartilage.*
3. When you cut the lung open, was it like a hollow balloon or bag, or was it spongy inside? What else did you observe when you cut the lung open and observed the inside?  
*The lung tissue is spongy. Learners might also observe other blood vessels within the lung tissue and notice some of the bigger tubes running through the tissue.*
4. When you placed a piece of the lung tissue into water, why do you think it floated?  
*Learners should see that the piece of tissue floats. This is because the lung tissue, even after an animal has died, contains a large amount of air within all the alveoli, which makes it float in water.*
5. When you blew air into the lung, what did it look and feel like? Did you have to squeeze the lung to force the air out again?  
*When learners blew into the lungs, they should note that they expand, but they are still soft to touch. Once inflated and left to lie on the table, some of the air will escape as the tissue relaxes down, but not completely, and learners might have to squeeze the lung to deflate it. Inflated lungs are paler/more cream coloured (as blood vessels on the surface are squashed flat and blood moves further into the lungs).*
6. In a human, what is responsible for pushing the air out of the lungs?  
*In humans, the diaphragm relaxes and therefore moves upwards and the rib cage also moves down and in. This reduces the volume of the chest cavity, increasing the pressure on the lungs and therefore forces the air out of the lungs.*

The process by which gaseous exchange occurs is called **diffusion**.

### How does diffusion work?

The movement of particles from an area where there is a high concentration to where there is a low concentration is called **diffusion**.

In the lung, each alveolus is surrounded by a network of capillaries. The two gases which diffuse between the alveoli and the blood in the capillaries are oxygen and carbon dioxide.

- oxygen diffuses into the cells of the alveolus and then into the blood in capillaries
- carbon dioxide diffuses out of the blood and into the cells of the alveolus, then into the air

#### VISIT

Watch an interesting clip about the amazing molecule haemoglobin which transports oxygen around the body! [bit.ly/160vSHr](http://bit.ly/160vSHr)

## **ACTIVITY:** Drawing gaseous exchange in the alveoli

### **INSTRUCTIONS:**

1. Draw a diagram to show alveoli surrounded by a capillary.
2. On this diagram, name the gases and indicate the direction in which the gases diffuse.
3. Indicate whether the blood is oxygenated or deoxygenated in the capillaries that travel towards and away from the alveolus.

1. Give your diagram a heading.

*Learner-dependent answer*

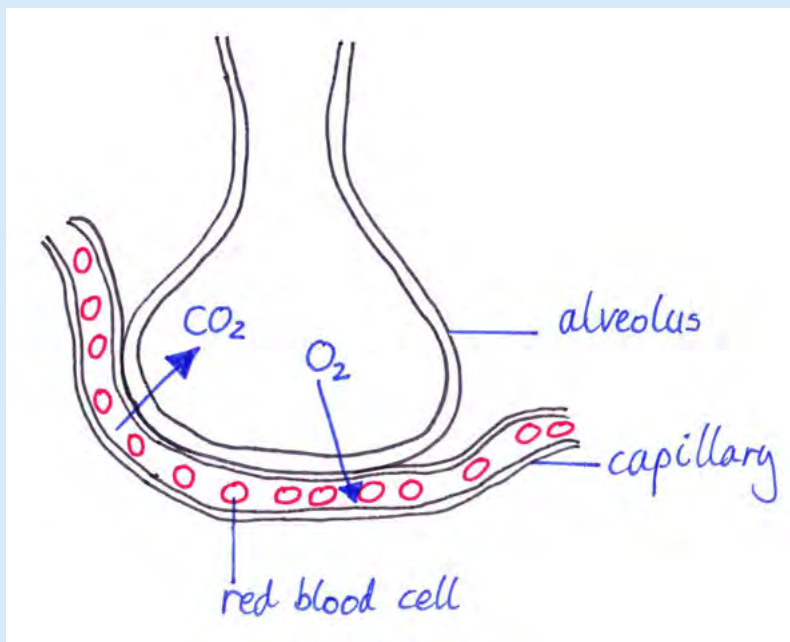


### **TEACHER'S NOTE**

The following diagram gives an example of something the learners might produce. You can also draw this up on the board when describing oxygen and carbon dioxide diffusion.

Possible headings that learners might write are:

- Gaseous exchange within the lungs
- Diffusion of carbon dioxide and oxygen within the lungs
- Diffusion of  $\text{CO}_2$  and  $\text{O}_2$  between the alveolus and capillary
- etc





## 4.3 Circulation and respiration

Blood is continually circulated to support cell respiration. Let's have a look at how this takes place.

### TEACHER'S NOTE

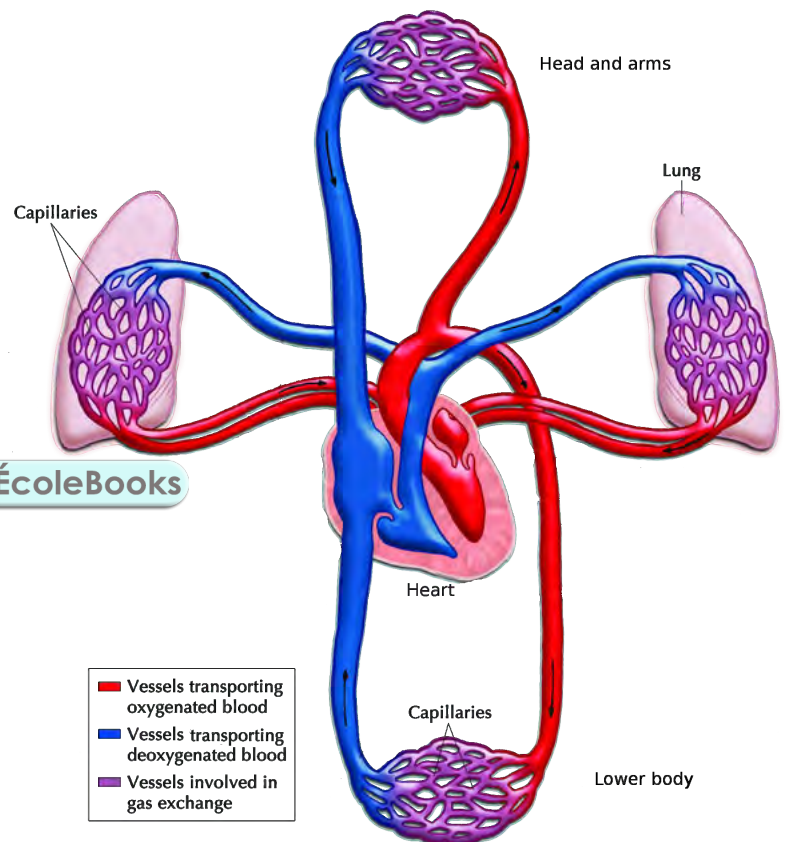
The video link in the visit box on respiration is quite long (about 25 minutes), but it could be a very good summary lesson.

### Blood circulation from the lungs to the heart

The heart pumps the blood around your body by rhythmic, repeated contractions. This is felt as your **heart beat**.

The oxygenated blood flows from the lungs to the left side of the heart. The left side then contracts to pump the blood out of the heart and into the aorta. The aorta is the main artery leaving the heart.

Have a look at the adjacent diagram which shows how the blood flows from the lungs to the heart and then to the rest of the body.

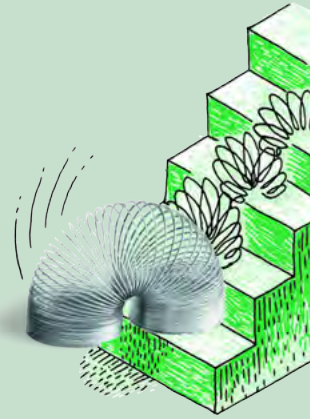


### TEACHER'S NOTE

In the video in the visit box showing how blood is circulated through the heart, learners do not need to know about the heart valves and electrical control at this stage - this is for interest only.

Let's take a closer look at the structure of this vital organ in the circulatory system.

## **ACTIVITY:** Heart dissection



### **TEACHER'S NOTE**

Learners will look at the heart in much more detail in Gr. 10 Life Sciences where the detailed structure of the heart will be studied, including the valves. This activity is meant as an introduction to the structure of the heart and for learners to experience a dissection. We suggest doing this as a demonstration as learners will do this practical in Gr. 10 Life Sciences again.

### **MATERIALS:**

### **TEACHER'S NOTE**

It is important to be tolerant of learners religious, cultural or personal beliefs which may prevent them from participating in this dissection, particularly if pig is used. A suggestion is to break learners up into groups, or else do the dissection as a demonstration in front of the class. The following materials are required for each dissection, whether in a group or when done as a demonstration. The number of groups will depend on how many hearts you are able to obtain and how many learners are willing to do the dissecting. For learners who are unwilling to handle the hearts, but still want to be involved, they could take photographs of the heart at different stages of the dissection using a digital camera or their mobile phone cameras.

- heart (sheep or pig)
- tray
- scalpel
- dissecting scissors
- rubber tubing (for example the Bunsen burner tubing) or straw
- ruler
- beaker of water
- water and soap for washing hands
- disinfectant

### **TEACHER'S NOTE**

Sometimes butchers will cut the blood vessels off the top of the heart, and may also remove the atria and cut into the ventricles at the abattoir. Discuss your needs with the butcher beforehand so that they can preserve the heart as much as possible. You can sometimes even obtain the heart and lungs together (usually referred to as a 'pluck'), which is useful to see how the blood vessels connect the organs. If you obtain hearts with long blood vessels, attached, cut off some of these sections to keep for studies of veins and arteries. As with the lung dissection, be sensitive to ethical issues and learners' concerns around the use of animal products in this way.

### Health and safety tips

As with the lung dissection, the same health and safety tips apply to the heart dissection.

### INSTRUCTIONS:

#### Part 1: Preparation:

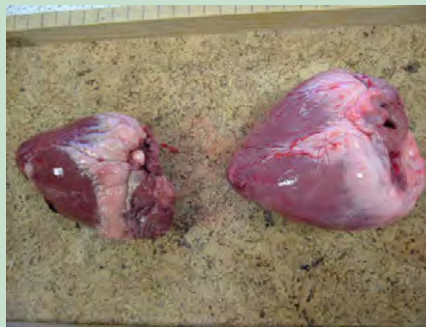
1. Place the heart on the tray on your workbench.
2. Make sure all your dissecting instruments have been disinfected and are sharp. Lay them out next to your tray.
3. Make sure you have access to a first aid kit if necessary.

#### Part 2: External structure

1. Take note of the external structure of the heart. Look at the general shape, colour and texture.

#### VISIT

Watch a video showing the structure of the heart  
[bit.ly/160w3T4](http://bit.ly/160w3T4)



*Two animal hearts on a tray.*

2. If you have access to a scale, measure the mass of the heart.
3. Use your ruler to measure the length of the heart.
4. Identify the following parts of the heart:
  - a) There are blood vessels entering and leaving the heart (**arteries and veins**). Arteries have much thicker, more rubbery walls than veins which have thin walls. See if you can identify the difference.
  - b) Place your fingers inside the blood vessels to feel their texture and strength. Look inside the main arteries and veins as well and describe what you see to your group. Place your one finger down the aorta and see if you can feel any structures. The following photo shows the aorta opening.



*Can you see the large opening of the aorta?*

### TEACHER'S NOTE

Learners should be able to feel the valves at the base of the aorta. These will become visible later when viewing the internal structure of the heart.

5. Examine the **surface** of the heart for blood vessels. Why do you think the surface of the heart also has blood vessels attached to it?



*Take note of the surface of the heart and the blood vessels attached to it.*

### TEACHER'S NOTE

The heart muscle also needs a supply of blood and oxygen in order to function. This is supplied by the coronary arteries. Learners should be encouraged to take notes in their workbooks or a separate notebook throughout the dissection.

6. Locate the **atria** and **ventricles**.
7. Locate which is the right and which is the left hand side of the heart.

### TEACHER'S NOTE

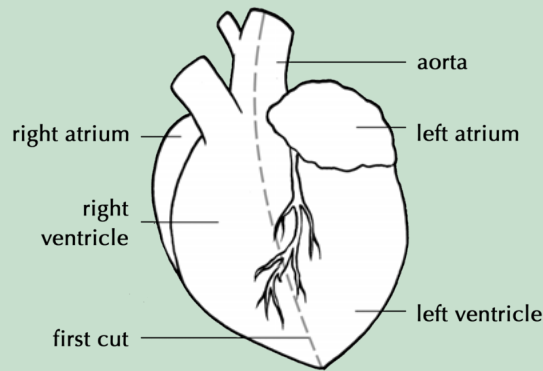
To locate which side is which in the heart, learners must hold the heart so that the coronary artery runs diagonally across the heart - this will be the the front. Then the left / right ventricles are on either side of the coronary arteries.

### VISIT

Watch this video to see how blood is pumped through the four chambers of the heart [bit.ly/16DEtyM](https://bit.ly/16DEtyM)

### Part 3: Internal structure

1. We are now going to cut into the heart to view the internal structure. Use the following diagrams to help you orientate the heart before cutting.
2. Make a cut down the aorta and then through the left ventricle to the tip of the heart. A tip is to first cut through the aorta using scissors, and then to cut through the left ventricle using the scalpel.

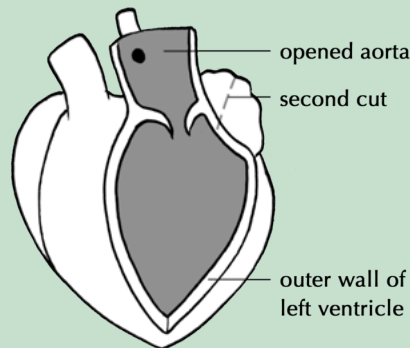


- Once you have made the cut, pull the ventricle walls apart so that you can view the inside. Can you see the structures at the base of the aorta that you felt in Part 1 (step b)? What do you think these structures do?

**TEACHER'S NOTE**

The aortic valve prevents the backflow of blood into the heart once it has been pumped out and into the aorta to travel to the rest of the body.

- Look at the following diagram to make the second cut upwards into the left atrium.



- Using your ruler, measure the thickness of the left atrium wall and the left ventricle wall. Write these measurements down.
- You can now cut open the right side of the heart in the same way. Measure the thickness of the right ventricle wall. The following diagram provides a detailed overview of the internal structure of the heart. We have not discussed all of these structures and you are not required to know all of these. However, for this dissection, use this diagram to see how many of these parts you can identify in your dissected heart. If you are able to locate them in the actual heart, draw a ring around the label in the following diagram.



## TEACHER'S NOTE

At this stage, you can also point out some of the other valves to the learners. This detail is not necessary to know, but it is very interesting when thinking about how the heart functions as a very efficient pump. Look at the areas where the atria and ventricles join to locate the bicuspid valve between the left atrium and ventricle, and the tricuspid valve between the right atrium and ventricle. They should be visible as thin flaps of tissue with tough "threads" or cords attached to the base of the flaps. The *tricuspid* valve on the right should have 3 flaps and the *bicuspid* valve on the left should have 2.

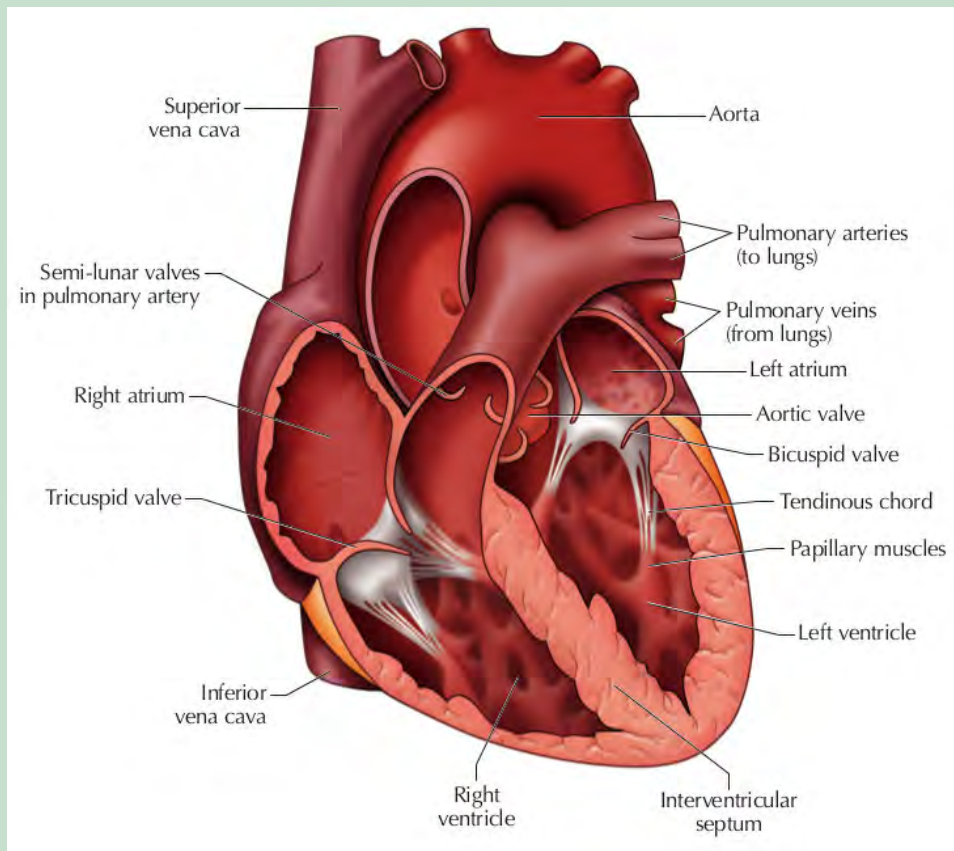


Diagram of the internal structure of the heart.

## QUESTIONS:

1. Write a description of the look, feel and colour of the heart you observed. If you were able to measure the mass, write this down, and include the length of the heart in centimeters.

*Learner-dependent answer.*

2. Write down the thickness that you measured for the left ventricle and atrium walls. Why do you think there is a difference in the thickness of these walls? Hint: Think back to where the atria have to pump the blood and where the ventricles have to pump blood.

*The ventricles have much thicker walls than the atria. This is because the ventricles need to pump the blood much further and with more force to the rest of the body, compared to the atria, which only pump blood into the ventricles.*

- Write down the thickness that you measured for the right ventricle wall. Mention possible reasons for the difference in thickness between the left and right ventricle walls. Once again, think about where each ventricle is pumping blood to.

*The left ventricle should be thicker than the right ventricle. The left ventricle has to pump blood to the whole body (systemic circuit), while the right ventricle only has to pump blood to the lungs (pulmonary circuit).*

**TAKE NOTE**

Remember that arteries carry blood AWAY from the heart and veins carry blood towards the heart.

Once the blood is pumped out of the heart, it enters the circulatory system in the body.

**Blood circulation from the heart to the rest of the body**

Once blood leaves the heart in the aorta, this main artery branches into smaller arteries which form a network throughout the body.



**ACTIVITY:** Feel your blood rushing through your body!

**TEACHER'S NOTE**

Later in this chapter learners are going to do an investigation into their heart rate at rest and after exercise and they will then need to be quite skilled in taking their pulse and determining their heart rate. This activity is therefore included in preparation for this. You can get learners to all find their pulse in the way they find easiest. Once they have done this, get them to count their heart rate while you time for 30 seconds, indicating "Stop" and "Start". To obtain their heart rate at beats per minute, learners then multiply by 2.

**INSTRUCTIONS:**

- Put your index (pointer) and middle fingers against your neck in the hollow between your trachea (windpipe) and the large neck muscles. Use your finger tips as these are more sensitive. You should feel the throbbing of your blood.

**TAKE NOTE**

A rate always measures something over time. In this activity we are calculating heart rate as beats per minute, as this is the most standard measurement used for heart rate. Can you think of some other units of measurements which indicate a rate?



*Measuring heart rate in the wrist.*

2. Can you find your pulse in your wrist? Place your middle and index fingers just below the creases in the skin of your wrist - on the side of your thumb. Press lightly until you feel the pulse which means the blood is pushing under your skin.
3. You can also try and find your pulse behind your knee, on the inside of your elbow or near the ankle joint.
4. Each throb of your pulse is when your heart pumps the blood from the left side of your heart into the arteries of your body, causing the pressure in the arteries to rise.

## QUESTIONS

1. Count how many times your heart beats in one minute. Alternatively, count your heart beats for 30 seconds while a friend or your teacher times you, and write the number on the line below.

*Learner-dependent answer*

2. Now, calculate your heart rate in beats per minute and write your answer on the line below.

*Learner-dependent answer. Learners have to multiply the number of heart beats in 30 seconds by two to calculate beats per minute.*

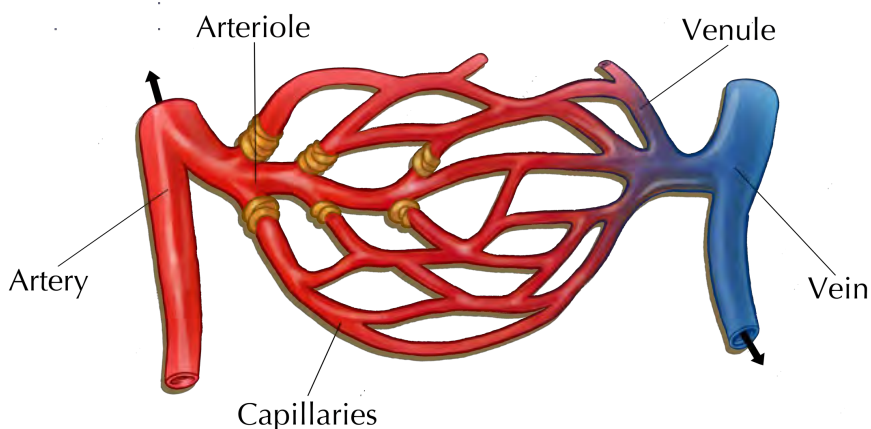
## TEACHER'S NOTE

Other units of measurement which indicate a rate are for example: km/h (kilometers per hour), m/s (meters per second), flow rate of a river in l/s (litres per second), etc.



Arteries then subdivide to form capillaries. Capillaries are in close contact with the body cells. Capillaries are much smaller than arteries. They form a fine network throughout the body's cells to make sure that all cells get a supply of blood and oxygen.

The capillaries leaving the cells with deoxygenated blood then combine to form veins. Veins from the body carry deoxygenated blood back to the heart.



**TAKE NOTE**

An exception to the rule of arteries carrying *oxygenated* blood, are the pulmonary arteries which carry deoxygenated blood away from the heart to the lungs to become oxygenated.

**Arteries**

- Arteries transport blood **away** from the heart.
- Arteries transport oxygenated blood (except for the pulmonary arteries).
- Arteries need to have strong muscular walls because they carry blood away from the heart under high pressure.

**Veins**

- Veins transport blood **towards** the heart.
- Veins transport deoxygenated blood (except for the pulmonary veins).
- The blood is flowing back to the heart and therefore the blood pressure in the veins is much lower.

**Capillaries**

- Capillaries form webs or networks around each cell to ensure that all cells receive nutrients and oxygen.
- Capillaries are much smaller than veins and arteries.



*This transmission electron micrograph shows a cross section through a capillary. The semicircular black structure within the capillary is a red blood cell. This shows how small capillaries are. They are only just wider than a red blood cell.*






## **ACTIVITY:** Tabulating differences between the blood vessels

### **INSTRUCTIONS:**

1. Compare arteries, veins and capillaries.
2. Use the following table in which to do this comparison.



### **TEACHER'S NOTE**

Blood vessel type	Artery	Vein	Capillary
<b>Image</b>			
<b>Function</b>	Transport blood to the rest of the body	Transport blood from the body to the lungs	Transport blood from arteries to veins
<b>Type of blood transported</b>	Oxygenated	Deoxygenated	Mixed
<b>Exceptions</b>	Pulmonary arteries transport deoxygenated blood	Pulmonary veins transport oxygenated blood	NA

### **TAKE NOTE**

Page back to Chapter 1 of Life and Living to refresh your memory about the structure of mitochondria.

### **VISIT**

An amazing summary video on respiration.  
[bit.ly/1bmhKdF](https://bit.ly/1bmhKdF)

## **Respiration within the cells**

Within the cells, the mitochondria use oxygen to respire. This is called cellular respiration.

- The mitochondria combine oxygen with food particles, such as glucose.
- Energy from the food particles is released and can be used by the cell to perform various processes.
- During cellular respiration, carbon dioxide is released as a by-product.

The carbon dioxide diffuses from the cells back into the blood in the capillaries. This blood therefore becomes deoxygenated as oxygen has been removed and carbon dioxide is added.



## Blood circulation from the body back to the heart and lungs

The deoxygenated blood in the body then returns to the right side of the heart through the veins in the circulatory system.

The right side of the heart pumps the deoxygenated blood to the lungs through the pulmonary arteries.



### ACTIVITY: A circulation simulation!

#### TEACHER'S NOTE

Where possible teachers should set up the following activity in advance of the class arriving. It is aimed specifically at 'kinetic' learners to make them 'walk the circulatory system' in order to remember how it works.

#### Materials needed:

- 3 hula hoops, or something similar
- white A4 sheets
- coloured paper
- red and blue string
- prestik

#### Preparation for the lesson:

1. Cut up coloured paper into blocks - you will need two different colours
  2. there should be enough blocks for each learner in the class to have at least one of each colour.
  3. one colour will represent oxygen and the other colour will represent carbon dioxide.
1. Make the following signs on the back of recycled A4 pages - write in a clear, neat font so everyone can see it.
  2. Left side of heart
  3. Right side of heart
  4. Lungs
  5. Arms and hands
  6. Legs and feet
  7. Brain
  8. Stomach
  9. Kidneys
  10. Face

[There are many other body parts that could be included and teachers are welcome to add to this list. For the purposes of this activity though time constraints were considered and it was decided to add only those listed here.]

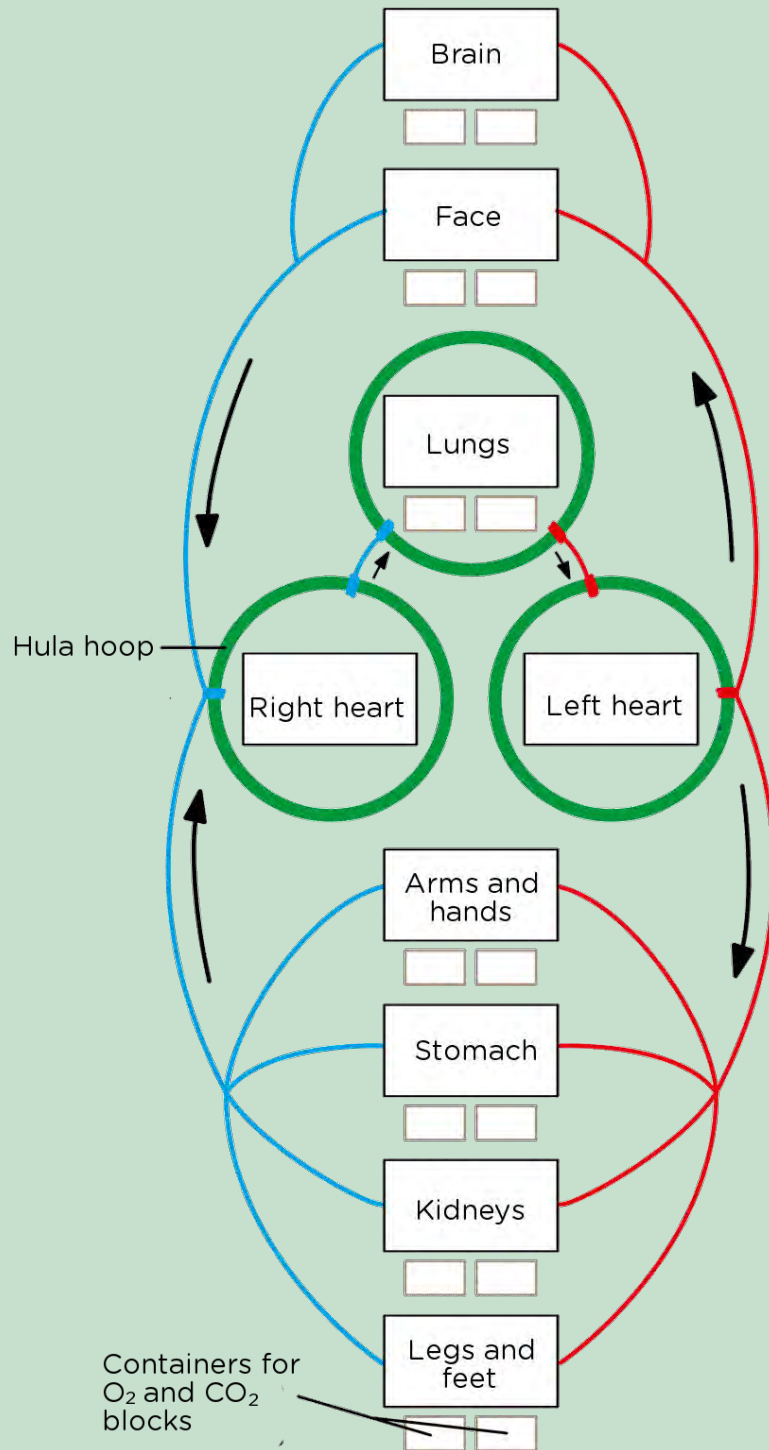
## TEACHER'S NOTE

1. Obtain the use of a large, open space, either in your classroom, a hall, or outside on the grass. Imagine a huge person is lying out on the space.
2. Lay out 2 hula hoops to represent the left and right side of the heart.
3. Place one more hula hoop above this to represent the lungs.
4. Lay out the signs on the A4 pages to illustrate where each of the body parts will be in relation to the heart and lungs.
5. Stick red wool (for oxygen carrying vessels) and blue wool (for carbon dioxide carrying vessels) with prestik or sellotape to the A4 posters (and between them) forming a large circulatory system as in the diagram in the activity.
6. Leave a pile of red and blue blocks of paper at each body part - it works well if you put these in ice-cream or yoghurt tubs
7. Learners start off in the lungs and will walk along the red lines to their different body parts as if they are traveling in the blood vessel to deliver oxygen. When they have delivered their oxygen (by dropping off the red blocks and picking up blue blocks) they will then travel along the blue lines to deliver carbon dioxide to the lungs and to get more oxygen.
8. As one learner leaves the lungs, send another one off so that you have several learners walking through the system at any one point.
9. If you have a large class, let a couple of learners walk through at a time. If you make the layout really big, then the whole class can form a long line of individual blood cells and move through in a line.

We are going to create a simulation of our circulation!

## INSTRUCTIONS:

1. Imagine that you are a red blood cell and you will be carrying oxygen around the body.
2. Your teacher will help your class to lay out the huge body in an open space using A4 sheets with labels and hula hoops as in the following diagram.
3. There are two colours of paper blocks at each organ or body part and in the lungs. One colour will represent oxygen (preferably red) and the other colour will represent carbon dioxide (preferably blue).
4. Start off by standing in the lungs and pick up oxygen. You now represent oxygenated blood.
5. Walk to the left side of the heart.
6. The heart now pumps you out to the body in the circulatory system. Leave the left heart hula hoop and walk to the organ or body part you are going to supply with oxygen.
7. When you reach the body part, drop off your oxygen block into the container and now pick up a coloured block representing carbon dioxide. You now represent deoxygenated blood.
8. Walk to the right side of the heart.
9. From here, the heart pumps you to the lungs. Walk to the lungs.
10. At the lungs, gaseous exchange takes place and you drop off the carbon dioxide you were carrying and pick up oxygen again.
11. You can now repeat the cycle and walk to a different body part.



**TEACHER'S NOTE**

Make sure learners are able to visualise that they are forming a complete cycle or system which repeats. If they are battling, you can walk through it with them first to explain. The first time you could even demonstrate the activity by starting in the lungs and getting learners to instruct you on where to walk to next.

## Heart rate

Your resting heart rate is often used as an indicator of how fit you are or whether there are possible health concerns that you should pay attention to.

### **ACTIVITY:** Homework activity to measure your resting heart rate

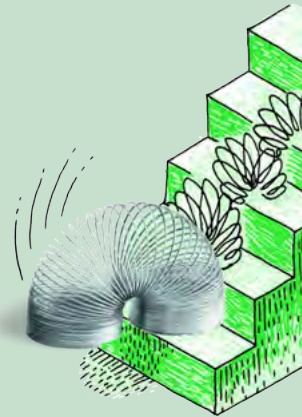
#### **TEACHER'S NOTE**

Get learners to do this activity in the 3 days leading up to the lesson where you will investigate the effect of exercise on heart rate.

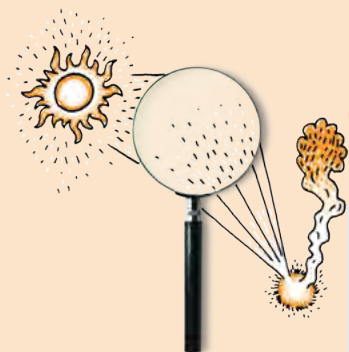
#### **INSTRUCTIONS:**

1. Take your resting heart rate first thing when you wake up in the morning. Record how many times per minute your heart beats.
2. Repeat this over 3 days to get an average - this is more reliable than a once-off reading.
3. Record your resting heart rates in the table.

	Heart rate (beats per minute)
Day 1	
Day 2	
Day 3	
<b>Average</b>	



We have now had a look at our heart rate when we are resting. But what happens when we do some kind of physical activity? Will your heart rate increase or decrease? Do you think you could use your heart rate as a measure of how fit you are? Let's investigate!



## **INVESTIGATION:** Measuring and comparing heart rates before and after exercise

### **TEACHER'S NOTE**

For this investigation, the basic instructions are given below, and then learners will have to design the investigation themselves. A suggestion is to break your class up into big groups of at least 10 learners. They can then discuss how they are going to do the investigation. Each learner must write down their own method and design after they have discussed how they are going to do the recordings within their group. The only materials that learners will need are timing devices - you can either provide some stopwatches, or learners can use the stopwatch on their mobile phones. If learners opt to run for example, suggest running on the spot, as it will be difficult otherwise to control how far or fast individual learners will run in 2 minutes. In general, fitter people have a slower resting heart rate and return to their resting heart rate faster than unfit people after a bout of exercise, but the focus for this activity should be that learners take objective measurements and analyse the data that they collect appropriately. Therefore if the findings of the investigation do not agree with the expected results, full credit should still be given for an accurate interpretation.

This is the first investigation that learners will be conducting in Gr. 9. An interesting video to watch beforehand about the scientific method is given in the visit box and titled "The times and troubles of the Scientific Method". It could be an interesting class exercise to watch this video first and then have a class discussion about learners' understanding of the scientific method. At school level, the scientific method is taught in specific steps, but it is very important for learners to also understand how science discoveries often take place at university level and that they often happen by chance or as a side result of another experiment.

### **INSTRUCTIONS:**

Measure the heart rate of at least 10 learners in your class after they have done 2 minutes of skipping or running on the spot. Discuss in your group how you are going to do this and write down your method. Record your measurements and use a graph to display your findings. Make deductions about your class' fitness levels based on their heart rates after completing the graphs and discuss the benefits of exercise for the circulatory and respiratory system (also known as the cardiovascular system).

### **AIM:**

1. What is the aim of your investigation?  
*Learner-dependent answer*



### TEACHER'S NOTE

The aim could vary slightly from one group to the next, but in general the aim is to see what the effect is of exercise on heart rate and to make deductions about class fitness.

#### A possible extension:

Investigate how quickly a learner's heart rate returns to resting heart rate after physical activity. This will indicate how much their heart rate increased during the exercise as you will measure before and after activity. But then you can also measure the heart rate at 1 minute intervals after the exercise to see how quickly the heart rate decreases to resting rate again. This gives a more rounded measure of fitness level as the faster a person is able to recover, the more fit they are. This should only be done as an extension if you feel your learners are capable and have time to do it within the lesson. This graph would be a line graph.

#### HYPOTHESIS:

1. What is your hypothesis for your investigation?

*Learner-dependent answer*

#### VISIT

A video on the scientific method [bit.ly/15qh1SY](https://bit.ly/15qh1SY)

### TEACHER'S NOTE

A possible hypothesis which learners might propose is: "Heart rate increases after exercise."

#### VARIABLES:

In any scientific investigation, it is crucial to identify the variables at the start.

- When you do an investigation you are going to change or vary one factor to answer your question. This is called the **independent variable**.
- The factor that you are measuring or observing is the **dependent variable**.
- Normally, you will have a third variable, the **control variable**. These are the factors that you want to keep the same (unvaried) during your test so they cannot affect your results.

1. What are the variables involved in this investigation?

*The independent variable is the type of activity - exercise or resting.*

*The dependent variable is the heart rate as this will depend on whether the learner is at rest or has done physical activity (and how vigorous the physical activity was).*

*There are several controlled variables: Learners of the same age, about the same mass, all girls / boys, all about the same fitness level, all doing the same type of exercise, all doing it for 2 minutes.*

#### MATERIALS:

Write a list of the materials you will need for this investigation. Possible materials to be listed are:

- stopwatch
- skipping rope (if learners are to skip, otherwise they may just run on the spot)
- recording sheet and pen

**METHOD:**

1. Write down the method below. The steps must be numbered.  
*Learner-dependent answer*

**TEACHER'S NOTE**

Make sure learners discuss all aspects of the investigation. You can help learners with this part of their discussion in their groups by pointing out questions that they should answer when writing their method. For example, how will we do the recording? This will depend on how many skipping ropes are available if they are to be used. Will one learner skip at a time while the others watch and record the time? Or if the learners are to jog on the spot for 2 minutes, then perhaps 5 learners can jog at once while the other 5 do the recordings. Learners must specify how they will record heart rate and where. Will it be on the wrist or the neck? Is it best to record heart rate for 10 (or 15) seconds and multiply 6 (or 4) to get the beats per minute? This is because if they record the heart rate for a whole minute after exercise, the rate might have started to slow down already by the end of the minute and therefore not be an accurate reflection of the heart rate immediately after exercise.

**RESULTS:**

1. Design a table that will record the heart rate of the 10 learners when at rest and after 2 minutes of physical activity (skipping or jogging on the spot). Remember to give your table a heading.  
*Learner-dependent answer*

**TEACHER'S NOTE**

A possible table that learners might produce could look as follows:

Table showing the heart rate of 10 learners before and after 2 minutes of skipping

Learner name	Heart rate before (beats/min)	Heart rate after (beats/min)
Megan		
Thembile		
etc		

Learners may also come up with additional columns, for example they may add a column to calculate the change in heart rate from before exercise to immediately after exercise.

## ANALYSIS:

In order to analyse your results, it is helpful to plot a graph as this helps you to see the relationship between the dependent and independent variables and to make comparisons. Below is a description of different types of graphs and when they are used.

- **Line graph:** A line graph is used if the data you have is numerical and changes continuously, often over time. A line graph is useful for visualising a trend in the data over time.
- **Bar graph:** A bar graph is used to compare different categories or groups, normally when the categories are words. There are spaces between the bars in a bar graph.
- A *double* bar graph can compare two sets of data. In a double bar graph, two of the bars touch and are shown in different colours, and are separated by a space from the next two bars.

### TEACHER'S NOTE

Learners may not understand how a double bar graph is different from a bar graph, and may not understand what is meant by two sets of data. An example of a double bar graph would be the minimum and maximum temperatures on different days of the week. In this example, the day of the week is the independent variable, and we are looking at two dependent variables (two sets of data) - namely the maximum and minimum temperatures. For a graph like this, one would indicate "days of the week" on the x-axis, and you would have two bars next to each other for each day. One would show the minimum temperature and one would show the maximum temperature. The bars showing the two temperatures would touch, and the days of the week would be separated by a space.

- **Histogram:** A histogram is used when the data for the independent variable is numerical and can be grouped into categories which are continuous. The bars in a histogram touch each other.
- **Pie graphs:** Pie graphs (or sector diagrams) are used to show the relative proportions or percentages of the categories when they make up a whole.

1. Which type of graph will you use to represent the data in this investigation? Give a reason for your answer.

### TEACHER'S NOTE

Learners might find this difficult to answer, but it is crucial that they understand the types of graphs and when each one should be used. In this investigation, we want to show the data for each learner along the independent axis (x-axis). The learners are not related in any way, nor are they numerical values - they are discrete categories described by words (ie. the name of the learner). We will therefore use a bar graph. In this investigation we will actually be using a double bar graph. There will be two bars for each learner - the first bar being the heart rate before exercise and the second bar being the heart rate after exercise.

2. How will you differentiate on your graph between the two sets of measurements for each learner (ie. heart rate before and after exercise)?

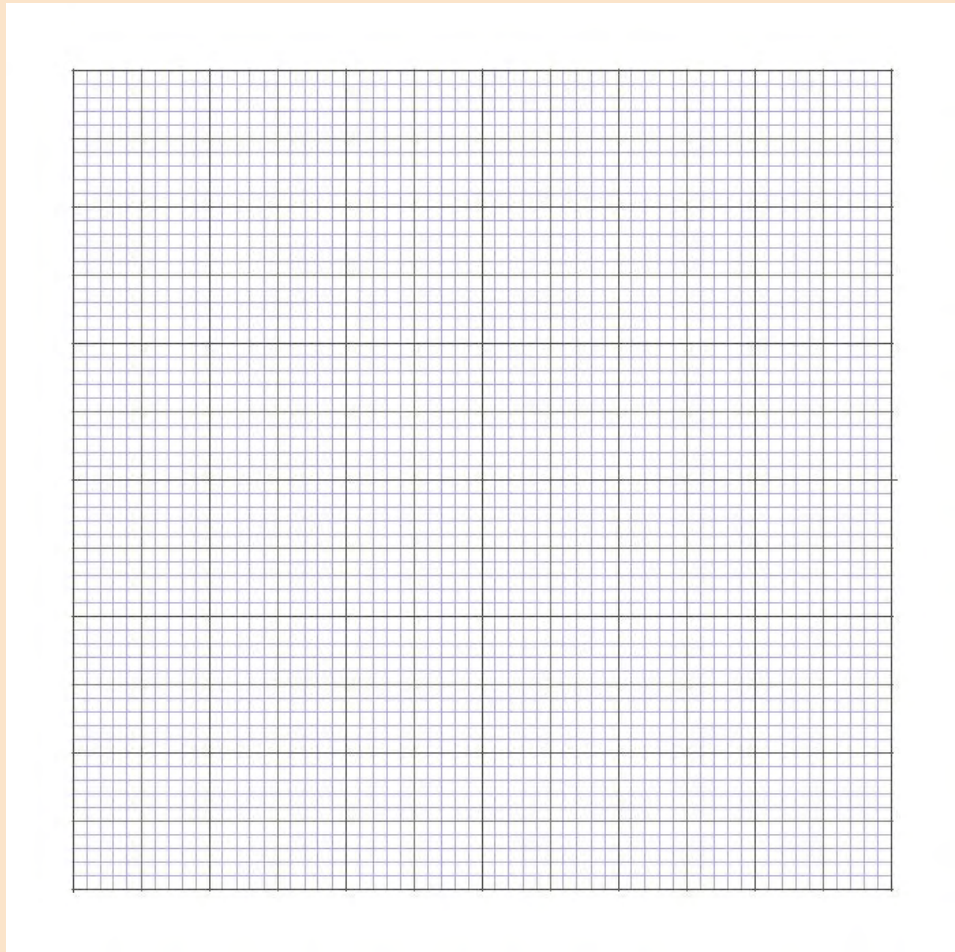
**TEACHER'S NOTE**

Learners can distinguish between the before and after readings by creating a key where the one set of data is in one colour or pattern and the other set is in another colour or pattern.

Tips for drawing your graph:

- Start by giving your graph a title, something that shows which dependent and independent variables you were studying.
- Use the appropriate axes for each variable: x-axis = independent variable (along the bottom of the graph) and y-axis = dependent variable (along the side).
- Label your x-axis and y-axis.
- Use an appropriate scale and use the space that you have been given to draw the graph wisely.

Draw your graph on the graph paper provided.



### TEACHER'S NOTE

When looking at learners' graphs or helping them to draw them, make sure they have the heart rate in beats/min on the dependent y-axis and the learners names on the independent x-axis. Each learner will have two bars, one for heart rate before exercise and one for heart rate after exercise. For each learner, these two bars should be touching, but there should be a space between the sets of bars for each learner. As a suggestion, if using the graph paper provided here, in order to fit 10 learners along the x-axis it is best to make each bar 2 blocks wide (the smallest blocks), with 1 or 2 blocks in between each learner. If you have graph paper available, perhaps provide learners with a sheet to practice on and once they know how to draw their graph, they can copy it into the workbook here.

1. Which learner in your group had the smallest increase in heart rate from before to after physical activity?

*Learner-dependent answer*

2. Which learner in your group had the largest increase in heart rate from before to after physical activity?

*Learner-dependent answer*

3. Rank the learners in your group from the smallest increase to the largest increase.

*Learner-dependent answer*

4. What deductions can you make about the fitness level of the learners in your group based on their heart rates before and after the physical activity? When you make deductions, ask yourself these questions:

- a) What do you see is happening?
- b) What do you notice that is different?
- c) What does this imply?

*Learners should deduce that the fitter an individual is, the smaller the increase in the heart rate from before to after physical activity. Learners that are unfit will sometimes show a bigger increase in heart rate after the physical activity (provided that the activity was carried out to the same level of effort).*

### TEACHER'S NOTE

It is vitally important that learners report their actual findings. If they do not come up with results that agree with what they are expecting to find, it is FAR better that they report what they found than that they "tweak" their results or try to alter their discussion or hypothesis to fit in with what is expected. Full credit and praise should be given to an investigation that was carried out well and truthfully reported, rather than one in which certain information or findings are made up or changed. If students know what they were expecting, and think that there is something wrong with their results they should be encouraged to make suggestions about why they didn't see what they were expecting to see in the discussion section that follows.

### DISCUSSION AND EVALUATION:

An important part of an investigation is to discuss your results and observations and evaluate them. At this point you get to talk about your results and explain them.



### TEACHER'S NOTE

The learners may also notice a trend in the resting heart rates of the members of their group that were recorded in the three days prior to this activity, and they are welcome to hypothesise and make observations. They are likely to notice for example, that the fittest members had the lowest resting heart rates.

You also point out any shortcomings of the investigation. What could you have done to improve the investigation? You can also point out any unexpected results in your investigation and try to explain these using your science background. You should do some background research into the benefits of exercise for the cardiovascular system and write some points in your discussion.

#### VISIT

Watch this video that summarises the respiratory and circulatory systems  
[bit.ly/16lJFU6](http://bit.ly/16lJFU6)

### TEACHER'S NOTE

Assess whether learners have adequately discussed their results. As previously mentioned, their actual results may not agree with what they *should* find. In this case they still deserve full credit for their observations. However they also need to show that they know what should have happened, based on their research around the topic. They should point out that fitter individuals have a stronger heart compared to unfit individuals. Like all muscles, the heart becomes stronger as a result of exercise, therefore, it can pump more blood through the body with every beat. As a result, during exercise, a fit heart does not need to pump as fast to deliver the same amount of blood that an unfit heart would, and it does so with less strain. Assess whether learners have pointed out any shortcomings in their investigation and if they have made suggestions. Learners should also discuss some of the benefits of exercise for the cardiovascular system, such as decreasing the risk of heart attack and other heart diseases.

### CONCLUSION:

1. Write a conclusion for your investigation. In a conclusion, you need to refer back to your hypothesis to see whether your results support or reject the hypothesis.

*Learner-dependent answer*

### REFERENCES:

If you researched any additional information to support your discussion, you need to reference these sources in the following way:

- **Books:** Surname of author, Name of book, Year published, Name of publisher, Page numbers you used.
- **Internet:** Give the full URL for the website.
- **Person:** Personal communication with "Name, Surname, Occupation."

#### TAKE NOTE

Simply listing Google or Wikipedia as your source is not recognised as a reference for your work.

## SUMMARY:

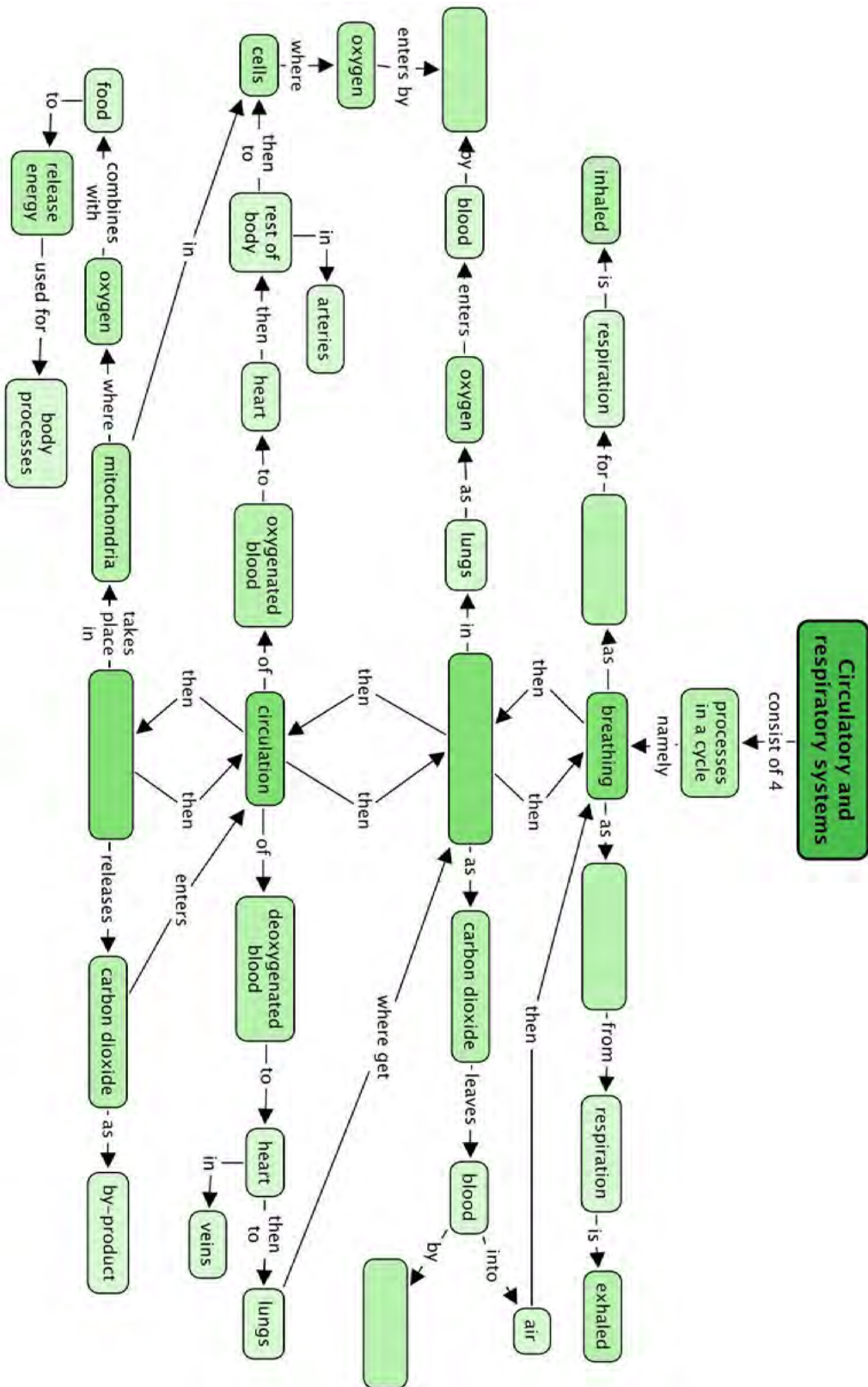
### Key Concepts

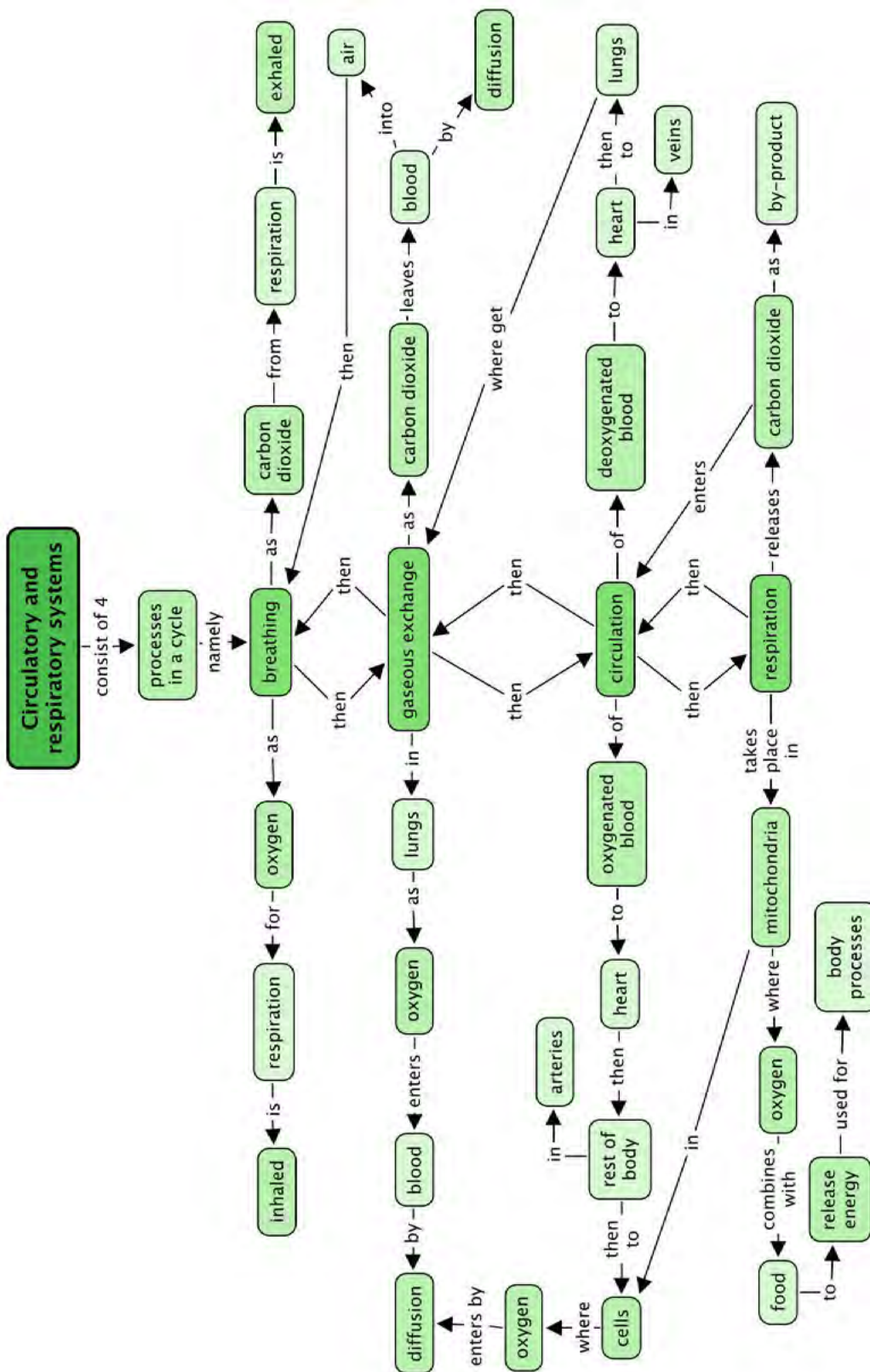
- Oxygen is inhaled in a process called breathing.
- In the lungs, gaseous exchange occurs by diffusion.
- Oxygenated blood is transported in pulmonary veins from the lungs to the left side of the heart.
- The oxygenated blood is pumped through the aorta and arteries to the different parts of the body.
- Arteries divide into capillary networks between the cells, where oxygen and food diffuse from blood to cells.
- The cells carry out cell respiration, forming carbon dioxide, which diffuses back to the capillaries.
- Capillaries flow into veins that carry the deoxygenated blood to the right side of the heart.
- At the heart the deoxygenated blood is transported to the lungs by the pulmonary artery where gaseous exchange takes place once more.
- The carbon dioxide from cellular respiration diffuses out of the blood into the lungs and is exhaled.

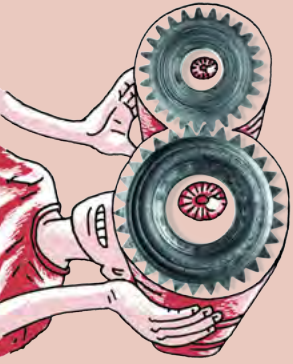
### Concept Map

From what we have learnt in this chapter, we can say that the circulatory and respiratory systems consist of 4 processes which occur in a cycle. Two of these processes are named in the concept map, and there are spaces to write the other two. During breathing, what is the gas which is inhaled for respiration, and which is the gas which is exhaled from respiration? Fill these in too. What is the name for the process by which these gases move across the cell membranes?









## REVISION:

1. Draw a flow diagram to show how the different components of the respiratory and circulatory systems function in a cycle. [6 marks]  
*learner-dependent*
2. Complete these sentences. Write just the word on the line below. [13 marks]
  - a) Oxygen diffuses into the blood from the air in the \_\_\_\_\_.
  - b) The blood vessels that carry blood away from the heart are called \_\_\_\_\_.
  - c) Tiny blood vessels called \_\_\_\_\_ come into close contact with \_\_\_\_\_.
  - d) Carbon dioxide \_\_\_\_\_ out of the cells into the \_\_\_\_\_.
  - e) \_\_\_\_\_ carry the \_\_\_\_\_ blood to the heart from where it is sent to the \_\_\_\_\_ to be oxygenated.
  - f) The chemical reaction that takes place in the \_\_\_\_\_ of the cell when oxygen and glucose combine to release \_\_\_\_\_ is called \_\_\_\_\_.

- a) *alveoli*
- b) *arteries*
- c) *capillaries, cells*
- d) *diffuses, capillaries/bloodstream*
- e) *Veins, deoxygenated, lungs*
- f) *mitochondria, energy, respiration*

Complete this table to describe what happens in the chest during breathing. [6 marks]

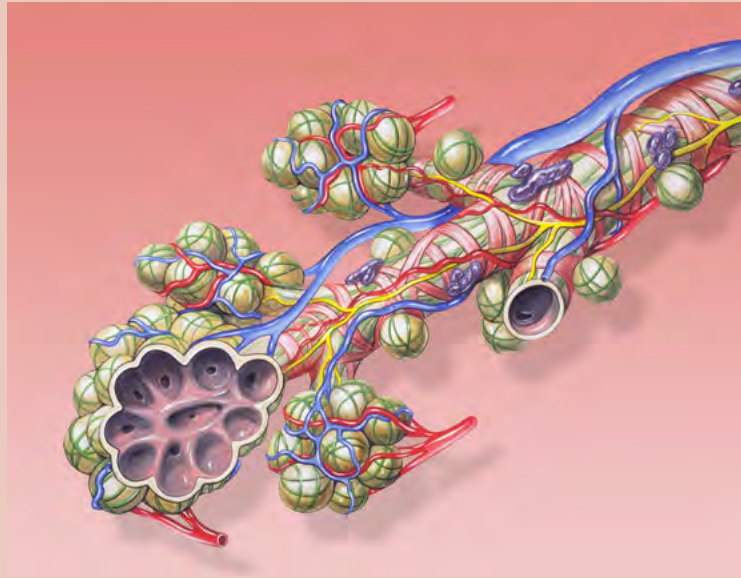
	<b>Inhaling</b>	<b>Exhaling</b>
<i>Chest volume</i>	<i>Expands</i>	<i>Becomes smaller</i>
<i>Pressure on lungs</i>	<i>Decreases</i>	<i>Increases</i>
<i>Air movement</i>	<i>Moves into lungs</i>	<i>Moves out of lungs</i>

3. Match the word on the left to its correct meaning on the right. Write only the letter next to the word to indicate the correct meaning. Use each letter only once. [13 marks]



<i>l</i>	<i>breathing</i>	<i>a</i>	<i>arteries, veins and capillaries</i>
<i>n</i>	<i>diaphragm</i>	<i>b</i>	<i>the type of tissue that keeps keeps the trachea open</i>
<i>i</i>	<i>alveoli</i>	<i>c</i>	<i>tubes leading from the trachea into the lungs</i>
<i>e</i>	<i>trachea</i>	<i>d</i>	<i>the movement of particles from a high to a low concentration through a semi-permeable membrane</i>
<i>k</i>	<i>heart</i>	<i>e</i>	<i>the tube that carries air to and from the mouth to the bronchi</i>
<i>h</i>	<i>veins</i>	<i>f</i>	<i>blood vessels that transport blood away from the heart</i>
<i>j</i>	<i>respiration</i>	<i>h</i>	<i>blood vessels that carry blood towards the heart</i>
<i>b</i>	<i>cartilage</i>	<i>i</i>	<i>small grape-like bunches at the ends of the bronchiole</i>
<i>c</i>	<i>bronchi</i>	<i>j</i>	<i>the process takes place in mitochondria to release energy for cells to use</i>
<i>m</i>	<i>capillaries</i>	<i>k</i>	<i>the organ responsible for pumping blood throughout the body</i>
<i>a</i>	<i>types of blood vessels</i>	<i>l</i>	<i>inhaling and exhaling</i>
<i>d</i>	<i>diffusion</i>	<i>m</i>	<i>blood vessels surround cells to allow for diffusion</i>
<i>f</i>	<i>arteries</i>	<i>n</i>	<i>a large dome shaped muscle across the bottom of the rib cage</i>

4. The following image is an artist's drawing of one of the structures you learnt about in this chapter. What does it represent? Give three reasons for your answer. [3 marks]



*This is showing a bronchiole and alveoli. This is evident as there is one main tube which is the bronchiole. There are several alveoli present, which are the sac-like structures within the lungs. You can also see that these are tiny sacs as in the bottom left, the sacs have been shown as open. You can also see the network of capillaries which surround the alveoli bringing deoxygenated blood to the lungs to become oxygenated.*

5. Describe how capillaries are suited to their function of allowing gaseous exchange within the lungs and at the cellular level in the body. [3 marks]  
*The capillaries are very small and thin-walled so that they can branch between the cells of the tissues and come into close contact with the cells to allow for diffusion. This also allows the capillaries to reach all the cells within the body to deliver oxygen and nutrients and remove waste products.*

Total [44 marks]





# 5 Digestive system

## TEACHER'S NOTE

### Chapter overview

1.5 weeks

Learners have already been introduced to the digestive system in Chapter 2. This chapter focuses more on a healthy diet and the different components making up a healthy diet. Learners will be required to conduct some food tests to investigate which foods contain which components, such as starch and fats. The chapter will also look at the alimentary canal and digestion in more detail to see how the food we eat becomes a form which can be absorbed into our bodies. In Gr 6 CAPS, learners do an introduction to nutrition and learn about the basic food groups.

#### 5.1 Healthy diet (3 hours)

Tasks	Skills	Recommendation
Activity: Comparing healthy and unhealthy foods	Working in pairs, comparing, describing, categorising	Suggested
Activity: Comparing meals	Comparing, describing, explaining	Suggested
Investigation: Which foods contain starch and fats and oils?	Investigating, observing, interpreting, describing, writing, explaining	CAPS suggested
Activity: How does your diet affect your health in the short and long term?	Researching, interpreting, predicting, explaining	CAPS suggested

#### 5.2 The alimentary canal and digestion (1.5 hours)

Tasks	Skills	Recommendation
Activity: The different organs in the digestive system	Identifying	Suggested
Activity: A digestion simulation	Working in groups, observing, describing, interpreting, comparing, writing	Suggested



## KEY QUESTIONS:

- Why do we need to follow a healthy diet? What does a healthy diet consist of?
- What makes one type of food healthy and another type of food unhealthy?
- Is it possible to prevent things like diarrhoea or constipation? What about ulcers?
- Why do we need to digest food?
- How is food digested in our bodies?
- Where does the digested food go?



In this chapter we are going to look more closely at the food we eat to see why certain foods are considered healthy and others unhealthy. We will then investigate how the food from our plates gets to our cells and why our digestive system is so well adapted for its job.

## 5.1 A healthy diet

Our human bodies are very active. Our bodies need a huge variety of different nutrients and substances in order to perform all these processes. We obtain these nutrients from the food we eat. The human body needs a balanced, healthy diet to keep functioning properly.



### ACTIVITY: Comparing healthy and unhealthy foods

#### INSTRUCTIONS:

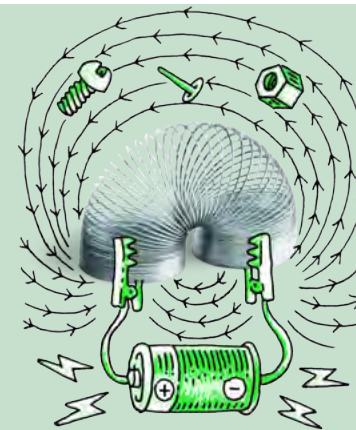
1. Work with a partner.
2. We often know if a food is healthy or unhealthy. List at least 10 healthy and 10 unhealthy foods in the following table.

Healthy food	Unhealthy food

When you are done share your food list with the class and record the class' ideas of healthy and unhealthy foods on a large sheet of paper or on the board. Display this in the class.

Study the list of healthy and unhealthy food.

1. What common characteristics can you identify in the food that the class





listed as healthy?

*Learner-dependent answer*

2. What common characteristics can you identify in the food that the class listed as unhealthy?

*Learner-dependent answer*

Let's take a closer look at what makes up a healthy diet.

### **The seven building blocks of a healthy diet**

The foods that we eat can be divided into different groups:

- proteins
- carbohydrates
- fats and oils
- vitamins
- minerals
- fibre (non-digestible carbohydrates)
- water

A healthy diet consists of foods from all of these groups.

#### **Proteins**

Proteins are our bodies' building blocks. They build and repair body cells and tissues. Foods rich in protein are: fish, meat, poultry, eggs, cheese and other food from animal sources. There are also many sources of protein from plants. For example: products made from soya beans, peas and beans, nuts and seeds.



*Meat.*



*Eggs.*



*Almond nuts.*



*Cheese.*

#### **VISIT**

A simulation about eating and exercise [bit.ly/19buenM](http://bit.ly/19buenM)

## Carbohydrates

Carbohydrates are the main supply of energy for our bodies. They break down in our digestive system to form glucose (which is a sugar). Examples of foods that contain carbohydrates are: whole grain bread, potatoes, pasta, rice, fruit, vegetables, maize and legumes.

Unfortunately many people eat too many carbohydrates, especially processed carbohydrates like sweets and biscuits, chips, pastries, soft drinks and sweetened fruit juices.



*Whole wheat bread.*



*Potatoes.*



*Rice.*



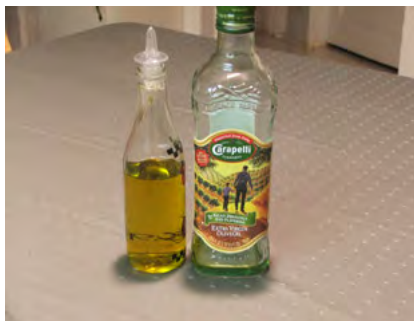
*Mealies (corn) contain a lot of carbohydrates.*

## Fats and oils

Fats and oils are important for many body processes:

- Fat protects and insulates your organs
- They help maintaining healthy hair and nails.
- Some vitamins can only be absorbed and transported when attached to fat molecules.
- Fats and oils also provide the body with energy.

However, some fats are better than others and having too much of any type is not a good idea.



Olive oil and canola oil are both healthy oils.



Sardines are high in healthy fats.

## Vitamins



Our sources of vitamins are from fruit...



...and vegetables.

### TAKE NOTE

Many people take large amounts of supplements to ensure they get enough vitamins and minerals. However it is rather wasteful as the body excretes any excess vitamins and minerals and only stores a few vitamins like Vitamin A, D, E and K.

Vitamins help with the different chemical reactions in our bodies:

- **vitamin A** helps strengthen our immune system and is good for eyesight in the dark
- **B vitamins** help us process energy from food
- **vitamin C** helps to keep your skin and gums healthy and improves the immune system
- **vitamin D** helps to build strong bones and teeth

Our main sources of vitamins are from fruit and vegetables. The following diagram summarises some of these sources for various vitamins.



Food sources of different vitamins.

## Minerals

Our bodies cannot produce minerals and we therefore need to include these in our diets. Some of the minerals we should include in our diets are:

- **calcium** which is essential for strong bones and teeth.
- **iron** which is needed for healthy blood.
- **magnesium** which is used for building strong bones, teeth and muscles.



- **sodium** which is also needed for muscle and nerve function, and more importantly it helps regulate the amount of water in the blood.

There are a variety of sources of minerals. For example, high levels of calcium are found in dairy products, meat is a high source of iron, and magnesium is found in lots of foods such as bananas, nuts, green leafy vegetables and milk. The most common source of sodium is in sodium chloride, which is table salt.

#### VISIT

Find out more and get a special dietary plan worked out just for you  
[bit.ly/181Y5J2](http://bit.ly/181Y5J2)

## Fibre

Fibre found in the skins of fruit and vegetables, and in wholegrain cereals, cannot be digested. It therefore travels through the alimentary canal. We need fibre in our diet as it helps us to have regular bowel movements and avoid constipation. .



*Beans are a good source of fibre.*



*High fibre breakfast cereal.*



## Water

Our bodies are made up of more than 50 percent water. Water is necessary to help our blood carry nutrients and waste around the body and to help the chemical reactions that occur in our cells. Water forms most of sweat, saliva and tears.



*You need to drink water daily.*



## ACTIVITY: Comparing meals



### TEACHER'S NOTE

This is an **optional** activity, and can also be done as a class discussion if you do not have time in class.

### INSTRUCTIONS:



1. Below are photographs of different meals for breakfast, lunch and dinner.
2. One of the meals is healthier than the other.
3. Choose which is the healthier option and explain why.

#### 1. Breakfast:

Option 1: Fruit loops	Option 2: Fruit salad
	

*The fruit salad is healthier as it contains a variety of fresh fruits which are high in fibre and packed with healthy vitamins. Fruit salad will satisfy some of your requirement of fruit and vegetables for the day. The fruit loops are unhealthy as they contain a lot of sugars and artificial colourants and flavourants. They have limited nutritional value in terms of vitamins and minerals.*



#### 2. Lunch:

Option 1: Hamburger	Option 2: Omelette with salad
	



*The omelette is the healthier option. As with the egg salad, this meal contains fresh salad and the eggs are a source of protein. The omelette possibly has meat or mushrooms and cheese which also adds to the nutritional content. The hamburger is unhealthy as although it contains meat, starch and cheese, the way it was probably prepared is unhealthy as the meat is fried in oil. There is also no fresh fruit or vegetables.*

**3. Supper:**

Option 1: Chicken pieces	Option 2: Beef, peas and rice
	

*The beef, peas and rice is the healthier option for supper as the meal contains starch (rice), meat for protein (beef) as well as vegetables (peas). The other meal is less healthy as it only contains one food group, namely protein from the chicken pieces.*



Different cultures and religions follow different diets. Some cultures will only eat certain types of food and will avoid other combinations. Some religions might restrict their followers to only certain foods while others have no real dietary laws. Within South Africa, we have a very diverse population with people from many cultures, backgrounds and religions. This makes our country a truly unique, diverse and interesting place in which to live!

**Testing food**

There are various chemical tests which are used to easily identify the type of food molecules present in different foods.

Once such test is the **starch test**. We can also test for the presences of fats and oils using the **emulsion test**.



## **INVESTIGATION:** Which foods contain starch and fats and oils?

In this investigation, learners will be provided with the background information and basic instructions. They will have to design the investigation themselves and then write up their findings in an experimental report.

Before the lesson starts, set up each workbench with the materials and apparatus the learners will require to do the food tests.

### **The materials required are (per learner or group):**

- various food items to test for starch: for example, pieces of bread, apple, tomato, boiled egg, cheese, cucumber, potato, yoghurt, ham (some substances must contain starch and some not)
- various food items to test for fats and oil: for example, the above food items can be used, and in addition, you could also provide peanut butter and butter
- petri dish per group or learner for the starch test
- bottle of iodine solution and dropper
- several test tubes for the fat emulsion test
- water
- glass rod (or any other suitable round hard item) for crushing food substances for fat emulsion test
- bottle of ethanol
- forceps

#### **TAKE NOTE**

In lower grades you might recall doing the starch test on plants to see which leaves store starch from the glucose produced in photosynthesis.

### **INSTRUCTIONS:**

1. You need to conduct an investigation to test whether the food substances you have been provided with contain starch or fats and oils or both.
2. A summary of each test is given below. You will need to design your investigation and conduct it.
3. Before starting, think about how you will record your results and write out your proposed method.

### **Starch iodine test:**

Iodine solution is an orange-brown colour. When iodine is added to a substance which has starch in it, the iodine reacts with the starch to produce a blue-black colour. The blue-black colour indicates the presence of starch.

### **TEACHER'S NOTE**

Learners will need to use the dropper to add a couple drops of the iodine solution to the food substance to be tested in a petri dish. Let them practise on a small piece of white paper, so they see the colour change before trying it on the food. Starch hold the fibres in paper together.

### **Fat emulsion test:**

To conduct the test, crush a piece of the food (or liquid) in a small amount of ethanol. Pour some of the mixture onto paper. Once the ethanol has

evaporated, oil stains on the paper will indicate the presence of fats or oils in the food.

#### AIM:

1. What is the aim of your investigation?

*To find out whether starch or fats and oils, or both are present in certain foods.*

#### HYPOTHESIS:

1. What is your hypothesis for this investigation?

*Learner-dependent answer*

#### TAKE NOTE

If you are allergic to iodine rather observe this experiment and do not participate.

#### TEACHER'S NOTE

This will vary depending on what food substances you provide to learners. An example of a hypothesis for this investigation is: "The iodine solution will turn blue-black when added to the potato, bread and apple, indicating these foods contain starch. The emulsion from the cheese, yoghurt, butter and peanut butter will turn milky white, indicating the presence of fats".

#### MATERIALS AND APPARATUS:

1. List the materials and apparatus you used in this investigation.

*Learner-dependent answer*

#### TEACHER'S NOTE

An example that learners could provide:

- samples (small) of the following foods - learners identify which foods they are testing for starch and fats.
- iodine solution with dropper
- petri dish
- forceps
- test tubes
- paper
- ethanol

#### METHOD:

1. Write down the method which you followed in this investigation.

*Learner-dependent answer*

#### TEACHER'S NOTE

Learners need to write the method in a list of numbered steps. Learners need to indicate that they collected the food samples and placed them in different petri dishes (bowls if these were not available). They then dropped iodine solution in turn on each of these samples observing and recording the results. They must then indicate how they did the fat emulsion test, by placing small pieces of the food substances in a test tube, adding ethanol and crushing and stirring with the rod or another rounded, hard object. They should then pour the mixture onto paper and allowed the ethanol to evaporate and record the results.

**RESULTS AND OBSERVATIONS:**

1. Use the following space to record your results and observations from this investigation.

*Learner-dependent answer*

**TEACHER'S NOTE**

Learners could draw a table to record their results and observations, or just list the foods which tested positive or negative for each substance. An example of the layout for a learners table could be:

Table to indicate the presence of starch or fats and oils in various food substances

Food substance	Result of iodine test	Contains starch?	Result of emulsion test	Contains fats?
Bread	Turned blue-black	Yes	No murky, white colour	No
Apple	Parts of apple turned blue-black	Yes	No murky, white colour	No
Cheese	Remained orange-brown/ did not turn blue-black	No	Emulsion turned murky, white colour	Yes
etc				

**DISCUSSION:**

1. Discuss and evaluate your results and findings and the importance of food tests.

**TEACHER'S NOTE**

Learners should discuss which types of foods contained starch and fats and which did not. They could note that plant material in particular contains starch because the plants photosynthesize specifically to produce glucose that are the building blocks for carbohydrates. Animal products (such as the ham and boiled egg) do not contain starch. Learners should also discuss any unusual findings which they did not expect and whether this could be a result of inaccuracy or contamination. Learners should also evaluate their results and whether they could have done anything to improve the investigation, such as possibly repeating the tests.

**CONCLUSION:**

1. What do you conclude from this investigation?

*Learner-dependent answer*

**TEACHER'S NOTE**

Learners must refer back to their hypothesis in the conclusion and either reject or accept it.

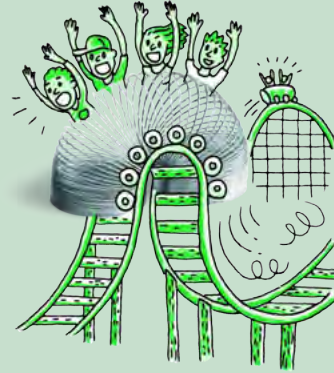
## Health problems relating to diet

In Chapter 2 this term, we looked at some of the health issues relating to the digestive system, such as ulcers, diarrhoea and eating disorders. There are also health issues which arise directly due to your diet. The following activity will introduce you to some of these health concerns.

**ACTIVITY:** How does your diet affect your health in the short and long term?

### TEACHER'S NOTE

Learners could do this as a quick class discussion as you go through the different conditions.



### INSTRUCTIONS:

1. Below is a table with descriptions of several health issues relating to a poor diet.
2. You need to read the descriptions and use your knowledge of the food groups to then classify what the diet of the person is deficient in, or else has a surplus of in their diet.
3. For some conditions, there may be a variety of causes, but this activity is focusing on the causes related to diet.



**TEACHER'S NOTE**

Name of health issue	Description	What does this person have a deficiency or surplus of in their diet?
Osteoporosis	Osteoporosis is a disease, most common in older women, where the bones become fragile and are more likely to break. Usually the bones lose density and become porous.	The main contributing factor is not enough calcium or Vitamin D in the diet. This can also be a genetic, inherited trait.
Anemia	Anemia is a condition of the blood when there are not enough healthy red blood cells. A patient feels tired and weak as the tissues and organs in the body are not able to get enough oxygen.	Too little iron in the diet. Iron is needed for healthy red blood cells to deliver oxygen to the tissues. Blood loss can also result in anemia, but this does not refer to diet.
Marasmus	This is a severe form of malnutrition due to starvation. The person becomes extremely thin (emaciated).	A severe deficiency of nearly all nutrients, especially protein and carbohydrates.
Constipation	A person has constipation when they have a bowel movement less than 3 times per week. The person may have hard stools and difficulty and pain when passing stools.	A diet lacking fibre. Fibre helps to produce stools and stimulate the digestive system. Not drinking enough fluids (water) can also cause constipation.

**5.2 Digestion and the alimentary canal****What is digestion?**

Digestion involves a variety of complex processes that turn the food that you eat into tiny molecules that can then be absorbed and transported to the cells of the body.

There are two types of digestion:

1. **Mechanical digestion** occurs when food is physically broken down through chewing, churning and mashing. Mechanical digestion takes place in your mouth and in your stomach.

### TEACHER'S NOTE

Mechanical digestion does not change the chemical properties of the food. Rather, it changes the physical properties by breaking large pieces up into small pieces, therefore it can also be called physical digestion.

2. **Chemical digestion** takes place when different digestive **enzyme** sbreak down the bits of food into smaller molecules. Enzymes are special proteins that speed up certain chemical reactions in the body. Chemical digestion starts in the mouth where enzymes in your saliva start to break down starch. Chemical digestion also takes place in the stomach and small intestine.

## The alimentary canal

We already studied the alimentary canal in Chapter 2 so we'll start by reviewing what we learnt there.

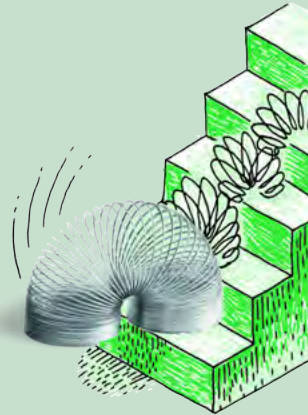
## ACTIVITY: The different organs in the digestive system

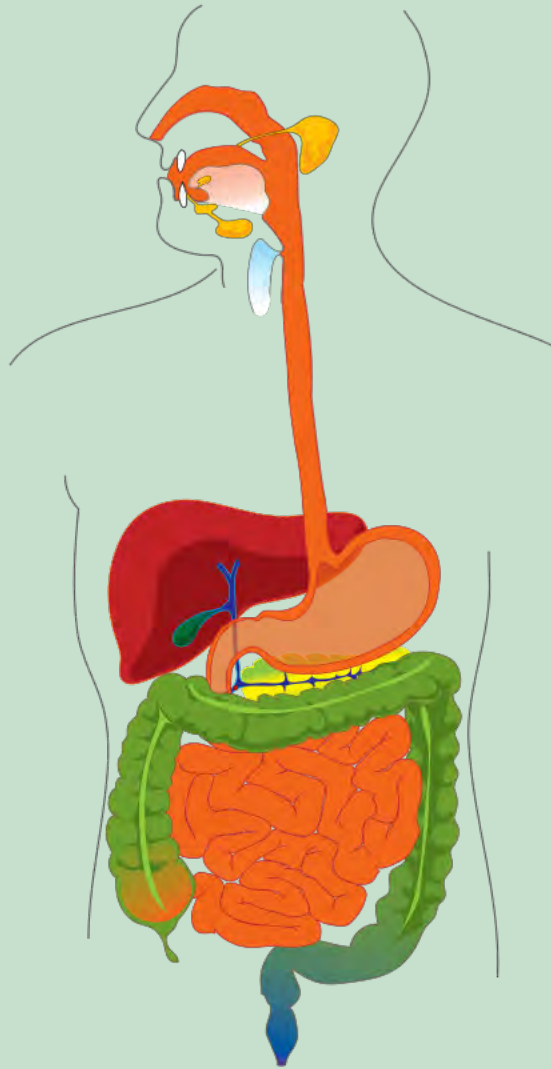
### INSTRUCTIONS:

1. Label the following diagram.
2. The labels have been provided for you. There are some which you might not have come across yet, as they are not the main components in the digestive system, but still play important roles.

#### Labels to include:

- large intestine
- anus
- oesophagus
- rectum
- stomach
- mouth
- small intestine
- liver
- gallbladder
- pancreas





#### TEACHER'S NOTE

Learners must draw straight, parallel label lines with a ruler and labels should be written one underneath the other. In this image, the liver is the large red organ next to the stomach, and the gallbladder is the small green part in front of it. The liver produces bile which it then secretes into the gallbladder to be stored before it enters the digestive tract. Bile helps with fat digestion. The pancreas, the yellow organ below the stomach in the diagram, is another organ which plays an important role in digestion as it produces the enzymes for chemical digestion which are secreted into the small intestine. The liver, pancreas and gallbladder are accessory organs to the digestive system. However, they are not part of the alimentary canal. Make learners aware that there is a difference in discussing the digestive system (including these accessory organs) and the alimentary canal (which only focuses on the organs and structures through which food passes and not the liver, pancreas and gallbladder).

Let us make a model of the alimentary canal that can demonstrate mechanical and chemical digestion in the different parts, and also learn about how the different parts are structurally adapted to suit their function.

### TEACHER'S NOTE

Although CAPS states that no detail of how the different parts of the alimentary canal are structurally adapted to suit their function, some of this information has been included in the following activity. It was felt that it is necessary to start developing this skill as learners will often have to describe structural adaptations for function in Life Sciences Gr. 10-12. This skill is often poorly developed in learners and so it is beneficial to start introducing learner to this kind of reasoning and explanations of biological structures from early on. This is an **optional activity**.

## ACTIVITY: A digestion simulation

### TEACHER'S NOTE

Objectives for this activity:

- Learn about how the different parts are structurally adapted to their function.
- Describe the parts of the alimentary canal and what each part's functions are.
- Understand physical and chemical digestion.
- Discuss how food travels from ingestion to digestion to absorption and egestion.
- Make observations regarding the process of digestion.

A suggestion is to make learners work in groups and produce one model per group. This way they will be able to discuss the model with each other as they are going along and there might also be less mess. Set up a workstation for each group prior to the lesson with the required materials laid out. The materials below are suggestions to be used to create a model of each part. However, you can also use other materials if you have more appropriate ideas or access to other materials in your classroom.

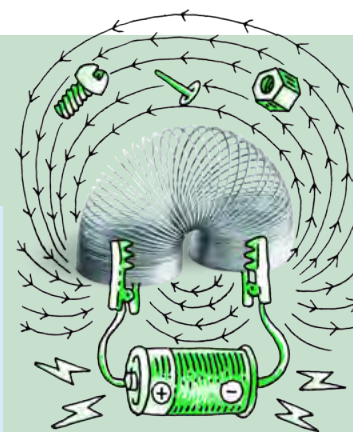
Alternatively, you could also do this activity as a demonstration in the front of the class, discussing the model and structures as you go along.

If you are not able to physically produce the model of digestion with your learners in class, you can still read through the activity and learners can still answer the questions and you can discuss the structural adaptations.

### MATERIALS:

Each group will need the following:

- large dish to work over, or black bags and newspaper
- crackers, white bread or viennas



### TAKE NOTE

Learning how to link the structural adaptations of an organ, tissue or cell to its function is a very important skill to start developing.

**VISIT**

Take a virtual tour through  
the alimentary canal

[bit.ly/15qh80h](http://bit.ly/15qh80h)

- mixing bowl
- scissors, pestle and potato masher
- water bottle that can squirt water through a small hole
- the inner tube of a kitchen paper towel roll or toilet paper roll
- a clear plastic Ziplock bag
- 30 - 40 ml of lemon juice, vinegar or a fizzy drink
- full length stocking with the toe section cut open - it helps if one leg is put inside the other to form a double layer
- bicarbonate of soda dissolved in water in syringes (10ml)
- large bowl

**INSTRUCTIONS:**

1. Work in groups and construct a model to demonstrate the different processes that food goes through in the different parts of the alimentary canal.
2. Make careful observations and describe in detail what happens at each stage.
3. Work over a large bowl or tray or sheets of newspaper and black bag to contain the mess which might be produced during this activity.

**Stage 1 - The mouth**

The function of the mouth is to ingest food and to start to digest the food. The mouth is specifically adapted for its function as follows:

- The lips keep the food in the mouth while chewing.
- Food is bitten off with the front teeth.
- Food is cut, torn and mashed into smaller parts by the different teeth in the mouth - this is mechanical digestion.
- The tongue moves the food around the mouth while it is being chewed. It also prepares the food for swallowing.
- Salivary glands secrete saliva. Saliva coats the food in the mouth making it easier to swallow. Saliva also contains enzymes which start to chemically digest.

**TEACHER'S NOTE**

Learners need to cut up the food with the scissors, break it up with the pestle and mash it with the potato masher. They then squirt water all over it and use their hands to make the food into a ball.

1. Using the mixing bowl to represent the mouth and the scissors, pestle and potato masher to represent and simulate the digestion of your food type that occurs in the mouth.
2. Squirt some water onto the mixture as you are 'digesting' the food.
3. Describe what is happening to the food at this point.

*The scissors, pestle and potato masher is mechanically breaking down the food into smaller particles (mechanical digestion). The water (saliva) sprayed on the food is covering it and starting to digest some of it (chemical digestion).*



4. Compare the model to the actual process in your mouth and what each part and action you are performing in the simulation represents.  
*The scissors are like the incisors that cut the food, the pestle is the pre-molars and the potato masher represents the molars. The water sprayed on the food is the saliva that starts chemical digestion. The hands making the ball with the food represents the action of the tongue and soft palate in making the bolus.*

## Stage 2 - The oesophagus

The pharynx (the throat) moves food from the mouth to the oesophagus. The oesophagus transports food from the pharynx to the stomach.

- A flap in the pharynx covers the trachea (windpipe) to prevent food from accidentally going into the trachea and causing the person to choke.
- The oesophagus is a muscular tube that moves the food by contracting in sections and relaxing in other sections. This is called peristalsis.
- A special circular muscle shuts the entrance of the stomach. It prevents the contents of the stomach from pushing back into the oesophagus which may lead to vomiting.

### VISIT

An interactive animation showing how different foods are digested and absorbed  
[bit.ly/1cWbzyC](https://bit.ly/1cWbzyC)

### TEACHER'S NOTE

One learner should hold the cardboard roll/tube with the one end in the bag while another learner tips the mixing bowl so that the food bolus rolls down the tube and into the bag.

1. Roll the ball of food you created in the mouth down the cardboard tube and into the clear Ziplock bag.
2. Describe what is happening to the food at this point.  
*The ball of food is being transported from the mouth to the stomach.*
3. Compare the model to the actual process in your oesophagus. Can you think of a better way of simulating the action of moving the food from the mouth to the stomach?  
*Learner-dependent answer*

### TEACHER'S NOTE

In the human body, the oesophagus transports the food (bolus) from the mouth to the stomach just like the cardboard tube allows the ball of food to travel from the mixing bowl representing the mouth to the Ziplock bag representing the stomach. Learners should note the downfall of this part of the model as food does not 'roll' down the oesophagus as they have done here in the simulation. Rather, the food is moved down by the peristaltic actions of the muscles surrounding the oesophagus. Learners should think up alternative ways to simulate or represent this action, such as using a plastic tube which is not hard and using your hands to squeeze the food down the tube and out the other side into the bag.

### Stage 3 - The stomach

The stomach is specifically adapted for its function as follows:

- The stomach has strong muscles which help churn the food to break it up further. This also mixes the pieces of food with the digestive gastric juices.
- Since the stomach has to store food and liquid, it has many folds and ridges in the wall that help to expand the stomach further.
- The lining of the stomach is replaced to prevent the stomach from digesting itself.
- The stomach secretes gastric juices when food is present. This helps the functioning of the enzymes in the chemical digestion of proteins.
- Cells in the stomach lining are adapted to absorb water.
- The lower end of the stomach has muscles which can control the emptying of the stomach contents.

#### **TEACHER'S NOTE**

Learners need to pour the digestive juices onto the food and then seal the stomach / Ziplock bag. They then simulate the stomach churning by shaking and churning the Ziplock bag with the food inside. This should go on for quite a while as the food often remains in the stomach for long periods.

1. The Ziplock bag represents the stomach. After the food has entered the stomach, pour one of the digestive juices (lemon juice, vinegar or Coca Cola) into the bag over the ball of food.
2. In your body, a special circular muscle closes and seals the stomach and digestive juices from the oesophagus. Seal the Ziplock as if you were sealing the actual upper end of the stomach.
3. Squeeze the bag to show the churning of food in the stomach.
4. Describe what is happening to the food at this point.  
*The churning and shaking is physically breaking up the food through mechanical digestion. The coke, vinegar or lemon juice aids chemical digestion.*
5. Compare the model to the actual process in your stomach.  
*The stomach muscles churn and move the food around to break it up through mechanical digestion just like your hands when they are churning and moving the food to break it up in the bag. The coke, vinegar or lemon juice added to the stomach represent the gastric juices which the stomach secretes from its walls to cause chemical digestion.*

## **Stage 4 - The small intestine**

In the small intestine, the digestion of proteins, carbohydrates and fats is completed and the end-products of these digestion processes are absorbed. The small intestine is specifically adapted for its function as follows:

- Since most of the digestion and absorption process takes place in the small intestines, it is especially long and folded to create an even bigger absorption area.
- The inner layer of the small intestine is lined with small finger like structures called villi which aid absorption and increases the area for absorption.
- The small intestine has a large network of capillaries surrounding it to transport the absorbed food away.
- The muscles of the small intestine control the direction in which the food flows through peristalsis.

### **TEACHER'S NOTE**

Learners need to let the food mixed with the digestive juices, run from the Ziplock into the stocking. It shouldn't be excessively runny but make sure they are working over a large dish to catch the excess liquid. They should be squirting small amounts of bicarbonate dissolved in water into the syringe to simulate the digestive enzymes being added to the small intestine.

You may want to explain how peristalsis works by showing how the muscles around the small intestine squeeze rhythmically to push the food from the stomach through the entire intestine. Let learners use their hands to simulate peristalsis - if one hand is squeezing tightly around the small intestine the other releases and relaxes around the small intestine.

1. The stocking that you have been provided with represents the small intestine. Cut a small corner off the bottom of the Ziplock bag and insert this end into the stocking.
2. Work over a large dish or black plastic bags for this part. While one learner is holding the stocking, the other learner should squeeze the food mixture into the stocking.
3. Use the syringes with the dissolved bicarbonate of soda and squirt the bicarbonate of soda into the food as it enters the stocking.
4. Simulate the action that takes place in the small intestine to move the food mixture through.
5. Describe what is happening to the food at this point.

*The food is mixing with the bicarbonate of soda dissolved in water and moving through the small intestine. The food takes a very long time to move through the small intestine and the liquid is running through the stockings and into the large dish or onto the table.*

6. Compare the model to the actual process in your small intestine.  
*When food arrives in the small intestine digestive enzymes are secreted from the pancreas and bile from the gallbladder. This is represented by the bicarbonate of soda mixture which is squirted into the stocking. These enzymes digest the food particles that are then able to be absorbed by the cells in the walls of the small intestine. The molecules move into the capillaries and blood stream that surrounds the small intestine. As learners squeeze the food along, some of the liquid runs out of the stocking and this represents the molecules being absorbed into the bloodstream. Learners could also compare the length of the small intestine to the long stocking being used. At the end of the process the food that is left is dryer and can move out of the small intestine as undigested waste that gets egested. In the same way the food that is left in the stocking is moved to the open end of the stocking and released.*

### Stage 5 - The large intestine

The large intestine absorbs water and mineral salts, to make some vitamins, and to decay the undigested food materials to form faeces. The large intestine is specifically adapted for its function as follows:

- Undigested waste remains in the large intestine for up to 24 hours in order to maximise the absorption of water from this region.
- The muscles in the large intestine are able to turn the waste material into faeces preparing it for egestion.
- When it is time to egest waste, the muscles in the large intestine create strong peristaltic movements to force the faeces out of the body via the rectum and anus.
- Circular muscles in the anus control the emptying of the waste materials.

#### **VISIT**

Watch a video with some fascinating facts about the digestive system  
[bit.ly/1cWbA5D](http://bit.ly/1cWbA5D)

1. Was this a worthwhile activity for you? Explain what you learnt from this activity and whether you think it was a worthwhile activity or not, giving reasons for your opinion.

*Learner generated answer.*

In exams and tests you will be asked how a specific structure is adapted to its function. Remember when you see such a question to break it down into four separate steps:

1. **Outline:** Give a brief explanation of the the main point you will discuss, i.e. structure, function and specific adaption(s).
2. **Structure:** Here you need to specify what the structure looks like.
3. **Function:** What does it need to do? What role does it play or purpose does it fulfil?
4. **Adaptation:** This is where you put together structure and function - it has X, so it can do Y. For example, it is thin, so gases diffuse through it quickly.

## SUMMARY:

### Key Concepts

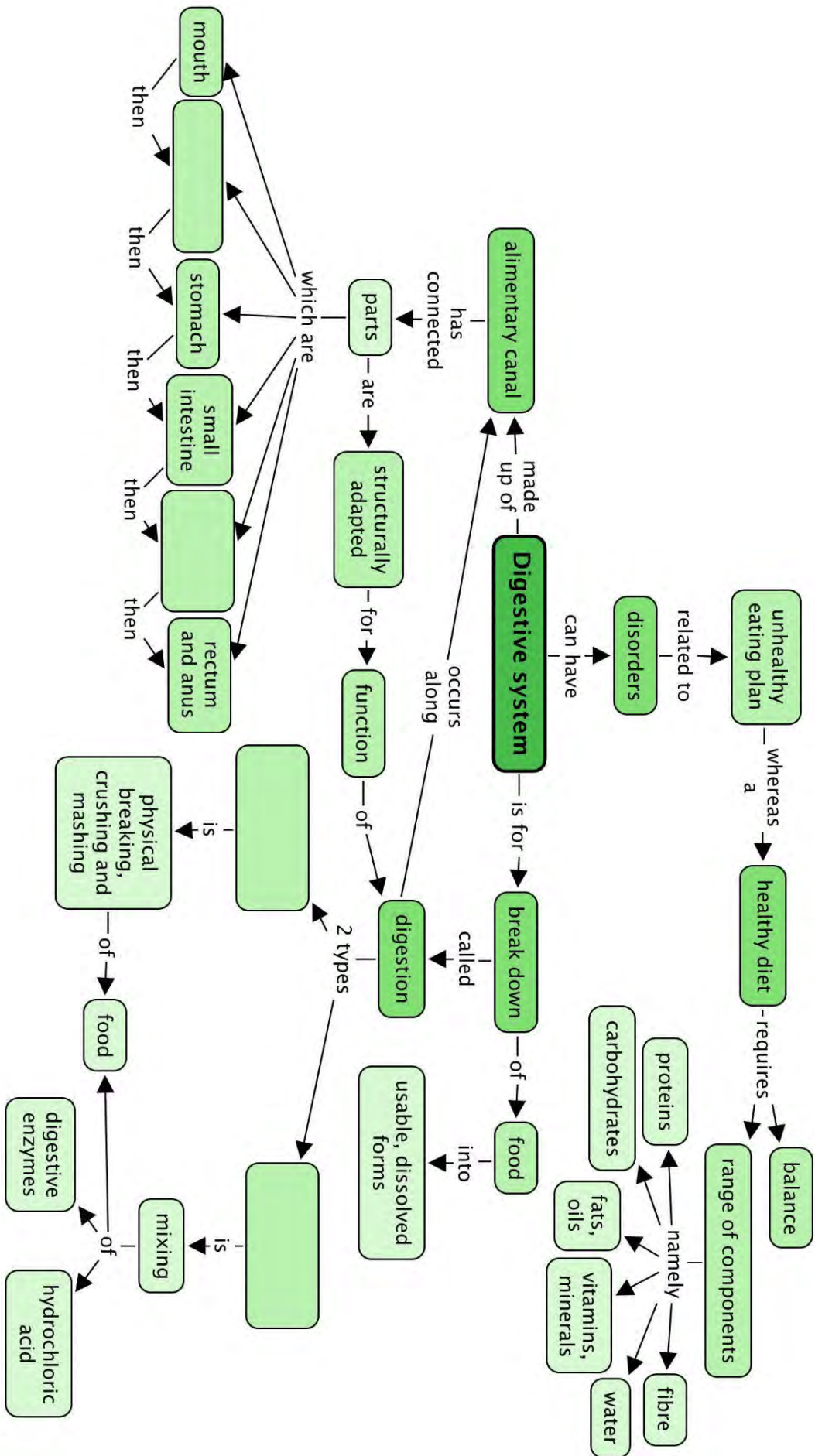
- There are seven building blocks in a healthy diet: proteins, carbohydrates, fats and oils, vitamins, minerals, fibre and water.
- A healthy diet includes the correct proportions of the seven building blocks.
- Problems in our digestive system can be related to an inappropriate diet that does not give our bodies the correct nutrients.
- Our alimentary canal is composed of the mouth, oesophagus, stomach, small intestine, large intestine, rectum and anus.
- Digestion is the breaking down of food into usable, dissolvable forms that can be absorbed.
- There are two types of digestion: mechanical (or physical) and chemical digestion.
- Each structure in the alimentary canal is specifically adapted to suit its purpose.

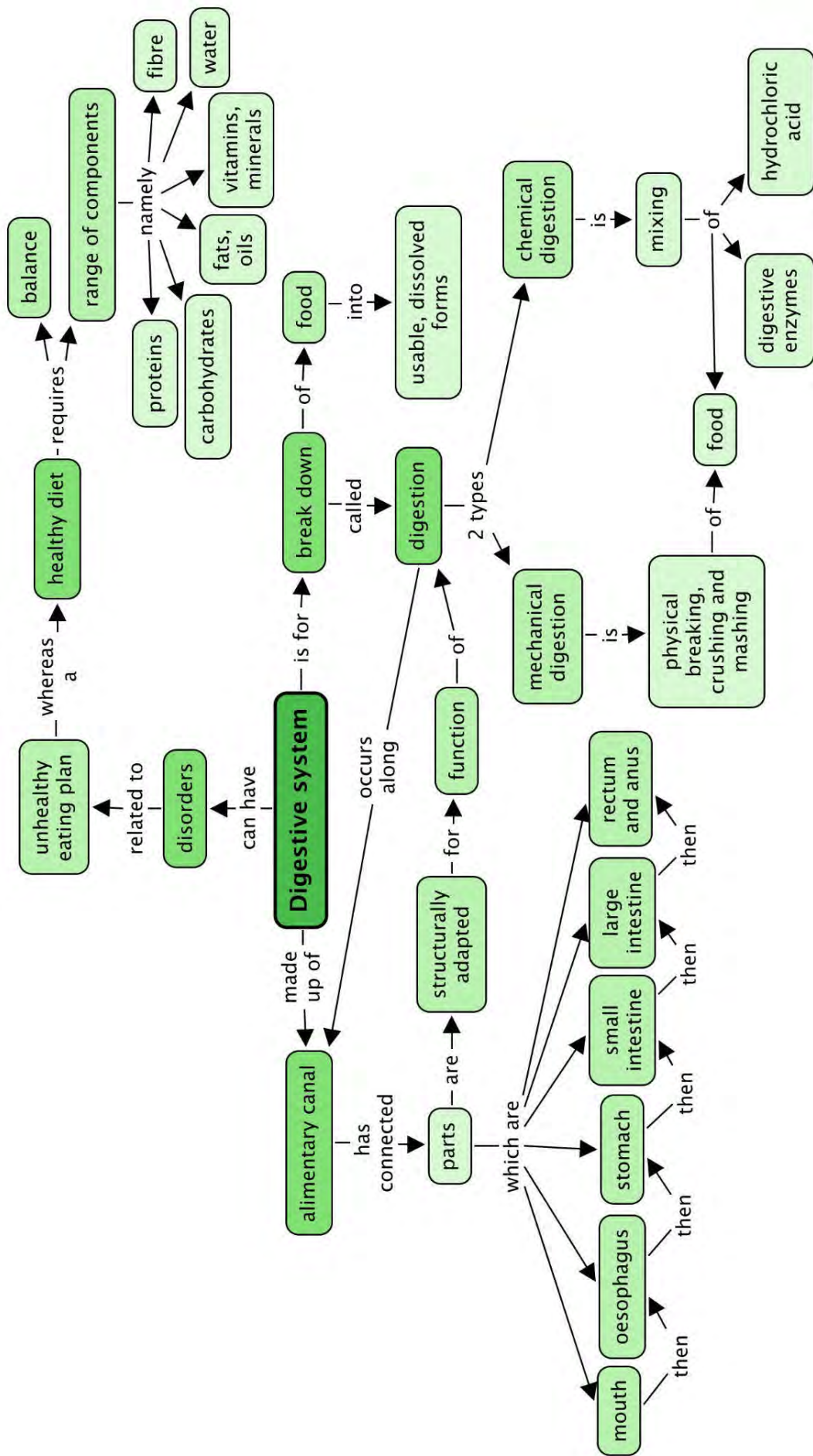
### Concept Map

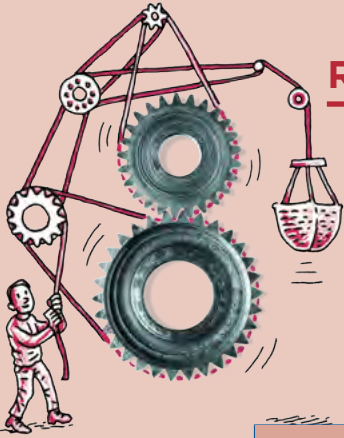
The alimentary canal is made of several parts linked together - two of these parts are missing in the concept map. We also looked at two types of digestion in this chapter. What are these? When filling them in on the concept map, you need to decide which space to put them in by looking at the concepts which come after to describe each type.











**REVISION:**

1. Describe what you understand the term 'healthy diet' means. [2 marks]  
*A healthy diet provides all the nutrients, such as carbohydrates, proteins, fats, vitamins, minerals and fibre that are needed for well-being, and contains them in correct amounts/ proportions.*
2. For each of the following food items, classify what nutrients you can get from them (i.e. protein, carbohydrates, vitamins, etc). Some food items provide more than one class of nutrient. [10 marks]

<i>Food item</i>	<i>Nutrients</i>	<i>Food item</i>	<i>Nutrients</i>
 <i>Fried chips.</i>	<i>Carbohydrates (starch), oil from frying.</i>	 <i>Strawberries.</i>	<i>Vitamins (especially vitamin C) and minerals, carbohydrates (sugar), water.</i>
 <i>Chicken pieces.</i>	<i>Protein and fats.</i>	 <i>Digestive biscuits.</i>	<i>Carbohydrates, fibre.</i>
 <i>Butternut.</i>	<i>Vitamins and minerals, starch.</i>	 <i>Yoghurt.</i>	<i>Minerals (calcium), protein, fats, water.</i>
 <i>Assorted nuts.</i>	<i>Fats and oils, protein, vitamins and minerals.</i>	 <i>Split peas and lentils.</i>	<i>Protein, fibre, starch, vitamins and minerals.</i>
 <i>Green beans.</i>	<i>Vitamins and minerals, protein, carbohydrates, fibre</i>	 <i>Margarine.</i>	<i>Fats and oils.</i>

3. Which of the foods in Question 2 contain starch? How can you test if they contain starch? [9 marks]

*The starch test will indicate whether a food contains starch - if you drop iodine solution on the food and the iodine turns from brownish-orange to blue-black then the food contains starch. Food that will possibly test positive for starch in the above examples are: green beans, split peas and lentils, butternut, digestive biscuits, fried chips.*

4. Why is it important to limit your intake of take-aways? [3 marks]

*Take-away food is usually cooked in large quantities of oil and contain many additives and fats to make it last longer and taste stronger which might not be good for the body.*

5. Give at least 2 reasons why we should eat raw fruit and vegetables. [2 marks]

*Heat can break down some vitamins and boiling dissolves them and minerals out of the food, so it's better to eat them raw.*

6. Some food may take up to 24 to 36 hours to digest and be fully absorbed. Why do you think this process takes so long and why is this a good thing? [2 marks]

*Food that is digested over a long period of time has all the beneficial nutrients removed from it rather than travelling through the digestive system really fast and having only a part of the nutritional value of the food absorbed from it.*

Total [28 marks]





## GLOSSARY

<b>absorption:</b>	food molecules pass into the bloodstream
<b>alimentary canal:</b>	the tube that runs from your mouth to your anus where food is digested, nutrients are absorbed and solid waste is egested
<b>alveoli:</b>	clusters of tiny air sacs in the lung that together provide a very large surface area
<b>antibiotic:</b>	a medicine that kills bacteria
<b>anus:</b>	the opening at the lower alimentary canal through which waste is eliminated from the body
<b>arteries:</b>	blood vessels that carry blood away from the heart
<b>atrium:</b>	the upper left and right chambers of the heart
<b>auditory:</b>	of or relating to the sense of hearing
<b>balanced diet:</b>	a way of eating that includes adequate amounts of the necessary nutrients required for healthy growth and activity in their correct proportions
<b>birth control:</b>	the limitation or control of the number of children that a couple or a woman want to conceive by the planned use of contraceptive techniques
<b>bladder:</b>	the membranous, balloon-like sac in our bodies in which urine is collected for excretion
<b>blood pressure:</b>	the pressure of the blood in the circulatory system against the walls of the blood vessels
<b>blood:</b>	the red liquid in the blood vessels of the body that transports nutrients and oxygen to cells and removes waste and carbon dioxide from the cells
<b>blood vessels:</b>	tube-like structures that carry blood to and from tissues and organs
<b>bowing:</b>	bending
<b>brain:</b>	the organ in the skull made of soft nervous tissue that coordinates activities, senses and intelligence
<b>breathing:</b>	taking air into the body through the mouth, trachea, bronchi and lungs and releasing carbon dioxide-rich air from the lungs, trachea and mouth
<b>brittle:</b>	hard but easily broken or shattered
<b>bronchioles:</b>	smaller, branched air passages in the lungs
<b>bronchi:</b>	the two large air tubes going into each lung from the trachea
<b>capillary:</b>	the smallest branching blood vessels that form a network between cells and join arteries to veins; diffusion between blood and cells occurs here
<b>carbohydrates:</b>	nutrients from plants, such as sugar and starch, that serve as a major source of energy in animals' diets
<b>carbon dioxide:</b>	a colourless, odourless gas that is released from the chemical breakdown of food during cellular respiration



<b>cartilage:</b>	firm, whitish, flexible connective tissue found in joints, outer ear, larynx, nose and in rings around the trachea
<b>cell membrane:</b>	the selectively permeable membrane that surrounds the cytoplasm of a cell
<b>cell:</b>	the structural and functional unit of all living organisms; the smallest living part of plants and animals
<b>cellular respiration:</b>	process whereby organic substances (from food) combine with oxygen in order to release energy; carbon dioxide and water are by-products
<b>cellulose:</b>	a special type of carbohydrate made up of many glucose molecules that that are packed very tightly together, so it doesn't dissolve in water; provides support in plants
<b>cell wall:</b>	tough, usually flexible layer that surrounds a plant's cell membrane; supports and protects the plant cell
<b>cervix:</b>	the neck of the uterus
<b>chemical digestion:</b>	breaking food into molecules that can dissolve in the blood and be transported to the cells using chemical agents (enzymes)
<b>chloroplast:</b>	a cell organelle found in plants that contains chlorophyll and can therefore photosynthesise
<b>cilia:</b>	small hair-like extensions in specialised cells in the lining of the nose and all breathing tubes that trap and remove dust and germs from the body
<b>closed blood system:</b>	blood never leaves blood vessels
<b>collagen:</b>	a strong, flexible protein in connective tissue that cannot stretch
<b>conception:</b>	moment of fertilization when the male sperm and the female ovum fuse together and a new individual is formed
<b>conduct:</b>	to carry impulses from one neuron the next
<b>contraception:</b>	any method that prevents pregnancy
<b>contraction:</b>	the shortening (tensing) of a muscle; term used to refer to the forceful tensing of the uterus muscles during childbirth
<b>contract:</b>	to get smaller or shorter
<b>cover slip:</b>	a small glass square which is placed over the specimen on a slide to view under a microscope
<b>cytoplasm:</b>	the gel-like material found within a plant or animal cell that is enclosed by the cell membrane but excluding the cell nucleus
<b>degenerative:</b>	a worsening in function over time
<b>dehydration:</b>	when the body loses too much water
<b>deoxygenate:</b>	to remove oxygen
<b>deprived:</b>	not given enough of something
<b>diaphragm:</b>	the dome-shaped muscle that separates the thorax from the abdomen; it plays a major role in breathing

<b>diet:</b>	what a person (or an animal) regularly eats or drinks
<b>differentiation:</b>	process by which a less specialised cell type becomes more structurally specialised to perform certain functions
<b>diffuse:</b>	move from an area of high concentration to an area of low concentration through a permeable membrane
<b>diffusion:</b>	the movement of a substance from an area of high concentration to a region of low concentration
<b>digest:</b>	break into pieces that are small enough to dissolve in the bloodstream and be absorbed into the cytoplasm
<b>digestion:</b>	breaking up food into small soluble parts that can be absorbed
<b>dissolve:</b>	when a solid breaks down into smaller and smaller particles until it mixes completely with a liquid (goes into solution)
<b>DNA:</b>	DeoxyriboNucleic Acid; molecule that stores information on how to make proteins and what characteristics the organism inherited from its parents
<b>egestion:</b>	passing out solid, undigested waste
<b>ejaculation/ ejaculate:</b>	the release of sperm from the penis
<b>embryo:</b>	a very young, developing baby
<b>emulsion:</b>	a mixture of two liquids that normally do not mix together, such as oil and water
<b>enzymes:</b>	special proteins that help reactions to take place in the body of the organism
<b>erection:</b>	the enlarged state or condition of tissues around the penis
<b>eukaryote:</b>	an organism that has genetic material inside a nucleus
<b>excrete:</b>	to remove metabolic waste products and carbon dioxide from the body
<b>excretion:</b>	removing harmful wastes that were made in the body and need to be removed from the body
<b>exhale:</b>	letting air rich in carbon dioxide out of the body through the mouth or nose, breathing out
<b>faeces:</b>	the waste from your body formed from undigested food in the intestines and passed out through the anus
<b>Fallopian tube (oviduct):</b>	a tube extending from the ovary to the uterus to transport a mature ovum
<b>fats:</b>	a nutrient that is very high in energy and doesn't mix with water and is found in oils and greasy foods
<b>fertilization:</b>	when a sperm fuses with an egg
<b>fibre:</b>	the cell walls of plant material that we eat that cannot be digested by humans
<b>flaccid:</b>	soft and hanging loosely

<b>foreskin:</b>	a layer of skin that covers and protects the head of the penis
<b>fracture:</b>	crack or break
<b>frame structure:</b>	a structure made by connecting beams and columns
<b>gamete cells:</b>	another name for 'sex cells' that fuse during fertilization
<b>gaseous exchange:</b>	the process in the lungs when oxygen enters the bloodstream and carbon dioxide is removed; at cellular level when oxygen is removed from the bloodstream and enters the cells and carbon dioxide is removed from cells and enters the bloodstream
<b>gastric:</b>	of or relating to the stomach
<b>gestation (pregnancy):</b>	the period (9 months) of development in the uterus from conception to birth
<b>glucose:</b>	a simple sugar molecule that is produced during photosynthesis and is the main source of energy for living organisms
<b>haemoglobin:</b>	a red iron-rich protein responsible for transporting oxygen in the blood
<b>heart chamber:</b>	any of the four spaces of the mammalian heart
<b>heart:</b>	the organ responsible for pumping blood throughout the body
<b>hereditary:</b>	characteristics that are transmitted from the parent to the offspring
<b>hormone:</b>	the body's chemical messengers that travel in the bloodstream to tissues and organs to affect many different reactions in the body
<b>implantation:</b>	the attachment of the fertilized egg into the wall of the uterus of the mother
<b>impulse:</b>	an electrical signal travelling along a nerve cell
<b>infection:</b>	when bacteria or viruses invade and multiply in the body's tissues and cells causing disease and illness
<b>ingestion:</b>	taking food into the mouth and body
<b>inhale:</b>	taking air rich in oxygen into the body through the mouth or nose, breathing in
<b>inherited:</b>	genetic characteristics received from the parent
<b>integrate:</b>	to make into a whole by bringing all the parts together; unify
<b>iodine solution:</b>	a brownish-orangy liquid that is used as an antiseptic and dye; it changes colour in the presence of starch
<b>jaundice:</b>	yellowing of the eyes and skins common in liver conditions
<b>joint:</b>	the place where two or more bones meet
<b>kidney:</b>	organ in the abdomen that filters the blood and produces urine
<b>labour:</b>	the process or effort of childbirth; the time during which this takes place

<b>ligament:</b>	a short band of tough, flexible, fibrous connective tissue that connects two bones or cartilage, or holds together a joint
<b>locomotion:</b>	movement or the ability to move from one place to another
<b>lungs:</b>	the organs used for breathing and gaseous exchange
<b>medium:</b>	a solution in which cells or organelles are suspended and in which reactions take place
<b>membrane:</b>	a thin flexible sheet or skin that acts as a boundary around a cell or cell organelle
<b>menopause:</b>	the changes that occur in an older female (around age 50) body when she is no longer able to reproduce
<b>menstrual cycle:</b>	a recurring series of bodily changes in women that occurs roughly every 28 days in which the lining of the uterus thickens in preparation for the possible implantation of a fertilized egg; when that doesn't happen the lining of the uterus breaks down and is discharged as menstrual blood
<b>metabolic:</b>	relating to the chemical processes and changes that happen within the cells of plants and animals
<b>metabolic waste products:</b>	any unwanted substance produced by the various body processes
<b>metabolize:</b>	any build-up or break-down process in the body
<b>microscope:</b>	an optical instrument used for viewing very small objects not often visible to the naked eye
<b>microscopic:</b>	so small that it can only be seen under a microscope
<b>mineral salts:</b>	chemical elements in food needed for growth and development, like, sodium, potassium, calcium, iron, phosphorous etc.
<b>minerals:</b>	the elements (like iron, sulfur and calcium) that are essential to animals and plants
<b>mitochondria:</b>	a cell organelle that uses oxygen and food molecules to release energy for the cell
<b>mucus:</b>	a slimy substance secreted by the mucous membranes and glands (in the nose for instance) for lubrication and protection
<b>multicellular organisms:</b>	organisms that have many cells
<b>muscle:</b>	a type of tissue in the body that can contract to produce movement
<b>nerve:</b>	a whitish bundle of neuron fibres that transmits impulses between the nerve centres in the brain and spinal cord and various parts of the body
<b>network:</b>	a structure that interconnects many different parts
<b>neuron:</b>	a specialized nerve cell that transmits nerve impulses
<b>nuclear membrane:</b>	a double-layered membrane that separates the content of the nucleus from the cytoplasm

<b>nucleolus:</b>	small dense round structure in the nucleus of a cell
<b>nucleus:</b>	structure with a membrane around it that contains the cell's hereditary information and controls the cell's growth and reproduction
<b>nutrients:</b>	components of food that provide the body with energy or supply the building blocks for growth and repair
<b>oestrogen:</b>	the female sex hormone that causes the development of many of the female secondary sex characteristics
<b>optic:</b>	of or relating to the eye or vision
<b>organelle(s):</b>	specialised structures inside the cytoplasm of the cell that perform functions for the cell
<b>organism:</b>	an individual animal, plant or single-celled life form
<b>ovary:</b>	the organ that produces the female ova (egg cells), as well as the female hormones oestrogen and progesterone
<b>ovulation:</b>	the process whereby a mature ovum or egg cell gets released from the ovaries
<b>ovum:</b>	the female egg cell produced in the ovaries of a woman
<b>oxygen:</b>	a colourless, odourless reactive gas is used in cell respiration of all organisms
<b>oxygenate:</b>	to supply with oxygen
<b>penis:</b>	one of the male sex organs
<b>peristalsis:</b>	the wave-like contraction and relaxation of the walls of the alimentary canal that helps move food forward
<b>pharynx:</b>	throat
<b>population growth rate:</b>	growth of a population over time seen as the change in the number of individuals (of any species) in a population per unit of time
<b>prokaryote:</b>	a type of organism that does not have a separate nucleus but has its hereditary material in the cytoplasm
<b>protein:</b>	group of biological molecules that provide structure and enable chemical reactions
<b>puberty:</b>	the time between childhood and adulthood when the sex organs mature with accompanying changes in the body that prepare the person's body for reproduction
<b>pulse:</b>	the rhythmical throbbing of the arteries as blood is pumped through them by the heart
<b>red blood cells:</b>	specialised cells in the bloodstream that contain haemoglobin and therefore can carry oxygen
<b>reproduction:</b>	any process by which organisms produce offspring
<b>respiration:</b>	the chemical process in cells that releases energy from food molecules by using oxygen and forming carbon dioxide as a waste product
<b>rupture:</b>	break or burst open

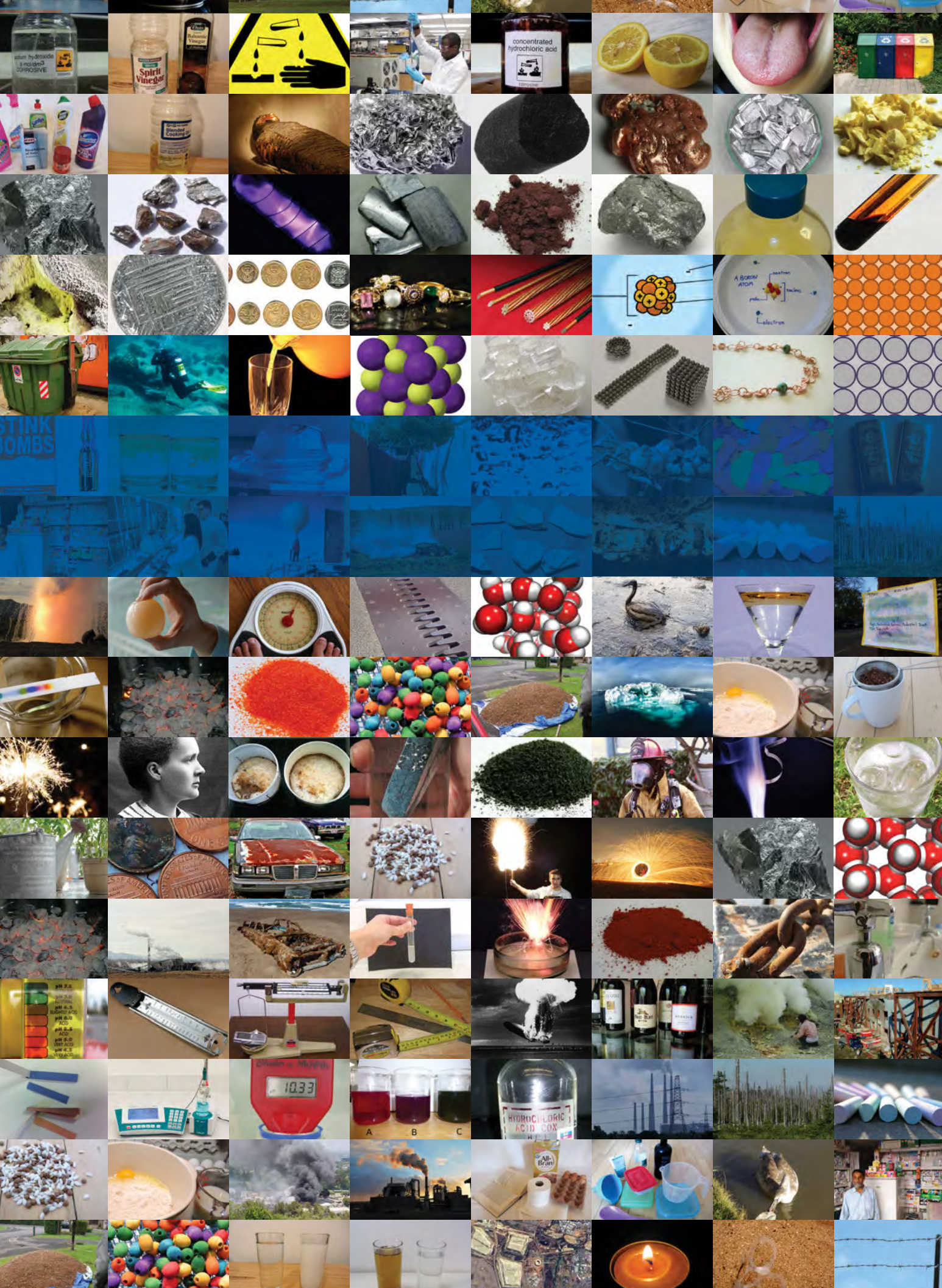


<b>saliva:</b>	the watery substance in the mouth that covers chewed food, moistens the mouth
<b>scrotum:</b>	the external sac of skin that encloses the testes in males
<b>selectively permeable:</b>	a feature and a function of the cell membrane that allows it to regulate the substances that enter and leave the cell
<b>self-propulsion:</b>	having the ability to move itself
<b>semen:</b>	the fluid that is produced in the male reproductive organs, containing sperm and other chemicals suspended in a liquid medium
<b>sexual intercourse:</b>	how the male sperm is introduced into a woman's body when the penis is placed inside the vagina
<b>slide:</b>	a small glass plate on which we mount specimens to examine under a microscope
<b>small intestine:</b>	the part of the alimentary canal between the stomach and large intestine where most of the digestion and absorption of nutrients takes place
<b>specialised:</b>	able to perform a particular function
<b>species:</b>	the most basic biological classification of organisms; organisms that are capable of mating with one another to produce FERTILE offspring
<b>specimen:</b>	a sample or small part of a larger organism that we want to examine or analyse; it can also mean an object or organism that was selected and presented as part of a collection or series
<b>sperm duct (vas deferens):</b>	the tube that connects the testes to the ejaculation duct
<b>sperm:</b>	the male sex cell produced by the testes
<b>starch:</b>	a large storage molecule in plants that is made from many glucose molecules joined together
<b>stem cell:</b>	a special undifferentiated cell that can become any of the other cell types
<b>stimulus:</b>	any change that is detected inside or outside the body, to which we need to react
<b>stomach:</b>	the wider part after the oesophagus where food is stored for a short while; proteins are digested here
<b>sugars:</b>	group of sweet-tasting simple carbohydrates that are made by plants during photosynthesis
<b>surrogacy:</b>	when a person or animal acts as a substitute for another third person; when a woman carries and delivers a child for another couple or person
<b>synthesis:</b>	the process by which organic molecules are made inside organisms
<b>temperature:</b>	how much heat is present in an object, substance or body; the degree of internal heat of someone's body
<b>tendons:</b>	an inelastic cord of strong fibres made of collagen tissue that attaches a muscle to a bone
<b>testes:</b>	male glands that produce sperm cells and male hormones

<b>testosterone:</b>	the male sex hormone that causes physical changes during puberty and controls the production of sperm
<b>toxic:</b>	poisonous
<b>trachea:</b>	(windpipe) the tube that carries air from the mouth and nose to the bronchial tubes in the lungs
<b>transmit:</b>	send out a message
<b>transport:</b>	move from one part of the body to another
<b>turgid:</b>	swollen or bulging outwards
<b>ulcer:</b>	an open sore in the alimentary canal
<b>umbilical cord:</b>	the cord or tube-like structure that connects the foetus at the abdomen with the placenta of the mother and transports nourishment and oxygen to the foetus and removes waste
<b>unicellular:</b>	consisting of a single cell
<b>urea:</b>	a metabolic waste product that is formed when protein is broken down in the liver
<b>ureter:</b>	the duct (tube) that joins the kidney and bladder and allows urine to pass from the kidney to the bladder
<b>urethra:</b>	the thin tube that allows urine to flow from the bladder to the outside
<b>urinate:</b>	to excrete or pass urine out of the body
<b>uterus:</b>	the hollow muscular organ in the pelvic area of female mammals in which the fertilized egg implants and develops (also known as the <i>womb</i> )
<b>vacuoles:</b>	a fluid-filled bag in the cytoplasm of most plant cells
<b>vagina:</b>	an elastic muscular tube or canal that connects the neck of the uterus (cervix) with the external opening
<b>variation:</b>	a change or slight difference
<b>veins:</b>	blood vessels that carry blood back to the heart
<b>ventricles:</b>	the lower left and right chambers of the heart
<b>vision:</b>	the ability to see
<b>vitamins:</b>	organic substances essential to normal growth and development in the body and found naturally in plant and animal products
<b>wet mount:</b>	when you mount a specimen on a slide using a drop of liquid
<b>womb:</b>	another non-technical term for uterus
<b>zygote:</b>	the result of two gametes that fuse; a fertilised ovum



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# 1 Compounds

## TEACHER'S NOTE

### Chapter overview

1 week

1. This chapter starts with a review of the main concepts surrounding Compounds, covered in Gr. 8 Matter and Materials.
2. This is followed by a section on the Periodic Table, first introduced in Gr. 7 Matter and Materials.
  - a) New information includes the terms *Group* and *Period* and the observation that elements from the same group exhibit similar chemical behaviour. You could discuss the Periodic Table being a classification table of the elements; an organising framework which helps us understand their properties, and their similarities and differences. Learners will be exposed to different formats of the Periodic Table. The idea is that learners should realise that information on the table can be added or taken away, depending on the purpose for which it will be used. This does not, however, alter the positions of the elements on the table, which are fixed.
  - b) It is an expectation of CAPS that learners should know the names and formulae of the first 20 elements on the table (as well as Fe, Cu and Zn). CAPS does not require that learners memorise the atomic number of each element, which would imply that the exact position of each of the 20 elements on the table is not examinable.
  - c) An important issue to note is that, according to CAPS: "each element on the Periodic Table (in its own block) has an atomic number (smaller number), mass number (larger number), name and symbol". This statement is not entirely correct. The larger number usually indicated on the table is NOT the mass number (defined as the sum of the number of protons and the number of neutrons), but rather the average atomic mass (this number is usually rounded to the nearest whole number, or to one decimal place). To understand the subtle but significant difference between mass number and average atomic mass, we need to provide some background: At this point the learners are under the impression that all atoms of a given element are identical. This is not strictly true. All elements exist as two or more isotopes. Isotopes are variants of a particular chemical element: while all isotopes of a given element share the same number of protons and electrons, each isotope differs from the others in its number of neutrons. Hence, it would not make sense to indicate the mass number on the table, as the mass number is different for each different isotope of a chemical element. The average atomic mass is a number that takes into account the masses of all the different isotopes of a given element AND the proportion in which each is found in the natural state of that element. The reason why it is important not to conflate the two concepts, mass number and average atomic mass, is because this manifests as a misconception at the higher levels, when it becomes important for learners to know the difference between them. In the text below, we will be using the term 'atomic mass' instead of 'mass number', because it is a more correct description of the 'larger number' that usually appears on the Periodic Table.



- In the final section of the chapter we return to chemical formulae, which received perfunctory treatment in Gr. 8 Matter and Materials (*Atoms*).
- We have once again included many 'sub-microscopic' diagrams to help learners imagine the small entities dealt with in this chapter. Learners will almost certainly need help switching between the symbolic (formulae) and sub-microscopic (molecular diagrams) representations. This is a very important skill that should receive careful attention at this point, as it will improve learners' chances of mastering the complexities of the subject at the higher levels. We have once again included activities where learners have to construct molecules using plasticine or play dough, to reinforce this skill.

The Play dough recipe provided in Gr. 8 Matter and Materials, is included here for easy reference.

### Play dough recipe

#### INGREDIENTS:

- 2 cups flour
- 2 cups warm water
- 1 cup salt
- 2 tablespoons vegetable oil
- 1 tablespoon cream of tartar (optional for improved elasticity)
- food colouring in different colours

#### METHOD:

- Mix all of the ingredients together, and stir over low heat. The dough will begin to thicken until it resembles mashed potatoes.
- When the dough pulls away from the sides and clumps in the centre, remove the pan from the heat and allow the dough to cool enough to handle. Note: If the dough is still sticky, it simply needs to be cooked for longer.
- Turn the dough out onto a clean surface and knead until smooth. Divide the dough into balls for colouring.
- Make a small depression in the centre of the ball, and pour some food colouring into it. Work the colour through the dough, adding more if you want a more intense colour.

#### 1.1 Elements and compounds (0.5 hours)

Tasks	Skills	Recommendation
Activity: Writing formulae and revision	Writing symbols/formulae, interpreting diagram	Optional (Revision)

#### 1.2 The Periodic Table (1 hour)

Tasks	Skills	Recommendation
Activity: Elements on the Periodic Table	Memorising names and symbols of the first 20 elements	CAPS suggested

### 1.3 Names of compounds (1.5 hours)

Tasks	Skills	Recommendation
Activity: Naming compounds of metals and non-metals	Interpreting, writing names	CAPS suggested
Activity: Writing names from the formulae of compounds	Interpreting, naming compounds, building models, drawing	CAPS suggested
Activity: Writing formulae from the names of compounds	Interpreting, writing formulae, building models, drawing	CAPS suggested



### KEY QUESTIONS:

- What is a compound?
- How is a compound different from an element?
- How is a mixture of elements different from a compound?
- What does the position of an element on the Periodic Table tell us about its properties?
- Where do we find metals, non-metals and semi-metals on the Periodic Table?
- What are the vertical columns of the Periodic Table called?
- What are the horizontal rows of the Periodic Table called?
- What do elements belonging to the same 'group' of the Periodic Table have in common?
- What additional information about an element can we find on the Periodic Table?
- What does the formula of a compound tell us about it?



## 1.1 Elements and compounds

### TEACHER'S NOTE

This first section is a revision of what learners should have covered in previous grades. It spans several pages, but it is mostly revision and has been included as a reference for learners. You will need to decide, based on your class, about how much time you need to dedicate revising these topics, or whether you get your learners to read over the content and complete the activity at the end.

Can you remember learning about compounds in Gr. 8 Matter and Materials? We will start this chapter by summarising and revising some of the main ideas about **elements** and **compounds** from Gr. 7 and 8. This should help us to link the new ideas in this chapter to what we already know.

## The particles that make up compounds

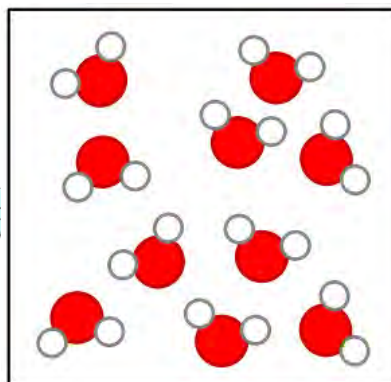
### TEACHER'S NOTE

Learners need to be made aware that compounds may occur as two types of structures, namely molecules and lattices:

1. When a compound is made up entirely of non-metals ( $\text{CO}_2$ ,  $\text{H}_2\text{O}$ , or  $\text{NH}_3$ , for example), the smallest unit of that compound will be a molecule.
2. However, when a compound is made up of a metal and a non-metal ( $\text{NaCl}$ , or  $\text{CuO}$ , for instance), the type of bonding in the compound is different. During bonding, the metal and non-metal atoms exchange electrons to form ions. Due to opposite charges attracting, these ions pack together in vast three-dimensional crystals or lattices, rather than forming simple molecules.

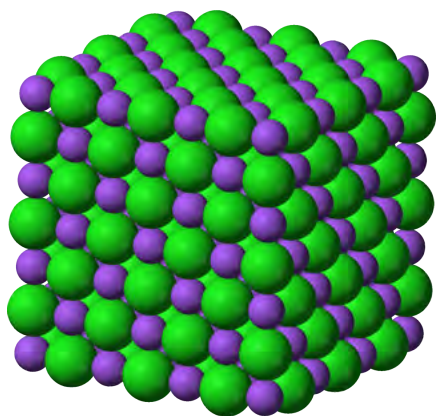
In this section we have included a brief mention of crystal lattices to avoid the misconception later that  $\text{NaCl}$  and other ionic compounds consist of molecules. Learners should know that  $\text{NaCl}$ , for instance, consists of a regular arrangement of sodium and chloride atoms combined in a 1:1 ratio, packed to form a crystal structure.

The particles of a compound always consist of two or more atoms. In Physical Sciences Gr. 10 you will learn that these atoms combine in different ways. In some cases they can form **molecules**. You may remember that 'molecule' is the word scientists use for a cluster of atoms that stick together in a specific way. Other compounds consist of atoms which are arranged in a regular pattern called a **crystal lattice**.



*Water molecules.*

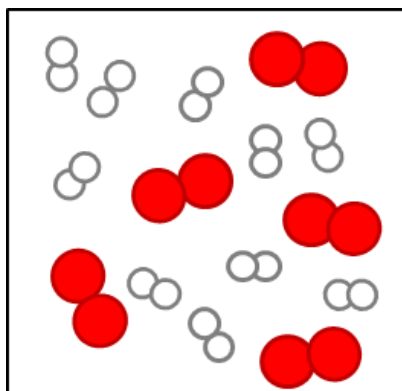
The molecules of a compound always consist of two or more different kinds of atoms, like the molecules of water in the following diagram.



*A sodium chloride crystal lattice consisting of sodium (purple) and chloride (green) atoms in a fixed ratio.*

Compounds that form crystal lattices consist of many atoms, but they always combine in a fixed ratio. For example, in sodium chloride (table salt), there is one chlorine atom for every sodium atom in the crystal. The smallest 'unit' that is repeated in the crystal consists of one Na and one Cl. The formula  $\text{NaCl}$  represents one 'formula unit' of  $\text{NaCl}$ .

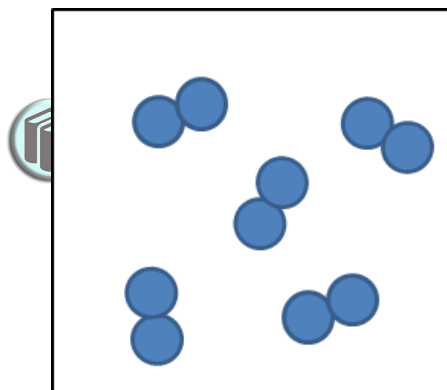
From the diagram of the water molecules and the sodium chloride lattice above, we can see that a compound is not simply a mixture of elements. A mixture of the elements hydrogen and oxygen would look like this:



*A mixture of hydrogen and oxygen molecules.*

Why are the hydrogen and oxygen atoms paired in the diagram above? Before we answer that question, here is an important reminder: Elements are made up of just one kind of atom.

Some elements exist as diatomic molecules, like the ones in the diagram on the right below and the hydrogen and oxygen molecules in the 'mixture' diagram above. The most important examples of diatomic molecules are  $H_2$ ,  $N_2$ ,  $O_2$ ,  $F_2$ ,  $Cl_2$ ,  $Br_2$ , and  $I_2$ . **Diatom** means 'consisting of *two atoms*'.

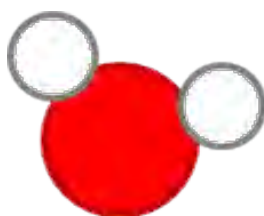


*Some elements exist as diatomic molecules.*

Can you see that the water molecules in the diagram above are all identical? That brings us to the next point about compounds.

### **The atoms in molecules and lattices are combined in a fixed ratio**

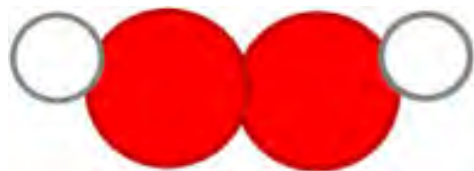
In water, for example, one oxygen atom (O) has combined with two hydrogen atoms (H). All water molecules are exactly the same in this respect.



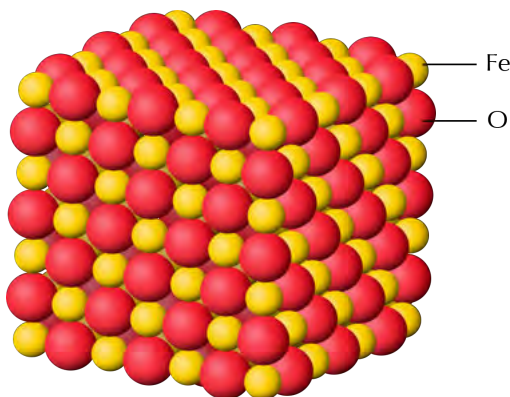
*All water molecules consist of one O atom and two H atoms and this gives water its specific properties.*

Any other combination of hydrogen and oxygen atoms would NOT be water. For example, hydrogen peroxide consists of the same elements as water

(hydrogen and oxygen) but the ratio is different: two oxygen atoms have combined with two hydrogen atoms.



*The hydrogen peroxide molecule consists of two O atoms and two H atoms. This gives hydrogen peroxide different properties to water.*



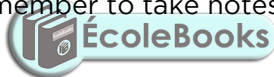
*In the crystal lattice of black iron oxide, there is one iron (Fe) atom for every oxygen (O) atom.*

The next important point about compounds is the following.

### **Each compound has a unique name and formula**

Water can be represented by the formula  $H_2O$ . The formula tells us that two hydrogen atoms (H) are combined with one oxygen atom (O) in a molecule of water.

What is the formula of hydrogen peroxide? Can you remember the name of the compound with the formula  $CO_2$ ? Remember to take notes as you discuss things in class!



#### **TEACHER'S NOTE**

The formula of hydrogen peroxide is  $H_2O_2$ . The formula  $CO_2$  is carbon dioxide.

What formula represents one 'formula unit' of the type of iron oxide in the previous diagram?

#### **TEACHER'S NOTE**

$FeO$

### **The atoms in a compound are held together by chemical bonds**

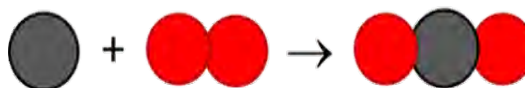
What holds the clusters of atoms that we call molecules together? When atoms combine to form molecules, they do so because they experience an attractive force between them. The forces that hold atoms together are called **chemical bonds**.

Next, we need to be reminded where compounds come from.



## Compounds form during chemical reactions

In all chemical reactions, the atoms in molecules rearrange themselves to form new molecules. This is how compounds form: the atoms in one set of compounds separate as bonds break between them, and they get rearranged into new groups as new bonds form. When this happens, we say a chemical reaction has occurred. Look at the following illustration.



In the example above, the elements to the left of the arrow are called the **reactants**. They have rearranged to form a new compound. This is called the **product** and it is shown to the right of the arrow.

Can you describe what happened to the atoms and the bonds in this reaction? Discuss which bond broke, which ones formed, and how the atoms were rearranged during the reaction.

### TEACHER'S NOTE

Discuss this with your class. Encourage them to take notes during your discussions.

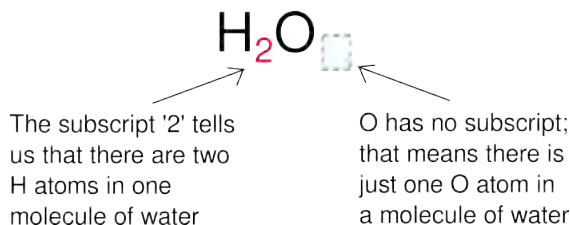
- The bond between the two red atoms broke.
- The black atom moved in between the two red atoms.
- Two new bonds formed: between the black atom and each of the two red atoms.

The final aspect of compounds that we learnt in Gr. 8 is that each compound can be represented by a unique chemical formula:

## A compound has a chemical formula

Compare the formula for water with the diagram of the water molecule you saw earlier. Can you make the connection?

The **chemical formula** of a compound is the same for all the molecules of that compound. When we read the formula, the subscripts tell us how many atoms of a particular element is in one molecule of that compound:



When we write  $\text{H}_2\text{O}$ , we actually mean  $\text{H}_2\text{O}_1$ . According to convention, we do not use 1 as subscript in formulae and so the first formula is the correct one. What it means is that there are 2 hydrogens to every 1 oxygen. This is also a ratio and can be written as 2:1. We will practise writing formulae in the next activity.

## ACTIVITY: Writing formulae and revision



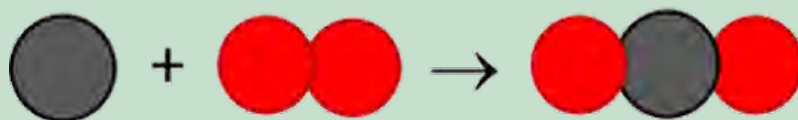
### INSTRUCTIONS:

1. In the following table, the names of some pure substances are given in the left-hand column. The middle column tells us what one molecule of each compound is made of.
2. You must use this information to write the formula of each compound in the final column, on the right.
3. The first row has been filled in for you, so that you have an example:
4. Column 1 contains the name: water
5. Column 2: one molecule of water contains two H atoms and one O atom.
6. Column 3: From the information in column two we can write the formula:  $H_2O$

Name of substance	What it is made of?	Chemical formula
water	2 H atoms and 1 O atom	$H_2O$
carbon dioxide	1 C atom and 2 O atoms	$CO_2$
ammonia	1 N atom and 3 H atoms	$NH_3$
methane	1 C atom and 4 H atoms	$CH_4$

### QUESTIONS:

1. What holds the atoms together in a compound?  
*A chemical bond holds the atoms together.*
2. The following diagram shows how carbon and oxygen react to form carbon dioxide.



What are the reactants and what is the product in this reaction? Write these names onto the diagram.

*the reactants are carbon (grey circle) and oxygen (red circles) and the product is carbon dioxide.*

3. Why is oxygen represented as two circles together?  
*The two circles each represent an oxygen atom as oxygen is a diatomic molecule meaning it exists as two oxygen atoms bonded together in diatomic molecules.*
4. Magnesium oxide has the formula  $MgO$ . what does this ratio tell us about the atoms in the compound?  
*It means that for every 1 magnesium atom, there is 1 oxygen atom joined to it in a chemical bond.*



Now that we have refreshed our memories, we are going to return to the table that scientists use to organise their knowledge about the elements. Can you remember what it is called?

## 1.2 The Periodic Table

### TEACHER'S NOTE

The first part of this section is a revision of what learners should have covered in previous grades.

We first encountered the Periodic Table in Gr. 7. Here is a summary of what we already know:

1. All the elements that are known, can be arranged on a table called the Periodic Table.
2. The discoveries of many scientists over many years contributed to the information in the Periodic Table, but the version of the table that we use today was originally proposed by Dmitri Mendeleev in the 1800s.
3. Each element has a fixed position on the Periodic Table. The elements are arranged in order of increasing atomic number, with the lightest element (hydrogen: H) in the top left hand corner.
4. An element's position on the Periodic Table tells us whether it is a metal, a non-metal or a semi-metal.
  - a) metals are found on the left hand side of the table;
  - b) non-metals are found on the far right hand side of the table; and
  - c) semi-metals are found in the region between the metals and non-metals.
5. An element can be identified in 3 different ways:
  - a) each element has a unique name;
  - b) each element has a unique chemical symbol; and
  - c) each element has a unique atomic number.
6. Metals are usually shiny, ductile, and malleable. Most are solids at room temperature and have high melting and boiling points.
7. Non-metals can be solids, liquids or gases at room temperature. They have a great variety of properties that usually depend on the state they are in.
8. The semi-metals are all solids at room temperature. They usually have a combination of metallic and non-metallic properties.

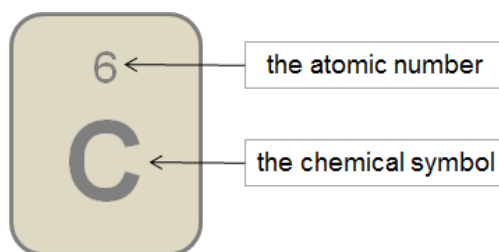
We learnt about the origins of the Periodic Table in Gr. 7. Let's also revise what we learnt then, so that we have a firm foundation for our new learning.

The Periodic Table is basically a chart that scientists use to list the known elements. The table consists of individual tiles for each of the elements. What information can we find on the Periodic Table? That is what the next section is all about.

## What information can we find on the Periodic Table?

The information that most commonly appears on each tile of the Periodic Table is the following:

- The chemical symbol; and
- The atomic number



The diagram alongside shows an example of one of the tiles on the Periodic Table. Can you identify the element it represents? How many protons does it have in its atoms?

An example of one of the tiles on the Periodic Table

### TEACHER'S NOTE

C is carbon. It has 6 protons (indicated by the atomic number).

### TEACHER'S NOTE

The atomic number ( $Z$ ) is usually written at the top of each tile for an element in the Periodic Table, and the larger atomic mass number ( $A$ ) is written at the bottom of each tile.

### TAKE NOTE

There is a large version of the Periodic Table printed on the inside cover of your workbooks for you to easily refer to.

There are different versions of the Periodic Table, which can each contain different information about the elements. Can you identify what information is provided about the elements in the following table?

### TEACHER'S NOTE

The table contains only the chemical symbol and atomic number of each element.

Periodic Table of the Elements

No. Element																																			
1	2															18																			
1	H																	2	He																
3	Li	4	Be											5	B	6	C	7	N	8	O	9	F	10	Ne										
11	Na	12	Mg											13	Al	14	Si	15	P	16	S	17	Cl	18	Ar										
19	K	20	Ca	21	Sc	22	Ti	23	V	24	Cr	25	Mn	26	Fe	27	Co	28	Ni	29	Cu	30	Zn	31	Ga	32	Ge	33	As	34	Se	35	Br	36	Kr
37	Rb	38	Sr	39	Y	40	Zr	41	Nb	42	Mo	43	Tc	44	Ru	45	Rh	46	Pd	47	Ag	48	Cd	49	In	50	Sn	51	Sb	52	Te	53	I	54	Xe
55	Cs	56	Ba	57, 71	La-Lu	72	Hf	73	Ta	74	W	75	Re	76	Os	77	Ir	78	Pt	79	Au	80	Hg	81	Tl	82	Pb	83	Bi	84	Po	85	At	86	Rn
87	Fr	88	Ra	89-103	Ac-Lr	104	Rf	105	Db	106	Sg	107	Bh	108	Hs	109	Mt	110	Ds	111	Rg	112	Cn	113	Uut	114	Uuq	115	Uup	116	Uuh	117	Uus	118	Uuo
57	La	58	Ce	59	Pr	60	Nd	61	Pm	62	Sm	63	Eu	64	Gd	65	Tb	66	Dy	67	Ho	68	Er	69	Tm	70	Yb	71	Lu						
89	Ac	90	Th	91	Pa	92	U	93	Np	94	Pu	95	Am	96	Cm	97	Bk	98	Cf	99	Es	100	Fm	101	Md	102	No	103	Lr						

Transition Metal  
 Metal  
 Nonmetal  
 Halogen  
 Noble Gas  
 Lanthanide  
 Actinide

The following Periodic Table only shows the symbols for the elements.

Other versions of the Periodic Table may contain additional information, such as:

- The element name; and/or
- The atomic mass, usually indicated at the bottom of each tile for an element.

The diagrams below show examples of how this information is sometimes presented.



**VISIT**  
An interactive site on the Periodic Table. Click on each element to view lots of interesting information about it [bit.ly/14nnga0](http://bit.ly/14nnga0)

29 ← the atomic number  
Cu ← the chemical symbol  
copper ← the element name

*This tile shows information about the element copper*

29 ← the atomic number  
Cu ← the chemical symbol  
63.5 ← the atomic mass

*This tile also shows information about the element copper. Instead of the element name, the atomic mass of copper is given.*

### How are the elements arranged on the Periodic Table?

We have learnt that the elements on the Periodic Table are arranged in a very specific way.

The elements are arranged in order of increasing atomic number. The element with the smallest atomic number is hydrogen (H: atomic number = 1) is in the top lefthand corner of the table. The elements with the largest atomic number are found at the bottom of the table.

The elements are also arranged in regions and these regions are often presented in different colours. The following Periodic Table shows us where the metals, non-metals and semi-metals can be found.



1 IA																	18 0	
1 H	2 IIA												3 B	4 C	5 N	6 O	7 F	8 He
3 Li	4 Be											13 Al	14 Si	15 P	16 S	17 Cl	18 Ar	
11 Na	12 Mg	3 IIIB	4 IVB	5 VB	6 VIB	7 VIIB	8 VII	9 VII	10 VII	11 IB	12 IIB							
19 K	20 Ca	21 Sc	22 Ti	23 V	24 Cr	25 Mn	26 Fe	27 Co	28 Ni	29 Cu	30 Zn	31 Ga	32 Ge	33 As	34 Se	35 Br	36 Kr	
37 Rb	38 Sr	39 Y	40 Zr	41 Nb	42 Mo	43 Tc	44 Ru	45 Rh	46 Pd	47 Ag	48 Cd	49 In	50 Sn	51 Sb	52 Te	53 I	54 Xe	
55 Cs	56 Ba	57-71 La-Lu	72 Hf	73 Ta	74 W	75 Re	76 Os	77 Ir	78 Pt	79 Au	80 Hg	81 Tl	82 Pb	83 Bi	84 Po	85 At	86 Rn	
87 Fr	88 Ra	89-103 Ac-Lr	104 Rf	105 Db	106 Sg	107 Bh	108 Hs	109 Mt	110 Ds	111 Rg	112 Cn	113 Uut	114 Uuq	115 Uup				

We can summarise:

- The **metals** are found on the left of the Periodic Table, reaching across almost the entire table, except the top right hand corner. In the table above, the metals are blue.
- The **non-metals** are found in a relatively small, triangular region at the top right hand side of the table. In the table above, the non-metals are red.
- A few elements that have metallic and non-metallic properties (called the **semi-metals**) separate the metals from the non-metals. They occur in a diagonal strip on the right hand side of the table. In the table above, the semi-metals are yellow.

**TAKE NOTE**

The semi-metals are also sometimes referred to as the metalloids.

Now that we have revised what we already learnt in previous grades, let's learn some new characteristics of the Periodic Table.

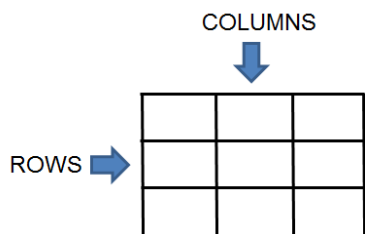
All tables have rows and columns. Can you remember the difference between vertical and horizontal? Draw short lines to show the difference between 'vertical' and 'horizontal' in the following table.

**TEACHER'S NOTE**

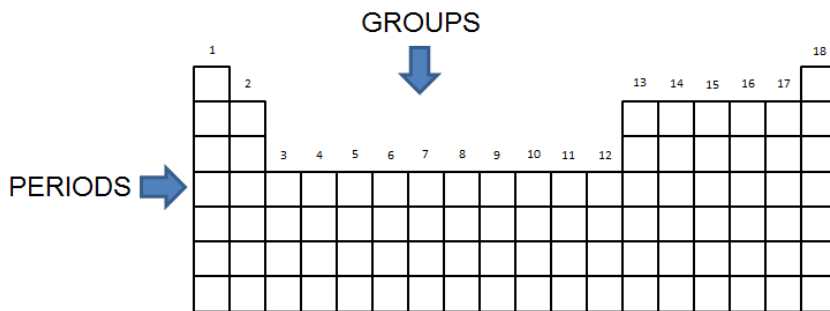
Learners should draw the following:

Vertical	Horizontal
	—

Vertical runs 'up and down', and horizontal runs 'from side to side'. In a conventional table the columns run vertically, and the rows run horizontally.



There are special words to describe the columns and rows of the Periodic Table. The following diagram shows what the column and rows are called.



**Groups:** The vertical columns of the Periodic Table are called groups. The groups on the Periodic Table are numbered in such a way that Group 1 is on the left. How many groups are there?

**TEACHER'S NOTE**

There are 18 groups.

The groups are numbered from 1 to 18. On older tables, the groups are numbered in a more complicated way. The colourful Periodic Table from Gr. 7 (shown earlier) is an example of the numbering style that you may find in older textbooks and other science resources.

**Periods:** The horizontal rows of the Periodic Table are called periods. The first period is at the top of the table. What is the first element in the third period?

**TEACHER'S NOTE**

It is sodium (Na).

Which element is in Group 14 and in the second period? Write its symbol and its name.

**TEACHER'S NOTE**

It is C, carbon.

## Names and chemical symbols

In Gr. 7 we learnt that each element has a unique name. We also learnt that each element has a unique symbol. There is a list of simple rules to remember when using chemical symbols:

1. Every element has its own, unique symbol.
2. The symbol is usually (but not always) the first one or two letters of the name of the element.
3. The first letter of the symbol is always a capital letter.
4. If the symbol has two letters, the second letter is always a small letter.
5. Some elements have symbols that come from their Latin names.

As scientists, we are expected to know the names and symbols of all the most important elements. You will not be expected to learn all of them off by heart just yet, but at the end of this chapter you must know the names and chemical symbols of the first 20 elements on the table. To make them a little easier to remember, they have been placed in a table below.

### VISIT

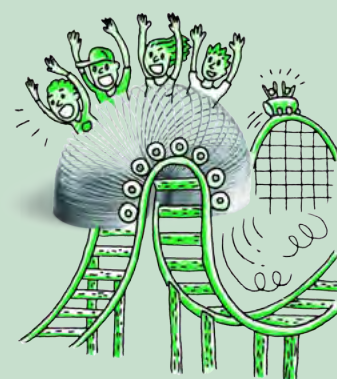
The Periodic Table song!

[bit.ly/18olBoT](http://bit.ly/18olBoT)

## ACTIVITY: Elements on the Periodic Table

### INSTRUCTIONS:

1. Use your Periodic Table to complete the following table.
2. Write the chemical symbol and element name for each of the first 20 elements, identified by their atomic numbers.



### TEACHER'S NOTE

Atomic number	Chemical symbol	Element 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	Sulfur
17	Cl	Chlorine
18	Ar	Argon
19	K	Potassium
20	Ca	Calcium

### TAKE NOTE

You need to know the names and symbols of the first 20 elements on the Periodic Table, as well as iron, copper and zinc.

3. There are three important industrial metals of which you need to know the names and formulae of. Their atomic numbers have been written in the table below. Complete the table by filling in the chemical symbols and element names.

**TEACHER'S NOTE**

Atomic number	Chemical symbol	Element name
26	Fe	Iron
29	Cu	Copper
30	Zn	Zinc

**QUESTIONS:****TEACHER'S NOTE**

This also serves as a revision of what learners covered in Gr. 8 about the atom.

1. What does the atomic number tell us about the atoms of an element?  
*It tells us how many protons are in the atoms.*
2. How many protons are there in oxygen atoms?  
*There are 8 protons (atomic number is 8).*
3. In most oxygen atoms, how many neutrons are there?  
*There are also 8 neutrons.*

**TEACHER'S NOTE**

Learners will only learn about isotopes in later grades, for now it is enough to know that the atomic mass gives an indication of the number of nucleons (protons and neutrons), so for oxygen, the atomic mass is 15.999 (rounded to the nearest integer it is 16), so the number of neutrons =  $16 - 8$ , which is 8.

4. In a neutral oxygen atom, how many electrons will there be?  
*There will be 8 electrons.*

**TEACHER'S NOTE**

At this stage, learners have not yet learned about ions, and so we only consider neutral atoms in which the number of electrons equals the number of protons.

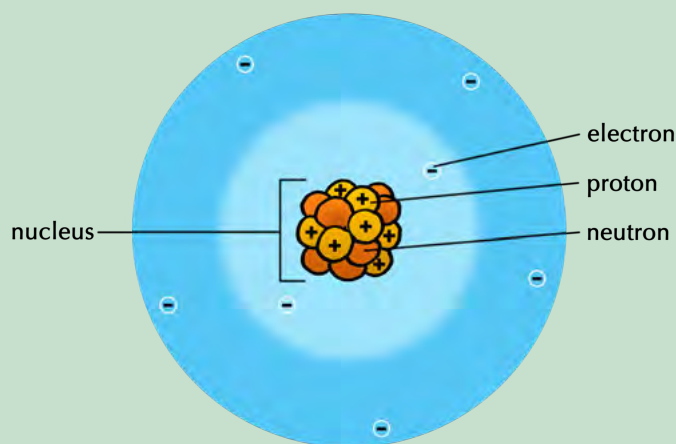
5. What is the charge on protons and electrons?  
*Electrons are negatively charged and protons are positively charged.*

6. How are the protons, neutrons and electrons (the sub-atomic particles) arranged in an atom?

*The protons and neutrons are clustered together in the centre, forming the nucleus, and the electrons occupy a much large space/cloud/area around the nucleus.*

7. Draw a model of an oxygen atom in the space provided. Label your diagram.

*Learners must draw a central nucleus with 8 protons and 8 neutrons, with 8 electrons forming a cloud around the nucleus. An example model of a nitrogen atom is given below as a reference:*



You may wonder why the Periodic Table has exactly 18 groups and not 14 or 10 or any other number. That is a very good question! The actual explanation is quite complex, and has to do with how the electrons inside the atom are distributed. You will learn about this in greater detail if you take Physical Sciences in Gr. 10.

### Properties of elements in the same group

Elements from the same group often have similar physical and chemical properties. For now, it is enough to know that the electrons in the atoms of an element determine the chemical properties of that element. And since the 'electron patterns' repeat after every 18<sup>th</sup> element, there are 18 groups. Since the elements in a group have similar 'electron patterns', they will behave similarly in chemical reactions.

The metals of Group 1 are called the **alkali metals**. Can you write the name and chemical symbol of the lightest member of the group? You can disregard hydrogen, which is really a non-metal, but is placed with the alkali metals on the Periodic Table because it has a similar electron pattern.

#### TEACHER'S NOTE

It is Lithium (Li).

#### VISIT

Watch this video of metal reacting with water!

[bit.ly/1cH6ADx](http://bit.ly/1cH6ADx)



**TEACHER'S NOTE**

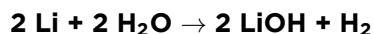
Here is a video to assist teachers in demonstrating the properties of alkali metals, including burning in air, and reaction with water. It is a long video but worth a watch. [bit.ly/11YFtOe](http://bit.ly/11YFtOe)



*Lithium metal is stored in oil and floats in the bottle. Why do you think this is?*

Lithium, and all the other alkali metals, are soft dull-grey metals. They look very similar and have similar **physical** properties. These elements all react in a very peculiar way with water.

For example, when a small piece of lithium is dropped in water, it will immediately start to react with the water. Here is the chemical equation for the reaction:

**TEACHER'S NOTE**

Ask learners firstly why they think it might be stored in oil and not water, for example. This is because it reacts very well with water and it also reacts slowly over time with oxygen in the air, so it is best to store it in oil. Next, ask learners why they think the piece of lithium metal floats in the bottle of oil. This is because lithium is the lightest metal in the universe and it is lighter and less dense than oil, so it floats. This links back to the particle model of matter and what learners covered in Gr. 8 on density of different materials.

The piece of lithium metal will dance around on the surface of the water, because the reaction produces hydrogen gas ( $\text{H}_2$ ), which causes tiny bubbles to stream from under the lithium. Heat is also given off and sometimes the hydrogen gas will start to burn on top of the water. The other product that forms is lithium hydroxide. Can you find its formula in the chemical equation above?

**TEACHER'S NOTE**

It is  $\text{LiOH}$ .

Write the word equation underneath the chemical equation above.

**TEACHER'S NOTE**

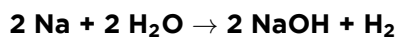
Learners should write the following word equation: lithium + water  $\rightarrow$  lithium oxide + hydrogen gas.

What are the reactants and the products in the above chemical reactions?

#### TEACHER'S NOTE

The reactants are lithium and water and the products are lithium hydroxide and hydrogen gas.

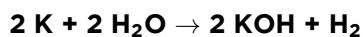
Now, the interesting thing is that all the other alkali metals behave in a similar way. Sodium is more reactive than lithium, so it not only bobs around on the surface of the water, but immediately bursts into flame. The chemical reaction is almost identical, though:



*When large amounts of sodium come into contact with water, there is an explosion, such as in this photo where water was poured on 1,5 kg of sodium.*

Can you see how similar it is to the reaction between lithium and water?

Potassium is even more reactive than sodium, so it explodes when it hits the surface of the water:



What you should notice is that these elements, all from the same group, react in the same way when they come into contact with water. That is what is meant when we say that elements from the same group have similar **chemical** properties.



*A small piece of potassium metal explodes as it reacts with water.*

### 1.3 Names of compounds

#### TEACHER'S NOTE

CAPS require that learners make models (using beads, beans, plasticine or playdough) of several elements and compounds. We have intentionally steered away from including activities in which 'molecules' of ionic compounds such as NaCl and CuO are required to be built or drawn. The reason for omissions of this

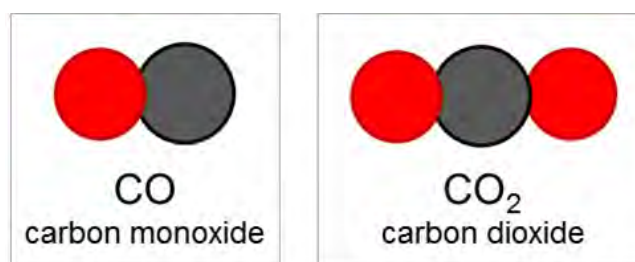
kind ties in with the earlier note in which it was explained that ionic compounds form lattices rather than molecules. Their fundamental units are not called molecules, but 'formula units'.

Perhaps there are two or more people in your class with the same name? Then you will know how confusing it can be when two people have the same name!

We have learnt that each element has a unique name. This is important, so that we do not end up confusing elements with each other.

### Each compound has a unique name

It is just as important for each compound to have a unique name. The following example will help you see why:



The two compounds CO and CO<sub>2</sub> consist of the same two elements, carbon and oxygen. If we named them both 'carbon oxide' (since they are both made of carbon and oxygen), we could easily confuse them. Under certain circumstances that could create problems, because CO is much more poisonous to humans and animals than CO<sub>2</sub>. So it is easy to see why each compound needs a unique name.

When we write the chemical formulae for compounds, they are always a combination of the symbols of the elements in the compound. For example, when we see the formula NaCl, we know that this compound consists of Na and Cl.

When we name compounds, the names of the elements in the compound are combined and sometimes changed slightly, to make a name for the compound.

When we hear the name *sodium chloride*, for instance, it is quite obvious that the compound being described must consist of *sodium* and *chlorine*. But, why is it *chloride* and not *chlorine*? Well, as you will see shortly, when we join up the names of the elements, the one that is named last is changed.

All the above may sound very complicated and for this reason a system has been developed for naming compounds. The system was developed by the **International Union of Pure and Applied Chemistry (IUPAC)**. The system is designed in such a way that the name of a compound describes the elements it contains and how they are combined.

The IUPAC system for naming compounds is very complex, but we do not need to learn all its rules. At this point we only need to learn how to name compounds consisting of two elements.

At this level we have to distinguish between two types of compounds, because the type of compound determines how it should be named.

## Type 1: Compounds that contain a metal and a non-metal

### TEACHER'S NOTE

These compounds are called ionic compounds because of the type of bonding involved. CAPS do not make a distinction between covalent and ionic compounds at this level. On the one hand this is understandable. Learners have not yet learnt about ionic and covalent bonding in compounds and would therefore not be able to understand the distinction between ionic and covalent compounds. On the other hand, without some distinction being made explicit, learners will fail to understand why MgO is named magnesium oxide when CO is named carbon monoxide, or MgCl<sub>2</sub> is called magnesium chloride, but SCl<sub>2</sub> is called sulfur dichloride. For this reason, we have decided to make a distinction between compounds that contain a metal and a non-metal (ionic compounds) and compounds that contain only non-metals (covalent compounds).

These are not the only possible combinations of elements possible - a semi-metal could combine with a non-metal, for instance in silicon dioxide (SiO<sub>2</sub>) - but the two types of compounds discussed here represent the two most common types of combinations of elements.

For compounds of this type, the rule is simple. The metal comes first and the non-metal second. The name of the non-metal changes slightly: the suffix *-ide* replaces the ending of the name.


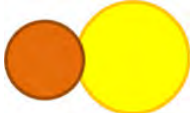


All compounds of this type form crystal lattices rather than molecules. What do we call the repeating 'units' in a crystal lattice?

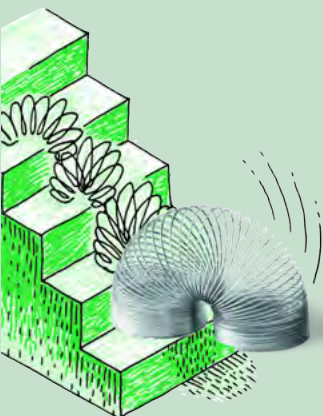
### TAKE NOTE

A 'suffix' is something placed at the **end** of a word. A 'prefix' is something placed at the **beginning** of a word.

### TEACHER'S NOTE

Formula unit

Formula	Consists of	Name	Picture of one formula unit of the compound
NaCl	Sodium and chlorine	Sodium chloride	
FeS	Iron and sulfur	Iron sulfide	
MgO	Magnesium and oxygen	Magnesium oxide	
LiF	Lithium and fluorine	Lithium fluoride	



## **ACTIVITY:** Naming compounds of metals and non-metals

### INSTRUCTIONS:

1. Refer to the Periodic Table and complete the following table.
2. You need to identify the elements which make up the compound and give the name of the compound.

<i>Formula</i>	<i>Which elements does it consist of?</i>	<i>Name</i>
$Li_2O$	2 Lithium and 1 oxygen	Lithium oxide
$KCl$	1 Potassium and 1 chlorine	Potassium chloride
$CuO$	1 Copper and 1 oxygen	Copper oxide
$NaBr$	1 Sodium and 1 bromine	Sodium bromide



### **Type 2: Compounds that contain only non-metals**

This type of compound is slightly more complicated to name. There are three rules that you have to follow. They are as follows:

#### **Rule 1:**

The name of the element further to the left on the Periodic Table comes first, followed by the name of the element further to the right on the table. The name of the second element changes slightly: the suffix *-ide* replaces the ending of the name.

For example:

- oxygen becomes *oxide*
- fluorine becomes *fluoride*
- chlorine become *chloride*
- nitrogen becomes *nitride*

#### **Rule 2:**

When two or more compounds have different numbers of the same elements (like  $CO$  and  $CO_2$  in our example above), we must add prefixes to avoid confusion.



The first four prefixes are listed in the table below:

Number of atoms	Prefix
1	mono-
2	di-
3	tri-
4	tetra-
5	penta-

#### TAKE NOTE

The prefix mono- is usually left out from the beginning of the first word of the name. For instance CO is carbon monoxide, not *monocarbon monoxide*.

Here are some examples of how this rule should be applied:

Compounds of carbon and oxygen:

- CO - carbon monoxide (notice that it is not mono-oxide, but monoxide)
- CO<sub>2</sub> - carbon dioxide

Compounds of nitrogen and oxygen:

- NO<sub>2</sub> - nitrogen dioxide
- N<sub>2</sub>O<sub>4</sub> - dinitrogen tetroxide (did you notice how tetraoxide becomes tetroxide?)

Compounds of sulfur and oxygen:

- SO<sub>2</sub> - sulfur dioxide
- SO<sub>3</sub> - sulfur trioxide



We are going to practice what we have learnt so far in the next two short activities. First, we will write names from formulae.

## ACTIVITY: Writing names from the formulae of compounds

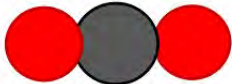
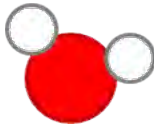
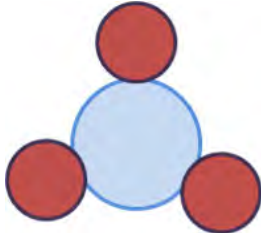
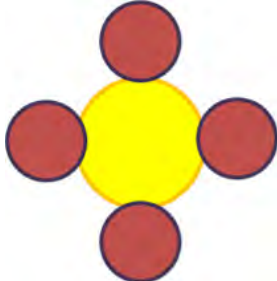
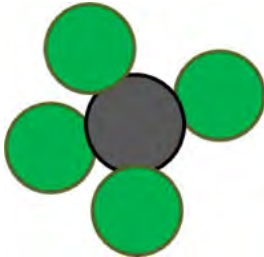
### MATERIALS:

- play dough, beans or beads

### INSTRUCTIONS:

1. How would you name the following compounds? Write the name next to each formula in the table below.
2. Build one molecule of each compound with play dough, beans or beads. If you are not sure how to arrange the atoms, here is an important tip: the atom that comes first in the name (it will usually also be the first atom in the formula) must be placed at the centre of the molecule. All the other atoms must be placed around it. They will be bonded to the atom at the centre, but not to each other.
3. Draw a picture of your molecule in the final column of the table.



<i>Formula of the compound</i>	<i>Name of the compound</i>	<i>Picture of one molecule of the compound</i>
$CO_2$	<i>carbon dioxide</i>	
$H_2O$	<i>hydrogen dioxide (water)</i>	
$PF_3$	<i>phosphorous trifluoride</i>	
$SF_4$	<i>sulfur tetrafluoride</i>	
$CCl_4$	<i>carbon tetrachloride</i>	

**TEACHER'S NOTE**

The colours of the atoms are not important, as long as atoms of the same element are the same colour. The sizes are not critical, but you may want to suggest to learners that the elements higher up on the Periodic Table will tend to be smaller than those lower down. If learners are unsure how to place the atoms, draw their attention to the tip given earlier: The atom that comes first in the name (or formula) must be placed at the centre of the molecule. All the other atoms must be bonded to the central atom.



Next, we will write formulae from the names of some compounds.

## **ACTIVITY:** Writing formulae from the names of compounds

### **MATERIALS:**

- play dough

### **INSTRUCTIONS:**

1. What formulae would you give the following compounds? Write the formula next to each name in the table below.
2. Build a model of each compound with play dough.
3. Draw a picture of one molecule of each compound in the final column of the table.



<i>Formula of the compound</i>	<i>Name of the compound</i>	<i>Picture of one molecule of the compound</i>
<i>HF</i>	<i>hydrogen fluoride</i>	
<i>H<sub>2</sub>S</i>	<i>dihydrogen sulfide</i>	
<i>SO<sub>3</sub></i>	<i>sulfur trioxide</i>	
<i>CO</i>	<i>carbon monoxide</i>	

### **VISIT**

Build some compound molecules with this simulation! [bit.ly/14CQ4PO](https://bit.ly/14CQ4PO)

**TEACHER'S NOTE**

The colours of the atoms are not important, as long as atoms of the same element are the same colour. The sizes are not critical, but you may want to suggest to learners that the elements higher up on the Periodic Table will tend to be smaller than those lower down.

There is one additional rule - an easy one to remember!

**Rule 3:**

Many compounds are not usually referred to by their systematic names. Instead, they have **common names** that are more widely known. For example, we use the name *water* for  $\text{H}_2\text{O}$ , *ammonia* for  $\text{NH}_3$ , and *methane* for  $\text{CH}_4$ .

In this chapter we reviewed all the information about compounds and about the Periodic Table, that we have learnt in previous years. We added some new information to both of these topics.

**TAKE NOTE**

Now we have learnt an important new skill, namely to write and interpret the names and formulae of compounds.

**TEACHER'S NOTE**

Here are some tips for teachers about the '*Build a molecule*' simulation. [bit.ly/17iXzKG](http://bit.ly/17iXzKG)

**SUMMARY:****Key Concepts****Elements**

- All the atoms in an element are of the same kind. This means that an element cannot be changed into other elements by any physical or chemical process.
- Elements can be built up of individual atoms, or as bonded pairs of atoms called diatomic molecules.
- When elements combine, they form compounds.

**Compounds**

- In a compound, atoms of two or more different kinds are chemically bonded in some fixed ratio.
- The atoms that make up a molecule are held together by special attractions called chemical bonds.
- Compounds can be formed and broken down in chemical reactions.
- A chemical reaction in which a compound is broken down into simpler compounds and even elements is called a decomposition reaction.
- Compounds cannot be separated by physical processes, but they can be separated into their elements (or simpler compounds) by chemical processes.



## The Periodic Table

- Each element has a fixed position on the Periodic Table. The elements are arranged in order of increasing atomic number, with the lightest element (hydrogen: H) in the top left hand corner.
- An element's position on the Periodic Table tells us whether it is a metal, a non-metal or a semi-metal.
  - metals are found on the left hand side of the table;
  - non-metals are found on the far right hand side of the table; and
  - semi-metals are found in the region between the metals and non-metals.
- An element can be identified in 3 different ways:
  - each element has a unique name;
  - each element has a unique chemical symbol; and
  - each element has a unique atomic number.
- The vertical columns of the Periodic Table are called groups. The Periodic Table has 18 groups.
- The horizontal rows of the Periodic Table are called periods. There are 7 periods.
- Elements belonging to the same 'group' of the Periodic Table exhibit the same chemical behaviour, and will often have similar properties.
- Many different versions of the Periodic Table exist. Typically, the element symbol, the atomic number and the atomic mass of each element are given on the table.

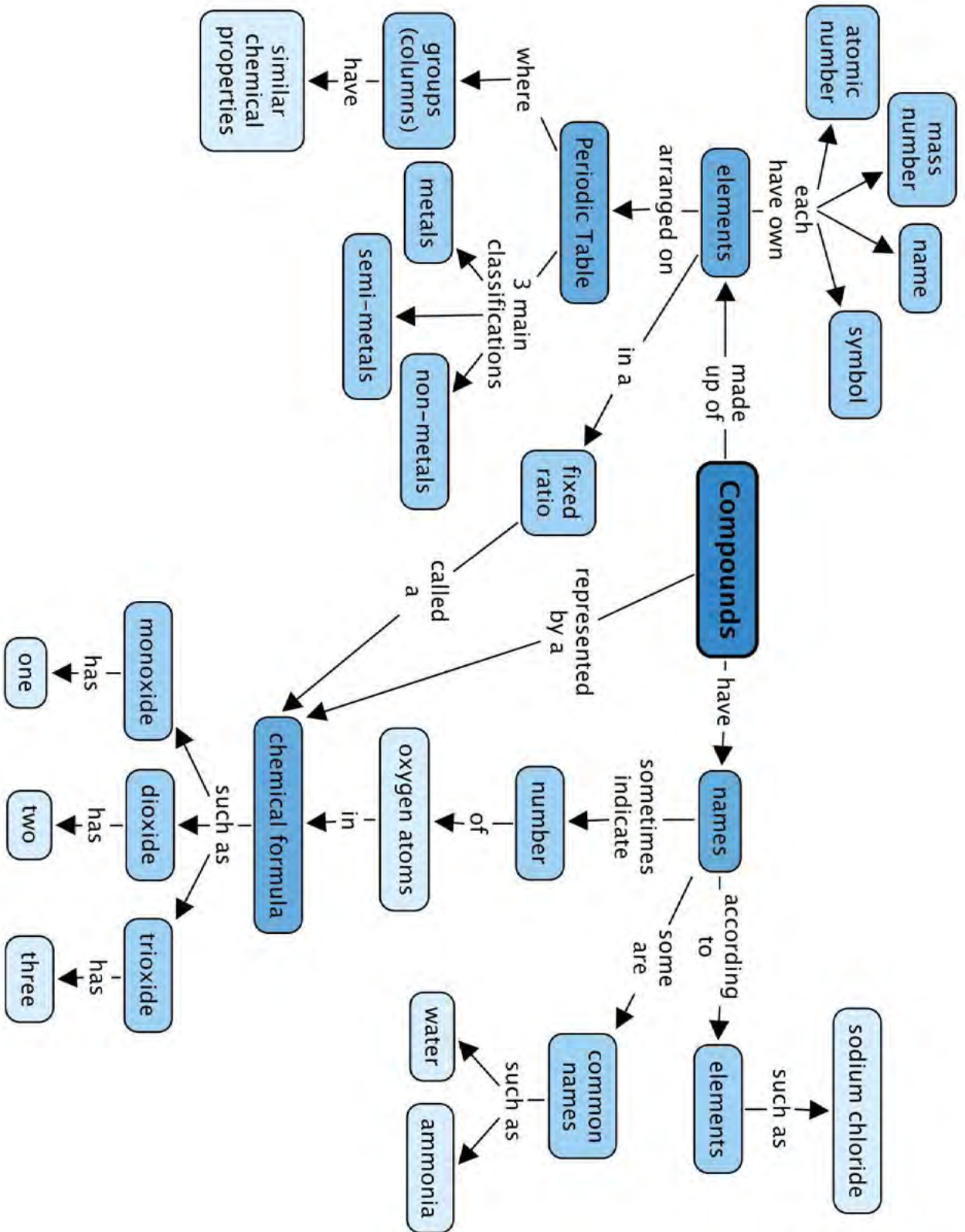
## Names and formulae

- Each compound has a unique name and formula.
- The formula of a compound tells us which elements are in the compound and how many atoms of each element have combined to form one molecule of that compound.
- There are rules for naming compounds that take into account how many atoms of each type are in one molecule of the compound.

## Concept Map

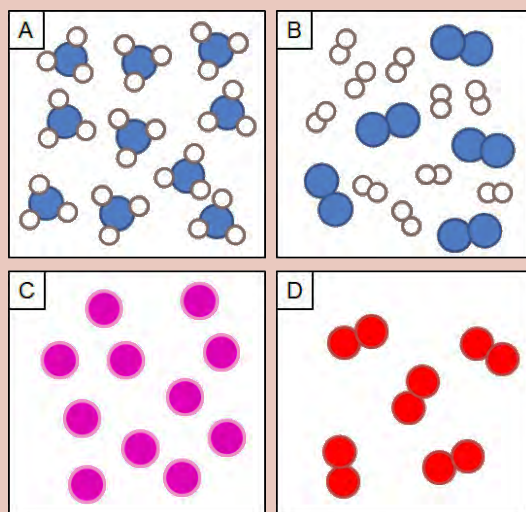
Study the concept map below summarising what we learnt in this chapter about compounds.



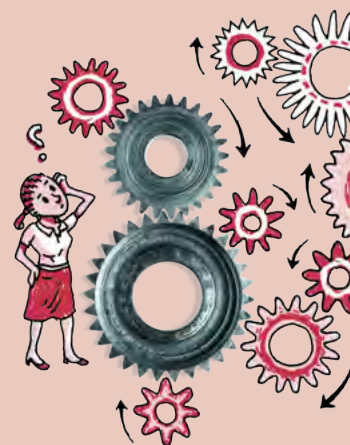





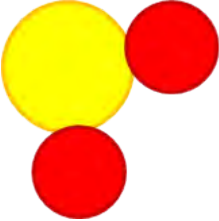
## REVISION:

1. Each of the four blocks below (labelled A to E) contain some matter. You must answer the following questions using the diagrams in the blocks. Each question may have more than one answer! [12 marks]



- Which block represents the particles of an element?  
*C and D*
  - Which block represents the particles in a compound?  
*A*
  - Which block represents the particles in a mixture?  
*B*
  - Which block represents diatomic particles?  
*B and D*
  - If the blue atoms are N and the white atoms are H, write the formula for the molecules in block A.  
*NH<sub>3</sub>*
  - If the blue atoms are N and the white atoms are H, write the formula for the molecules in block B.  
*N<sub>2</sub> and H<sub>2</sub>*
  - Which blocks contain molecules?  
*A, B and D*
  - Which block contains single atoms?  
*C*
2. How would you name the following compounds?
- Write the name next to each formula in the table below.
  - Build a model of each compound with play dough.
  - Draw a picture of one molecule of each compound in the final column of the table.
- [12 marks]

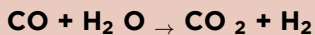


<i>Formula of the compound</i>	<i>Name of the compound</i>	<i>Picture of one molecule of the compound</i>
$NH_3$	<i>ammonia</i>	
$CO_2$	<i>carbon dioxide</i>	
$CuCl_2$	<i>copper(II) chloride</i>	
$SO_2$	<i>sulfur dioxide</i>	

3. What are the formulae of the following compounds? [4 marks]

<i>Formula of the compound</i>	<i>Name of the compound</i>
$NaCl$	<i>sodium chloride</i>
$N_2O$	<i>dinitrogen monoxide</i>
$SO_3$	<i>sulfur trioxide</i>
$CO$	<i>carbon monoxide</i>

4. Here is a balanced chemical equation. Answer the four questions below that relate to this equation: [8 marks]



- Write the formulae of the reactants of this reaction.  
*CO and H<sub>2</sub>O*
- Write the names of the reactants of this reaction.  
*carbon monoxide and water*
- Write the formulae of the products of this reaction.  
*CO<sub>2</sub> and H<sub>2</sub>*
- Write the names of the products of this reaction.  
*carbon dioxide and hydrogen*

5. The table below contains the chemical formulae of a few compounds. You have to write the number of atoms of each element(s) combined in one molecule of each compound. The first row has been filled in for you as an example. [8 marks]

<b>Chemical formula</b>	<b>What it is made of?</b>
$H_2O$	2 hydrogen atoms and 1 oxygen atom
$SF_4$	1 sulfur atom and 4 fluorine atoms
$NO_2$	1 nitrogen atom and 2 oxygen atoms
$Fe_2O_3$	2 iron atoms and 3 oxygen atoms
$Na_2O$	2 sodium atoms 1 oxygen atom

Total [44 marks]



# 2 Chemical reactions

## TEACHER'S NOTE

### Chapter overview

1 week

This chapter builds on the introduction to chemical equations given in Chapter 1 and 3 of Gr. 8 Matter and Materials.

By this stage, learners should know that atoms are rearranged during a chemical reaction. The atoms do not change; only their arrangement in relation to each other changes.

Learners were introduced to particle diagrams in Gr. 8 and this skill will be further reinforced in this chapter. We have tried to introduce learners to the idea that chemical reactions can be thought of in different ways. Ultimately, they have to be able to write chemical equations, but this is a very complex skill. By starting with word equations and progressing to submicroscopic representations (picture equations) before translating the latter to the symbolic format (chemical equations), we hope to build/scaffold the learning of chemical equations as well as develop learners' ability to imagine events on the submicroscopic scale.

#### 2.1 Thinking about chemical equations (0.5 hours)

Tasks	Skills	Recommendation
Activity: Drawing water	Drawing	Optional (Suggested)

#### 2.2 How do we represent chemical equations? (1 hour)

Tasks	Skills	Recommendation
Activity: Identifying the different types of equations	Identifying, sorting and classifying, interpreting	Optional (Suggested)

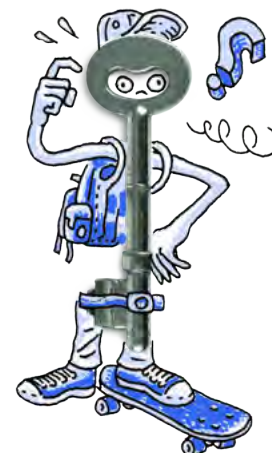


## 2.3 Balanced equations (1.5 hours)

Tasks	Skills	Recommendation
Activity: When is a reaction balanced?	Interpreting, writing formulae, balancing equations	Optional (Suggested)
Activity: Magnesium burning in oxygen	Interpreting, writing formulae, balancing equations	CAPS suggested
Activity: Iron reacts with oxygen	Interpreting, writing formulae, balancing equations, comparing	CAPS suggested
Activity: Copper reacts with oxygen	Interpreting, writing formulae, balancing equations, comparing, drawing	CAPS suggested

### KEY QUESTIONS:

- What is a chemical reaction?
- How can we represent what happens in a chemical reaction?
- What do the different symbols in a chemical reaction equation mean?
- What do the numbers in a chemical reaction mean?
- What does it mean to balance a chemical equation?
- How can we tell if a reaction is balanced?
- How do we translate between word equations, picture equations and chemical equations?



In Gr. 8 Matter and Materials we learnt about **chemical reactions** for the first time. Can you remember the main ideas about chemical reactions? Here they are again:

- During chemical reactions, materials are changed into new materials with new chemical and physical properties.
- The materials we start with are called **reactants**, and the new materials that form are called **products**.
- During a chemical reaction, atoms are rearranged. This requires that bonds are broken in the reactants and new bonds are formed in the products.

In this chapter we are going to build on these ideas. We will focus on two things:

1. how to write chemical reaction equations; and
2. how to balance chemical reaction equations.

This will prepare us for the chapters that follow this one, in which we will be looking at different types of chemical reactions.

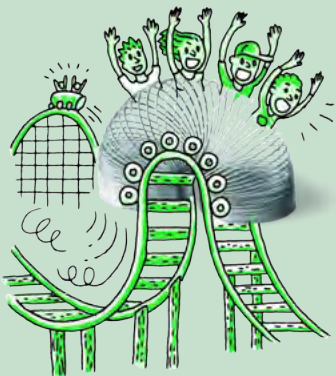
Before we get to chemical reactions, however, it is important that we remind ourselves of the different ways that we have been thinking about chemical compounds up to now. The next section will show how they all fit together.

## 2.1 Thinking about chemical reactions

Scientists learn to think about compounds on three different levels:

- macroscopic
- microscopic
- submicroscopic

As a young scientist, you have already been introduced to this kind of thinking. The three levels can also be thought of as three different ways to represent compounds. The next activity will help you understand what this means.



### ACTIVITY: Drawing water

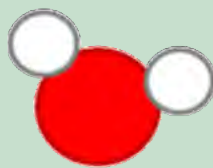
#### INSTRUCTIONS:

The instruction for this activity is really simple: Draw a picture of water. You may use the space below for your drawing.

#### TEACHER'S NOTE

Do not give any further instructions, but allow the learners to interpret the question in any way they want to. Ask the learners to show their work. Some may draw a landscape with water (a dam or river) and others may draw a glass or similar container with clear colourless liquid inside it. Perhaps one or two will draw a water molecule or the chemical formula for water. Get some of the learners to redraw their pictures on the board.

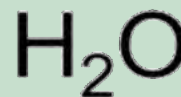
Your drawing may look like one of the diagrams below. They all represent water. But which one is correct?



(i)



(ii)

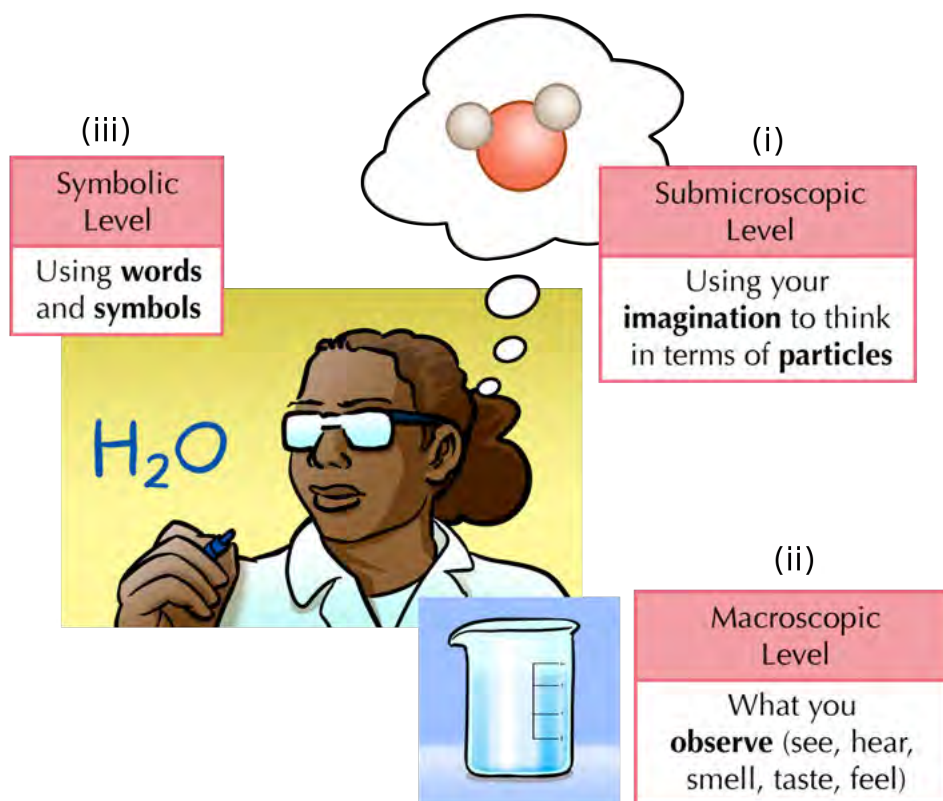


(iii)

They are all correct!

The three diagrams above all represent water, but they are very different from each other. We say that they are three different **representations** of the same thing, namely water.

The following diagram shows how the three representations fit together.



#### TAKE NOTE

Submicroscopic means 'smaller than microscopic', or 'too small to see through a microscope'. Sometimes it helps to think that this is what we would see if we had special 'submicroscopic goggles' on to 'see' at the atomic level!

#### VISIT

Find out about special microscopes which enable people to 'see' atoms  
[bit.ly/19YIOCU](http://bit.ly/19YIOCU)

The water molecule in the top right shows what a particle of water would look like (i). We cannot see water particles with our eyes, therefore we have to imagine them. This is why the water molecule is inside a thought bubble. We call this a **submicroscopic representation**.

The beaker of water shows what water looks like to our eyes (ii). We call this a **macroscopic representation**, because it is observable. That means it can be observed by using our senses such as seeing, feeling, hearing, tasting or touching.

The chemical formula on the left uses chemical symbols to represent water (iii). We have learnt that chemical formulae are made up of element symbols. We can think of chemical symbols and formulae as a chemical 'language', because they tell a story. The 'story' told by the formula  $H_2O$  is that a water molecule consists of two atoms of H and one atom of O. The formula ' $H_2O$ ' is a **symbolic representation**.

Experienced scientists can move easily between these three levels. They can translate the symbolic language of chemical formulae to submicroscopic pictures in their mind. This is what we will practice in this chapter.

Before moving on, try another example where you draw the 3 different levels of carbon dioxide in the space below. Label each level.

#### TEACHER'S NOTE

Learners could draw a closed container with a clear gas in it for the macroscopic representation. They should write the formula  $CO_2$  for the symbolic representation. They should draw a carbon dioxide molecule for the submicroscopic representation as follows:

**VISIT**

The world's smallest movie made with atoms [bit.ly/168BHFa](http://bit.ly/168BHFa) and how the scientists made it [bit.ly/1cYU80s](http://bit.ly/1cYU80s)



## 2.2 How do we represent chemical reactions?

How would you define a chemical reaction? Write down some of your ideas. The following words may help you formulate your sentences.

reactants, products, bonds, rearranged, atoms, molecules, new compounds

### TEACHER'S NOTE

Get learners to first take some notes and describe what they think a chemical reaction is. You can even just ask them the question and get their definitions.

A chemical reaction is a rearrangement of atoms in which one or more compounds are changed into new compounds.

All chemical reactions can be represented by equations and models. To some people, chemical equations may seem very hard to understand. Since atoms and molecules can not be seen they have to be imagined and that can be quite difficult! Luckily, we have had some preparation because we have been drawing molecules since Gr. 7.

Anytime that atoms separate from each other and recombine into different combinations of atoms, we say a chemical reaction has occurred. No atoms are lost or gained, they are simply rearranged.

### 1. Word equations

When we represent a chemical reaction in terms of words, we write a **word equation**. For example, when hydrogen gas reacts with oxygen gas to form water, we can write a word equation for the reaction as follows:

**hydrogen + oxygen → water**

To the left of the arrow, we have the 'before' situation. This side represents the substances we have before the reaction takes place. They are called the **reactants**. What are the reactants of this reaction?

### TEACHER'S NOTE

The reactants are hydrogen and oxygen.

**TAKE NOTE**

In mathematic equations we use an equal sign (=) for example  $2 + 2 = 4$ , but in scientific chemical equations, we use an arrow ( $\rightarrow$ ), for example  $C + O_2 \rightarrow CO_2$ .

To the right of the arrow we have the 'after' situation. This side represents the substances that we have after the reaction has taken place. They are called the **products**. What is the product of this reaction?

#### TEACHER'S NOTE

The product is water.

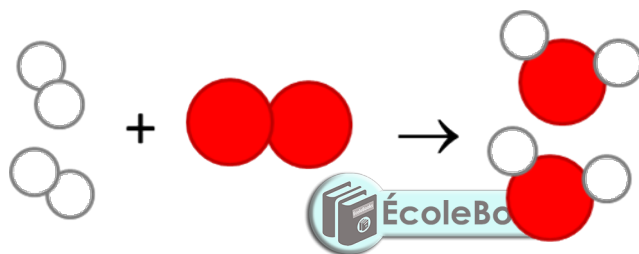
## 2. Picture equations

The same reaction of hydrogen reacting with oxygen, can also be represented in pictures called submicroscopic diagrams. The diagram below shows that the atoms in two hydrogen molecules ( $H_2$ ) and one oxygen molecule ( $O_2$ ) on the left rearrange to form the two water molecules ( $H_2O$ ) on the right of the arrow. Hydrogen atoms are white circles and oxygen atoms are red circles.

What kind of representation is this: macroscopic, submicroscopic, or symbolic?

#### TEACHER'S NOTE

Submicroscopic, because it shows the particles.



Now we are going to convert our submicroscopic picture to a symbolic one:

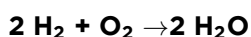
What is the product of the above reaction? What are the reactants of the above reaction? Write their formulae.

#### TEACHER'S NOTE

The product is  $H_2O$ . The reactants are  $H_2$  and  $O_2$ .

## 3. Chemical equations

When we represent a chemical reaction in terms of chemical formulae (symbols), it is called a **chemical equation**. The chemical equation for the above reaction would be as follows:



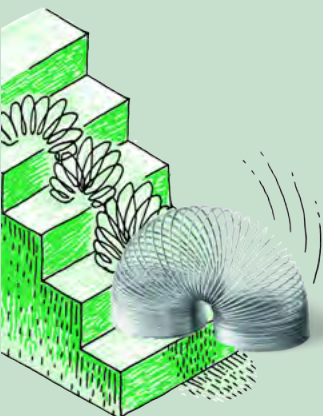
What kind of representation is this: macroscopic, submicroscopic, or symbolic?

#### TEACHER'S NOTE

Symbolic, because it uses formulae (symbols).

We still have reactants on the left and products on the right.





## ACTIVITY: Identifying the different types of equations

### INSTRUCTIONS:

- Complete the following table by identifying the different types of equations which have been shown, namely word, picture or chemical equations.

Equation	Type of equation
	Picture equation
carbon dioxide + water → glucose + oxygen	Word equation
$Fe + O_2 \rightarrow Fe_2O_3$	Symbolic/chemical equation
	Picture equation
$C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$	Symbolic/chemical equation

### QUESTIONS:

- What process does the equation, carbon dioxide + water → glucose + oxygen, represent?  
*Photosynthesis.*
- What process does the equation,  $C_6H_{12}O_6 + 6O_2 \rightarrow 6CO_2 + 6H_2O$ , represent?  
*Cellular respiration.*

When you look at the reaction equation above you will notice two kinds of numbers:

- Numbers *in front of* chemical formulae in the equation. They are called **coefficients**.
- Smaller numbers used *inside and below* the chemical formulae. These are called **subscripts**.

Coefficients and subscripts mean different things, as you will see in the next section.

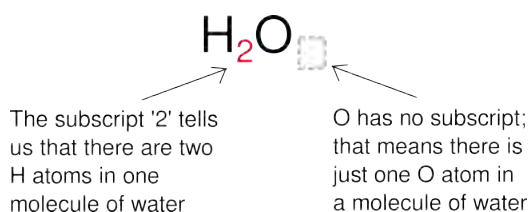
## Coefficients and subscripts in chemical equations

Why is there a '2' in front of the formula for water ( $\text{H}_2\text{O}$ ) in the chemical equation for water? This is because two molecules of  $\text{H}_2\text{O}$  can be made from two molecules of  $\text{H}_2$  and one molecule of  $\text{O}_2$  in our reaction.

The numbers in front of the formulae in the chemical equation are called **coefficients**. They represent the numbers of individual molecules that are in the chemical reaction.

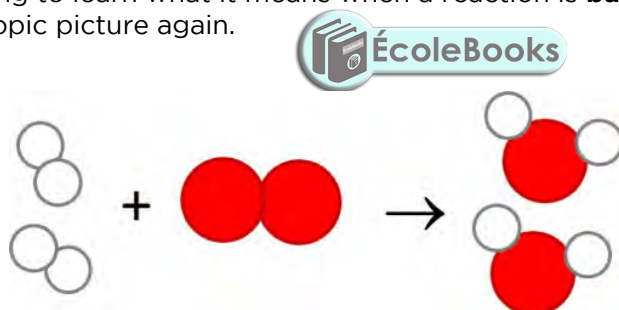
You will notice that  $\text{O}_2$  does not have a coefficient in the reaction above. When there is no coefficient, it means that just one molecule of that substance takes part in the reaction.

In the previous chapter, we learnt how to interpret chemical formulae. When we read the formula, the **subscripts** tell us how many atoms of a particular element are in one molecule of that compound.



## 2.3 Balanced equations

Now we are going to learn what it means when a reaction is **balanced**. Here is our submicroscopic picture again.



### TEACHER'S NOTE

When learners draw a diatomic molecule, the two atoms must be **touching** to show that they are chemically bonded, otherwise it is wrong.

Count how many H atoms are on the left side of the reaction. How many on the right?

### TEACHER'S NOTE

Four H atoms on the left and four H atoms on the right.

Count how many O atoms are on the left side of the reaction. How many on the right?

**VISIT**

Simulation on balancing  
chemical equations  
[bit.ly/17ImOVN](http://bit.ly/17ImOVN)

**TEACHER'S NOTE**

Two O atoms on the left and two O atoms on the right.

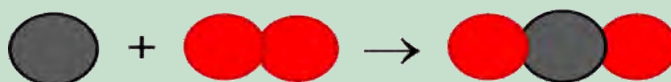
Did you notice that the numbers and types of atoms are the same on the left and on the right of the reaction? The reactants have four H atoms and two O atoms. The products have four H atoms and two O atoms.

When this is true of a reaction equation, we say the equation is **balanced**.

**ACTIVITY:** When is a reaction balanced?

**INSTRUCTIONS:**

1. Study the equation below. The black atoms are carbon (C), and the red atoms are oxygen (O). They will not always necessarily be this colour - this is just a representation.
2. Answer the questions that follow.



**QUESTIONS:**

1. What kind of representation is this: macroscopic, submicroscopic or symbolic?  
*Submicroscopic, because it shows the particles.*
2. Write a symbolic representation (a chemical equation) for the above reaction.  
 *$C + O_2 \rightarrow CO_2$*
3. Write the formulae for the reactants of this reaction.  
*C and  $O_2$*
4. Write the formula for the product of the reaction.  
 *$CO_2$*
5. Count how many C atoms are on the left side of the reaction. How many on the right?  
*One C atom on the left and one C atom on the right.*
6. Count how many O atoms are on the left side of the reaction. How many on the right?  
*Two O atoms on the left and two O atoms on the right.*
7. Is the reaction balanced? Why do you say so?  
*Yes, the reaction is balanced because equal numbers of the same kinds of atoms are on both sides of the reaction equation.*

Now that we know how to recognise a balanced equation, we are going to learn how to balance them!

What is a balanced equation? Write down your own definition.

### TEACHER'S NOTE

Either get learners to write down their own definitions and then read them out to the class, or they can just volunteer answers. You can get learners to start with: We say an equation is balanced when... A potential answer is: "We say a reaction is balanced when the total numbers and types of atoms in the reactants are equal to those in the products".

We are going to use a few examples of real reactions to learn how to balance equations. In the chapters following this one, we are going to see what these reactions look like in real life, but for now, we will just focus on how to balance equations.

## ACTIVITY: Magnesium burning in oxygen

When magnesium metal burns in oxygen, we can write the following word equation for the reaction that occurs between these two elements:

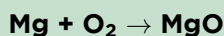


*Magnesium flakes burning in oxygen in a sparkler.*

### QUESTIONS:

1. What are the reactants of the reaction?  
*The reactants are magnesium and oxygen.*
2. What is the product?  
*The product is magnesium oxide.*

We can change the word equation into a chemical equation:



3. What kind of representation is this: macroscopic, submicroscopic, or symbolic?  
*Symbolic, because it uses formulae (symbols).*



4. Is the equation balanced? If you are not sure, count the number of each type of atom on the left, and on the right. Perhaps it will help to look at a submicroscopic representation (a particle diagram) of the reaction:



You can write your results in the table below:

Number of atoms	Reactants	Products
Mg	1	1
O	2	1

5. What is your conclusion: Is the equation balanced? Explain your answer.  
*No, the equation is not balanced because the numbers of the atoms are not the same in the reactants and products.*

So how could we balance the equation to describe magnesium burning in oxygen? When balancing reactions, there is one simple rule:

You may only add compounds that are already in the equation. This means only coefficients may be changed, not subscripts!

Let's try a few alternative solutions. Would it help to add an O atom on the right, like this?

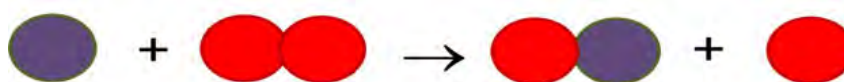


Now the O atoms are balanced on both sides of the equation, but we don't have MgO on the right anymore. We have changed the formula on the right to MgO<sub>2</sub>. That means we have changed a subscript in the formula. You cannot change the formula of a compound when balancing chemical equations.

#### TEACHER'S NOTE

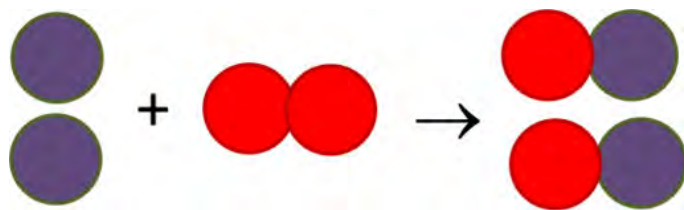
Ask learners why it is not allowed. Is MgO the same as MgO<sub>2</sub>? Remind them of the earlier example of H<sub>2</sub>O and H<sub>2</sub>O<sub>2</sub>, which were not the same compound. MgO and MgO<sub>2</sub> can not be the same compound because they do not have the same chemical formula. The ratio of Mg and O atoms are different in the two compounds. (The compound MgO<sub>2</sub> does not even exist, but you do not have to go into this.)

Adding single atoms to any side of the equation is also not allowed. That means the following equation is also not correct:





Remember that we may only use the chemical formulae that are already in the equation. We need two MgO's on the right to balance the two O's in O<sub>2</sub>. We also need two Mg's on the left to balance the two MgO's on the right.



Can you build this equation with play dough balls or beads? When you convert the play dough 'reactants' to 'products', are there any unused 'atoms' left behind afterwards?

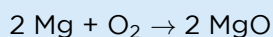
#### TEACHER'S NOTE

No, there are not. Get learners to actually do this activity and practice making the equation using balanced numbers of atoms.

Now, let us take this a step further. We are going to convert our balanced submicroscopic equation to a symbolic chemical equation. Write down a balanced equation for magnesium burning in oxygen to produce magnesium oxide.

#### TEACHER'S NOTE

Write this up on the board and explain again how the equation is balanced:



Here are a few important rules for balancing chemical equations:

- When we balance reaction equations we may ONLY add coefficients to the chemical formulae that are already in the equation.
- We may NOT change the chemical formulae of any of the reactants or products by changing the subscripts in a formula.
- We may NOT add other reactants or products. This includes adding single atoms of any of the elements already in the reaction equation.
- We may NOT remove reactants or products.

We are now ready to practice balancing other reaction equations.



## ACTIVITY: Iron reacts with oxygen

When iron rusts, it is because the iron metal reacts with oxygen in the air to form iron oxide.



*An old car with rust on the bonnet.*

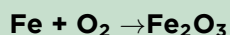


*A closeup photo of a rusted barrel.*

The word equation is the following:



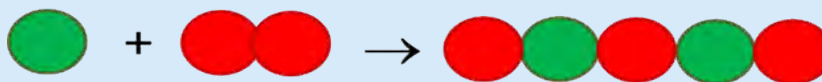
The chemical equation is the following:



Is the equation balanced? Draw a submicroscopic picture to help you decide.

### TEACHER'S NOTE

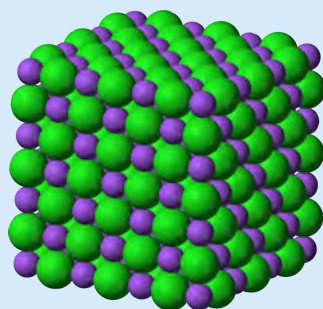
Learner's diagram should look like this. They may find it difficult to convert the equations into diagrams. Help them to interpret the formulae in the following way: Fe on its own means there is just one atom of iron (Fe). O<sub>2</sub> means there must be two atoms of O, linked up to form a molecule. Fe<sub>2</sub>O<sub>3</sub> means two Fe atoms and three O atoms are clustered together.



The colours are not important, as long as all the atoms of the same element are the same colour.

**TEACHER'S NOTE**

The arrangement of the atoms in the  $\text{Fe}_2\text{O}_3$  'cluster' is also not important. Since  $\text{Fe}_2\text{O}_3$  is an ionic compound, we would not ordinarily speak of a 'molecule' of  $\text{Fe}_2\text{O}_3$ . Like all other ionic compounds, it consists of large clusters of  $\text{Fe}^{3+}$  and  $\text{O}^{2-}$  ions in a regular crystalline packing that extends in three dimensions, much like the ionic lattice of NaCl in the picture below (shown in Chapter 1 also).



It is not recommended that you mention this information here, as it more likely to confuse learners at this point than add to their understanding of balancing equations.

You could also use a table like the one below:

**TEACHER'S NOTE**

Number of atoms	Reactants	Products
Fe	1	
O	2	

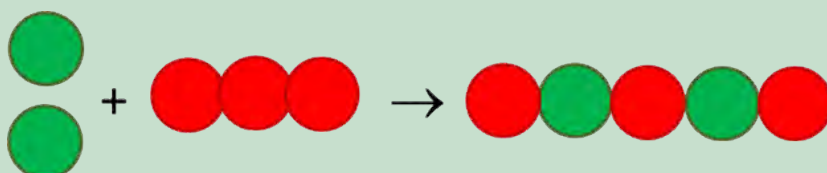
What is your verdict: Is the equation balanced? Explain your answer.

**TEACHER'S NOTE**

No, the equation is not balanced because the numbers of the atoms are not the same in the reactants and products.

How could we balance the reaction? Three possibilities (Plans A, B and C) are given below. You must evaluate each plan, and say if it is allowed or not.

Plan A

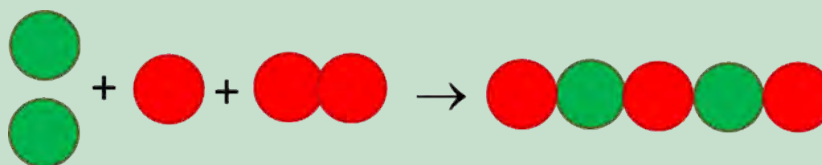


## TEACHER'S NOTE

Changes made	Is this change allowed? Yes/no?	Reason
Add one Fe atom on the reactant side.	Yes	The Fe atom is already a reactant.
Change O <sub>2</sub> to O <sub>3</sub> on the reactant side of the equation.	No	Changes to formulae are not allowed.

- Convert the picture equation above to a chemical equation.  
 $2\text{Fe} + \text{O}_3 \rightarrow \text{Fe}_2\text{O}_3$
- Did any coefficients change? Remember that this is allowed.  
*Yes.*
- Did any formulae change, or were any new formulae added? Remember that this is NOT allowed.  
*Yes.*
- What do you think: Can this plan work? Explain your answer.  
*No, because a formula was changed.*

## Plan B

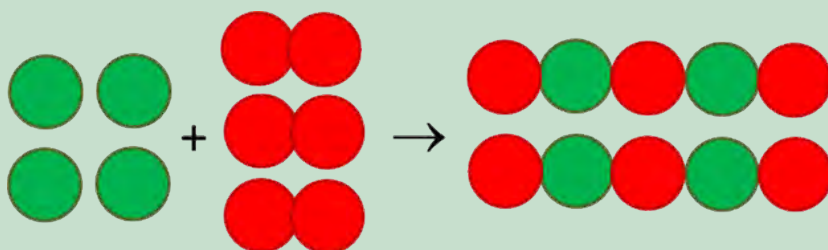


## TEACHER'S NOTE

Changes made	Is this change allowed? Yes/no?	Reason
Add one Fe atom on the reactant side.	Yes	The Fe atom is already a reactant.
Add one O atom on the reactant side.	No	Adding single atoms is not allowed, unless they are already in the reaction AS SINGLE ATOMS.

- Convert the picture equation to a chemical equation.  
 $Two\text{Fe} + \text{O} + \text{O}_2 \rightarrow \text{Fe}_2\text{O}_3$
- Did any coefficients change? Remember that this is allowed.  
*Yes.*
- Did any formulae change, or were any new formulae added? Remember that this is NOT allowed.  
*Yes.*
- What do you think: Can this plan work? Explain why or why not.  
*No, because adding formulae is not allowed.*

Plan C



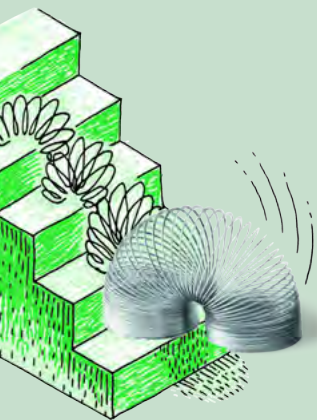
TEACHER'S NOTE

Changes made	Is this change allowed? Yes/no?	Reason
Add three Fe atoms on the reactant side.	Yes	The Fe atom is already a reactant.
Add two O <sub>2</sub> molecule on the reactant side.	Yes	The O <sub>2</sub> molecule is already a reactant.
Add one Fe <sub>2</sub> O <sub>3</sub> on the product side.	Yes	Fe <sub>2</sub> O <sub>3</sub> is already a product.

- Convert the picture equation to a chemical equation.  
 $4 \text{Fe} + 3 \text{O}_2 \rightarrow 2 \text{Fe}_2\text{O}_3$
- Did any coefficients change? Remember that this is allowed.  
*Yes.*
- Did any formulae change, or were any new formulae added? Remember that this is NOT allowed.  
*No.*
- What do you think: Can this plan work? Explain why or why not.  
*Yes, because none of the rules for balancing equations were broken.*
- Which of the three plans (A, B or C) helped us to balance the equation using only moves that are allowed?  
*Plan C*
- Are there any other plans that you can think of to balance this equation?  
*Learners should be encouraged to try out other possibilities. They should come to the conclusion that the reaction proposed in Plan C is the only correct one.*

In the next activity we will balance an equation that is much simpler, but we are not going to include all the explanations of the previous activity.





## ACTIVITY: Copper reacts with oxygen

Have you ever noticed how copper items tarnish over time?

This dark layer of tarnish is the result of a slow reaction between copper and oxygen, to form copper oxide.



One of these copper coins is tarnished as it has become coated in a black substance.

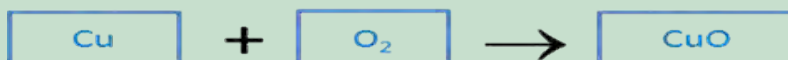
### QUESTIONS:

1. Write the word equation for this reaction. The words are all in the sentence above, they just need to be placed in the correct positions.

*Learners should fill in the answers as follows:*



2. Convert the word equation into a chemical equation. You do not have to balance it yet.

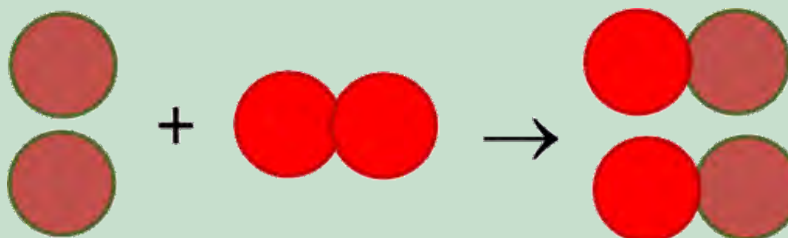


3. Convert the chemical equation to a picture equation. It does not have to be balanced.

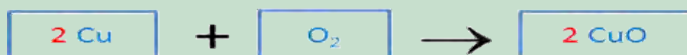
*Learner's drawing should look similar to the following. Colours do not have to be the same as shown here, but they must show a difference between the different elements. If learners do not have different coloured pencils, they can also use different patterns to distinguish the different atoms.*



4. Now, redraw the picture equation so that it is balanced. Remember that no 'new' compounds may be added; we are only allowed to draw more of the molecules that are already there.



5. Convert the balanced picture equation to a balanced chemical equation.



In the chapters that follow, there will be more opportunities to write and balance chemical equations.

## SUMMARY:

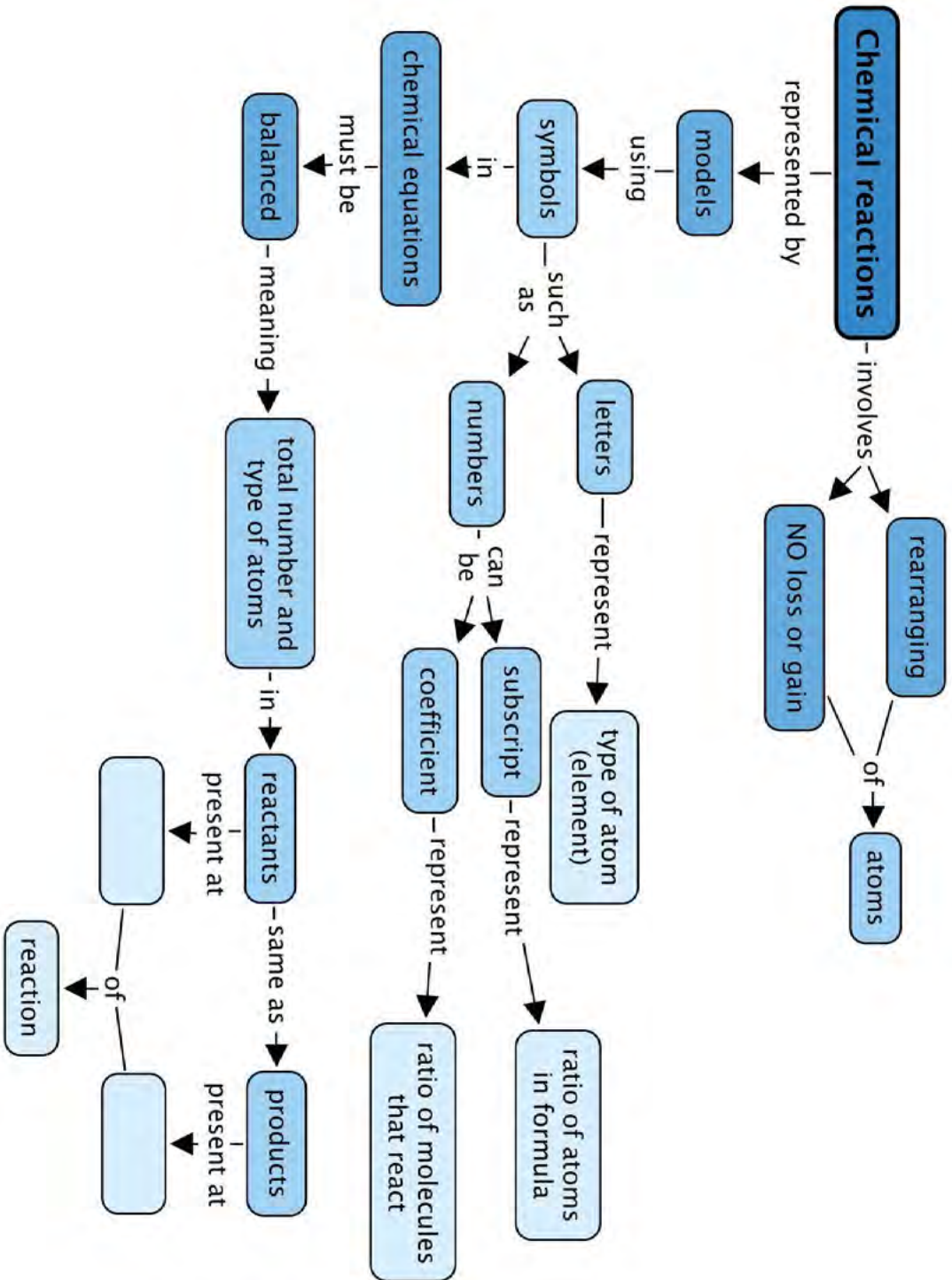
### Key Concepts

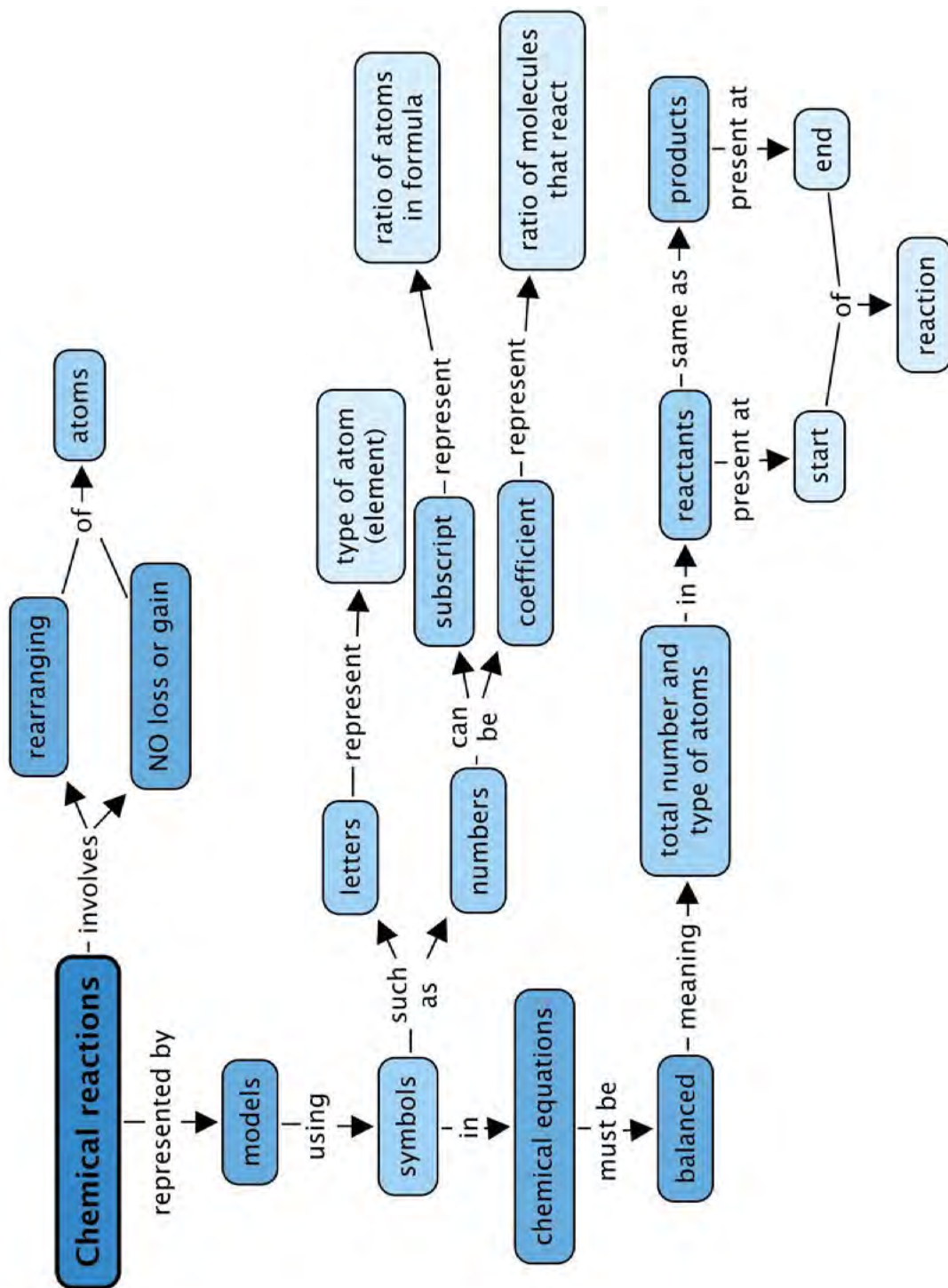
- There are a number of different ways to represent chemical equations:
  - With models and pictures (in submicroscopic representations);
  - with symbols and formulae (in chemical equations); and
  - with words (in word equations).
- Numbers are used in two different ways in chemical equations:
  - Coefficients in front of chemical formulae indicate the numbers of atoms or molecules of a specific type that take part in the reaction; and
  - Subscripts inside chemical formulae indicate the number of atoms of a specific type in that particular compound.
- Chemical reactions happen when atoms in compounds rearrange; no atoms are lost or gained during a chemical reaction.
- In a balanced equation equal numbers of the same kinds of atoms are on opposite sides of the reaction equation.

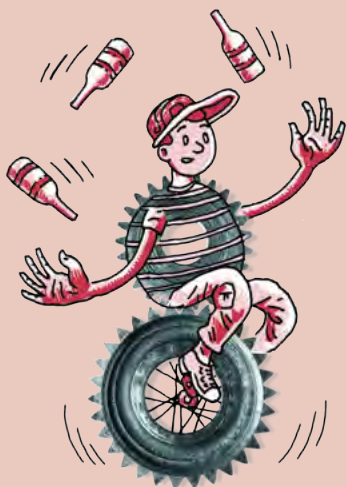
### Concept Map

The following concept map is incomplete. You need to describe when you get reactants and when you get products in a chemical reaction.



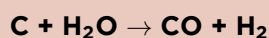






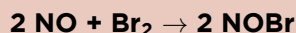
## REVISION:

- Why can we not change the subscripts in the formulae of reactants and products when we want to balance an equation? [2 marks]  
*This is because it will change the formula of the compound which then represents a different compound, and not the one involved in the reaction.*
- Write the balanced chemical equation between carbon and oxygen to form carbon dioxide. [1 mark]  
 $C + O_2 \rightarrow CO_2$
- Write the balanced chemical equation between hydrogen and oxygen to form water. [1 mark]  
 $2H_2 + O_2 \rightarrow 2H_2O$ .
- Here is a balanced chemical equation:



Answer the four questions below that relate to this equation: [8 marks]

- Write the formulae of the reactants of this reaction.
  - Write the names of the reactants of this reaction.
  - Write the formulae of the products of this reaction.
  - Write the names of the products of this reaction.
- a) *C and H<sub>2</sub>O.*  
**NOTE:** *Learners do not need to know this equation, it is just to practice balancing equations.*
- carbon and water*
  - CO and H<sub>2</sub>*
  - carbon monoxide and hydrogen*
- The balanced equation below represents the reaction between nitrogen monoxide (NO) and bromine (Br<sub>2</sub>):



Complete the table by counting how much of each atom is on each side of the reaction equation. [6 marks]

**NOTE:** *Learners do not need to know this equation, it is just to practice balancing equations.*

Number of atoms	In the reactants	In the product
Nitrogen (N)	2	2
Oxygen (O)	2	2
Bromine (Br)	2	2

- Turn the following chemical equations into word equations: [2 x 3 = 6 marks]
  - $2 CO + O_2 \rightarrow 2 CO_2$
  - $2 Mg + O_2 \rightarrow 2 MgO$
  - carbon monoxide + oxygen → carbon dioxide*
  - magnesium + oxygen → magnesium oxide*



7. Turn the following word equations into chemical equations:

[2 x 3 = 6 marks]

a) sulfur + oxygen → sulfur dioxide

b) carbon monoxide + water → carbon dioxide + hydrogen

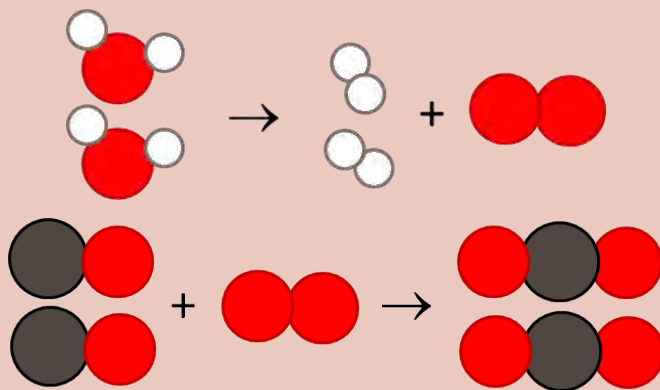
a)  $S + O_2 \rightarrow SO_2$

b)  $CO + H_2O \rightarrow CO_2 + H_2$

8. Turn the following picture equations into chemical equations.

[2 x 3 = 6 marks]

- The red circles represent oxygen (O) atoms.
- The white circles represent hydrogen (H) atoms.
- The grey circles represent carbon (C) atoms.
- The yellow circles represent sulfur (S) atoms.



a)  $2 H_2O \rightarrow 2 H_2 + O_2$

b)  $2 CO + O_2 \rightarrow 2 CO_2$

9. Write the following chemical equations as word equations:

[4 x 1 = 4 marks]

a)  $4 Fe + 3 O_2 \rightarrow 2 Fe_2O_3$

b) What does this product look like?

c)  $2 Mg + O_2 \rightarrow 2 MgO$

d) What does the product look like?

a) *iron + oxygen → iron oxide*

b) *It is a brown rusty coating (rust).*

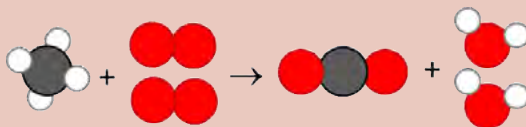
c) *magnesium + oxygen → magnesium oxide*

d) *It is a white powder.*

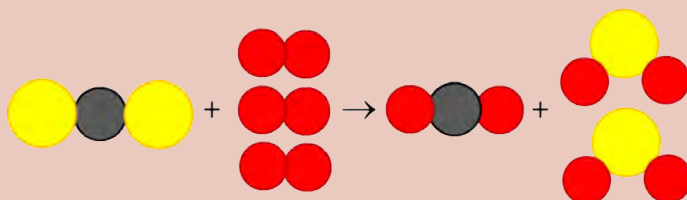
10. Turn the following chemical equations into picture equations:

[2 x 4 = 8 marks]

a)  $CH_4 + 2 O_2 \rightarrow CO_2 + 2 H_2O$



b)  $CS_2 + 3 O_2 \rightarrow CO_2 + 2 SO_2$



Total [48 marks]



**TEACHER'S NOTE****Chapter overview**

1.5 weeks

In this chapter learners will again encounter the reactions of selected metals with oxygen that were used as examples in the previous chapter. In this chapter, however, there will be a greater focus on the actual reactions - these should be demonstrated to the class - and the commonalities between them. Once again, the writing of chemical equations will be scaffolded by the process of starting with a word equation (macroscopic representation) and progressing through a picture equation (submicroscopic representation) to end at the chemical equation (symbolic representation).

The content has also been presented in a slightly different order to CAPS in that the example reactions are first explored, and then the general reaction of metals with oxygen is explained, once learners have already seen example chemical equations.

3.1 The reaction of iron with oxygen (1 hour)

Tasks	Skills	Recommendation
Activity: Three different levels of interpretation in science	Sorting and classifying, interpreting, identifying	Optional (Revision)
Activity: The reaction of iron with oxygen	Demonstration of steel wool burning, observing, recording, communicating, describing	CAPS suggested

3.2 The reaction with magnesium and oxygen (1 hour)

Tasks	Skills	Recommendation
Activity: The reaction of magnesium with oxygen	Demonstration of magnesium burning, observing, recording, communicating, describing	CAPS suggested

3.3 The general reaction of metals with oxygen (0.5 hours)

(Questions within the text)

### 3.4 The formation of rust (1.5 hour)

Tasks	Skills	Recommendation
Activity: The reaction between iron and oxygen in air	Demonstrating, observing, recording, describing,	Optional (Suggested)
Activity: Why is rust a problem?	Identifying problems and issues	Optional (Suggested)

### 3.5 Ways to prevent rust (0.5 hours)

(Questions within the text)



#### KEY QUESTIONS:

- What happens when a metal reacts with oxygen?
- What is the product called?
- How can we represent the general reaction between a metal and oxygen?
- What is a combustion reaction?
- What is rust and how does it form?
- How can iron be made more rust-resistant?



In the previous chapter, we learnt how to write and balance equations. The three examples we learnt about were:

- magnesium + oxygen  $\rightarrow$  magnesium oxide
- iron + oxygen  $\rightarrow$  iron oxide
- copper + oxygen  $\rightarrow$  copper oxide

Which groups do magnesium, iron and copper come from?

#### TEACHER'S NOTE

Magnesium is group 2, iron is group 8 and copper is group 11. This is important as elements in the same group will react similarly.

In these reactions, the elements that react with oxygen are all **metals**. If you are not convinced of this, find them on the Periodic Table below in the front of your book. Can you see that they are all found in the region occupied by the metals? Where are metals located on the Periodic Table?

#### TEACHER'S NOTE

On the left.

The names of the products of the three reactions above have something in common. Write down the names. Can you see what they have in common?

**TEACHER'S NOTE**

The products are: magnesium oxide, iron oxide, copper oxide. They all have 'oxide' in their name.

**TAKE NOTE**

The metals will react similarly with the other elements in the same group as oxygen (group 16).

The products are all **metal oxides**. What exactly are metal oxides? As we will see later when we draw diagrams and write formulae to represent these reactions, they are compounds in which a metal is combined with oxygen, in some fixed ratio.

We are going to look at two of the reactions shown previously in greater detail in this chapter. Remember that they are not the only reactions of metals with oxygen; they are just the ones that have been chosen as examples.

First, we will observe the actual reactions. Your teacher will demonstrate, while you make observations. Afterwards we will write about these reactions using 'scientific language' as we write reaction equations for each one. Before we start, here is a reminder of something we discussed in Chapter 1.



**ACTIVITY:** Three different levels of interpretation in science

In the first chapter of Gr. 9 Matter and Materials, we learnt that scientists interpret chemical reactions on three different levels. Those three levels are:

- the macroscopic level;
- the submicroscopic level; and
- the symbolic level.

Check whether you still remember what each level refers to, by completing the following table.

<i>When we do the following:</i>	<i>We are operating on this level: Macroscopic/submicroscopic/symbolic</i>
<i>Observe actual reactions (see, hear, smell, touch, taste). Describe what we see in words.</i>	<i>Macroscopic</i>
<i>Imagine the behaviour of particles during reactions. Draw pictures of particles in substances.</i>	<i>Submicroscopic</i>
<i>Write chemical formulae. Write reaction equations.</i>	<i>Symbolic</i>

Soon your teacher will demonstrate two reactions, while you will be making observations. Which of the three levels will you be operating at?

#### TEACHER'S NOTE

The macroscopic level.

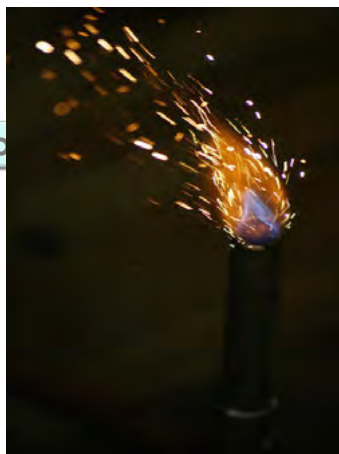
The purpose of these demonstrations is to give you a chance to make macroscopic observations of the chemical changes that take place during the reactions. This chapter will also help you to link those macroscopic observations with pictures and equations that you learnt to write in the previous chapter.

### 3.1 The reaction of iron with oxygen

We will be looking at how iron reacts with oxygen. In some cases, you might use steel wool for these experiments. Do you know what steel wool is? It is wire wool made of very fine steel threads. Steel is an alloy made mostly of iron. So, when we look at how steel wool burns in oxygen, we are actually looking at how iron reacts with oxygen.



*Steel wool spinning creates interesting photos as the iron burns in oxygen and creates orange sparks.*



*Iron shavings look like sparks when they burn in the blue flame of a Bunsen burner.*

#### TAKE NOTE

A metal alloy is a solid mixture of two or more different metal elements. Examples are steel and brass.

Your teacher will perform a demonstration in which iron is burned in air. When a substance burns in air, the reaction is called a **combustion reaction**. When a substance combusts in air, it is really reacting with oxygen.





## ACTIVITY: The reaction of iron with oxygen

### TEACHER'S NOTE

It is recommended that you demonstrate this reaction to the learners, because of the hazards involved when burning metals.

Safety precautions to observe during the demonstrations:

1. Wear safety goggles and a protective coat.
2. Exercise caution when burning the steel wool, as sparks may be produced. Learners should be cautioned against standing too close during the demonstration.
3. Place a clean beaker or watch glass underneath to catch any metal oxide that forms during the reaction. Students can examine the reaction product afterwards to formulate their observations.

### MATERIALS:

- Bunsen burner or spirit burner
- matches
- safety goggles
- steel wool
- tongs

### INSTRUCTIONS:

1. Your teacher will demonstrate the combustion of iron in oxygen (which is present in air).
2. You should make careful observations during the demonstration and write these down in the spaces provided below. To guide you, some questions have been provided.

#### VISIT

You can see a video of steel wool burning here:  
[bit.ly/1cYPyz7](http://bit.ly/1cYPyz7)

### QUESTIONS:

1. We used steel wool in this demonstration, but what is steel wool mostly made of?  
*Steel wool is an alloy made mostly of iron.*  
**Note:** *The other elements in steel include carbon, manganese, phosphorus, sulfur, silicon, and traces of oxygen, nitrogen and aluminum. Learners do not need to know the names of the other elements in steel wool.*
2. Look at the metal before it is burned. Describe what it looks like.  
*Learners' observations may include any of the following: The steel wool consists of thin threads of iron. It looks like hair made of metal. Depending on the state of the steel wool, learners may describe it as shiny, or dull grey, metallic, or even rusty. Encourage creative descriptions.*
3. Can you see the oxygen that the metal will react with? Can you describe it?  
*Oxygen gas can not be seen or directly observed and so it cannot be described.*
4. What do you observe during the reaction? Describe anything you see, hear, or smell.
  - *Learners may see the steel wool burning and bright orange sparks falling. They may even notice some smoke.*

- Learners may hear the crackling sound of the steel wool burning.
  - Learners may notice a metallic smell in the air.
  - Learners may experience the heat from the combustion reaction.
5. What does the product of the reaction look like? Describe it in as much detail as possible.  
*The product is a reddish-brown, crumbly solid.*

If you think the reaction when iron burns in oxygen is spectacular, the next demonstration will amaze you!

### 3.2 The reaction of magnesium with oxygen

Your teacher will perform a demonstration in which magnesium is burned in air.



*Magnesium burns with a bright white flame.*

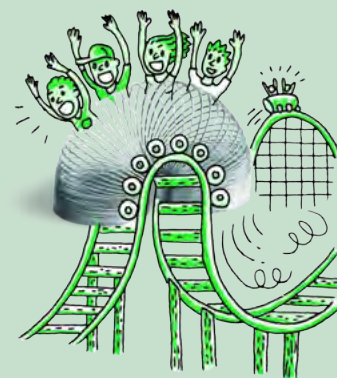
#### VISIT

A video showing magnesium burning in oxygen [bit.ly/14nA93l](https://bit.ly/14nA93l)

#### ACTIVITY: The reaction of magnesium with oxygen

##### MATERIALS:

- Bunsen burner or spirit burner
- matches
- safety goggles
- magnesium ribbon
- tongs
- watch glass or beaker



**TEACHER'S NOTE**

It is recommended that you demonstrate the reaction to the learners, because of the hazards involved with burning metals.

Instructions:

1. Wear safety goggles and a protective coat.
2. Caution learners not to look directly at the intense white flame produced by the burning magnesium.
3. Place a clean beaker or watch glass underneath to catch any metal oxide that forms during each reaction. Students can examine the reaction product afterwards to formulate their observations.
4. You may want to retain the product of the magnesium combustion reaction for a follow-up experiment in the chapter *Reactions of acids with metal oxides*.
5. You can also mix the product in water at this stage and test if it is an acid or base.

**INSTRUCTIONS:**

1. Your teacher will demonstrate the combustion of magnesium in oxygen.
2. You should make careful observations during the demonstration and write these down in the spaces provided below.

**QUESTIONS:**

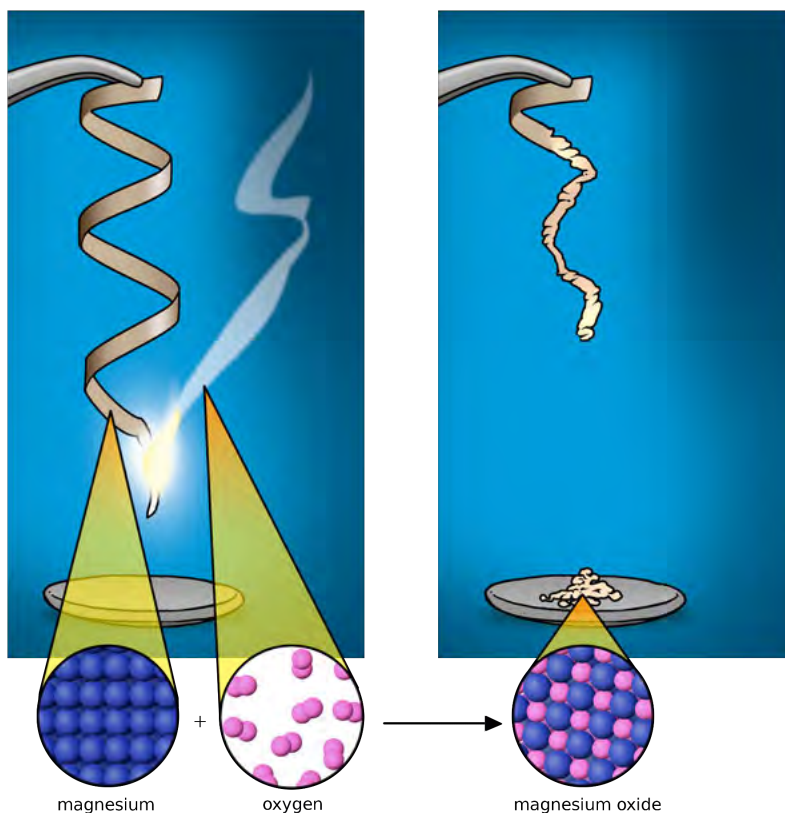
1. Describe the physical form (shape) of the metal in this experiment.  
*The magnesium is in the form of magnesium 'ribbon'.*
2. What do we call reactions where a substance burns in air?  
*Combustion reactions.*
3. How would you describe the physical appearance or colour of the metal before it is burned?  
*Learners' observations may include any of the following: The magnesium ribbon looks like a thin strip of metal. It looks like metal tape. Depending on the state of the ribbon, learners may describe it as shiny, or dark grey, black, metallic, or even tarnished. Encourage creative descriptions.*
4. Can you see the oxygen that the metal will react with? Can you describe it?  
*Oxygen gas can not be seen or directly observed and so it cannot be described.*
5. What do you observe during the reaction? Describe anything you see, hear, or smell.
  - *Learners may see the magnesium burning with a blinding white light. They may notice some smoke.*
  - *Learners may hear crackling or hissing as the magnesium burns.*
  - *Learners may notice a hot, metallic smell in the air.*
  - *Learners may experience the heat from the combustion reaction.*
6. What does the product of the reaction look like? Describe it in as much detail as possible.  
*The product is a soft, white, powdery solid.*

Magnesium is in group 2 in the Periodic Table. Do you remember that we said that elements in the same group will behave similarly. This means that they will react in a similar way. We have studied how magnesium reacts with oxygen, but calcium, for example, will behave in a similar way. You can watch the video in the visit link to confirm this.

**VISIT**

Video showing calcium reacting with oxygen  
[bit.ly/19n3u7c](http://bit.ly/19n3u7c)

The following diagram combines the macroscopic, submicroscopic and symbolic representations of the reaction that you have just observed.



*A photographer using an antique camera and flash that works with magnesium powder.*



Now that we have made our macroscopic observations of the two reactions, we are ready to write about these reactions in scientific language.

### 3.3 The general reaction of metals with oxygen

Let us start by writing word equations for the two reactions that we have just performed. Word equations are often easier to write than picture equations or chemical equations and so they are a good starting point when we want to write reactions.

Write the word equation for the reaction between iron and oxygen and for the reaction between magnesium and oxygen.

**TEACHER'S NOTE**

The word equations are:

- iron + oxygen → iron oxide
- magnesium + oxygen → magnesium oxide

You can write these on the board.

**The word equation**

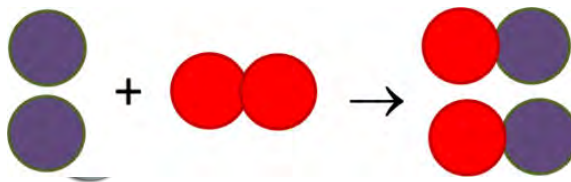
We can write a general word equation for reactions in which a metal reacts with oxygen:

**metal + oxygen → metal oxide**

When we use words to describe a reaction, we are still operating on the macroscopic level. Next, we are going to translate our word equation to a picture equation.

**The picture equation**

When we represent a chemical reaction as a particle diagram, such as in the picture equation below, we are operating on the submicroscopic level.



Can you identify the reactants in the above equation? The purple atoms are magnesium and the oxygen atoms are red. Write down the name and chemical formula of the product of the reaction.

**TEACHER'S NOTE**

The product is magnesium oxide (MgO)

The picture is not the same for all reactions of metals with oxygen.

**The chemical equation**

We can go further and translate the picture equation for the reaction between magnesium and oxygen to a chemical equation:

**2 Mg + O<sub>2</sub> → 2 MgO**

Since the chemical equation consists of symbols, we can think of this as a symbolic representation.

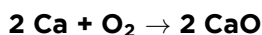
Can you remember what the numbers in front of the formulae in the chemical equation are called? Can you remember what the numbers inside a chemical formula are called?



**TEACHER'S NOTE**

Coefficients and subscripts, respectively.

As we have said, the metals in the same group will react in the same way as each other with oxygen. So, calcium reacts with oxygen in the same way as magnesium reacts with oxygen. The chemical equations also show similarities. The chemical equation for the reaction between calcium and oxygen is:



What is the product called in this reaction?

**TEACHER'S NOTE**

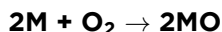
Calcium oxide.

What group are calcium and magnesium from?

**TEACHER'S NOTE**

Group 2.

A metal oxide has the the general formula  $\text{MO}$  or  $\text{M}_2\text{O}$ . In the formula,  $\text{M}$  represents a metal atom and  $\text{O}$  represents oxygen. We can therefore say that metals from Group 2 will react with oxygen and have the following general equation, where  $\text{M}$  represent a Group 2 metal.



To know whether  $\text{MO}$  or  $\text{M}_2\text{O}$  will be the correct formula, here are two simple rules for you to remember:

**TEACHER'S NOTE**

This is a suggested way to assist learners to write the formulae. Once learners have learnt about valencies in Gr. 10-12, they will be able to use this information to write the formulae of compounds. for now though, this is sufficient.

1. **Metal oxides from group 1 on the Periodic Table will have the formula  $\text{M}_2\text{O}$ .**

Can you write two examples? Look at the Periodic Table at the front of the book, pick any two metals from group 1 and write their formulae using this rule.

**TEACHER'S NOTE**

Any two of the following:  $\text{Li}_2\text{O}$ ,  $\text{Na}_2\text{O}$ ,  $\text{K}_2\text{O}$ ,  $\text{Rb}_2\text{O}$ ,  $\text{Cs}_2\text{O}$

2. **Metal oxides from group 2 will have the formula  $\text{MO}$ .**

Can you write 2 examples?

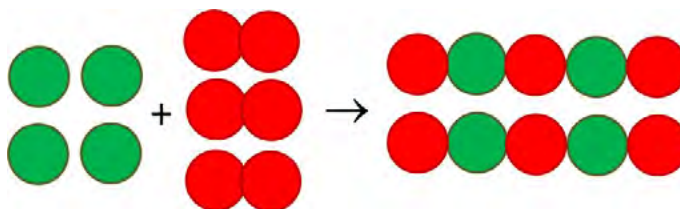
**TAKE NOTE**

Metal oxides of the types  $\text{M}_2\text{O}_3$  and  $\text{MO}_2$  also occur, but we will limit our discussion to the first two types.

**TEACHER'S NOTE**

Any two of the following: BeO, MgO, CaO, SeO, BaO

Iron is from Group 8. Here is the picture equation of the reaction between iron and oxygen (iron is green and oxygen is red).



Write the chemical equation and word equation for this reaction underneath the picture equation.

**TEACHER'S NOTE**

Learners should write the following in line with the respective pictures in the above diagram:

- iron + oxygen → iron oxide
- $4 \text{ Fe} + 3 \text{ O}_2 \rightarrow 2 \text{ Fe}_2\text{O}_3$



In the next section, we are going to return to the macroscopic world to see another example of the reaction between iron and oxygen that you should be very familiar with - the formation of rust.

### 3.4 The formation of rust

Do you know what rust is? The pictures below will provide some clues.



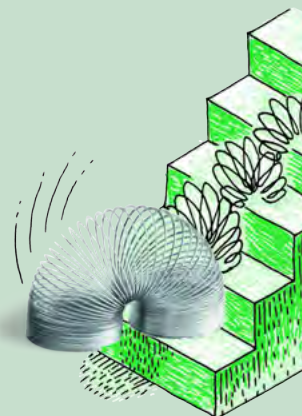
*Different objects which rust.*

## **ACTIVITY:** The reaction between iron and oxygen in air

### TEACHER'S NOTE

Here is a suggested activity for you to show how rust forms. This is not required by CAPS. It can be set up as a demonstration. You can then compare this reaction with the one that you did previously where iron was burned in oxygen in a combustion reaction.

This experiment will require a place where it can remain undisturbed for two or three days. It may be worth setting up this experiment at the start of this section. Take note: The test tube may be difficult to clean at the end of this experiment.



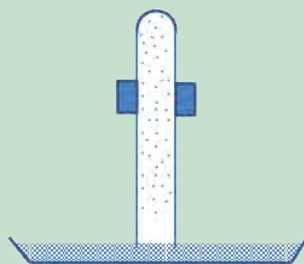
### MATERIALS:

- test tube
- clamp
- retort stand
- dish
- iron filings
- water

### INSTRUCTIONS:

1. Rinse a test tube with water to wet the inside.
2. Carefully sprinkle a spatula of iron filings around the sides of the test tube.
3. Invert the test tube in a dish of water. Use a clamp attached to a retort stand to hold the test tube in place.
4. Over the three days the water must remain above the lip of the test tube.

Here is a simple diagram showing the experimental setup with the clamp holding the test tube upright.



### QUESTIONS:

1. What do the iron filings look like at the start of the experiment?  
*They are a silvery colour.*
2. What are the reactants in this experiment?  
*Iron and oxygen (and water).*
3. Is there something present that is aiding or speeding up the reaction?  
*The water.*
4. What does the product look like at the end of the reaction?  
*It is a brown, red colour.*



Rust is a word to describe the flaky, crusty, reddish-brown product that forms on iron when it reacts with oxygen in the air.

When your teacher burned the iron earlier, it reacted quickly with oxygen to form iron oxide. Here is a picture of iron oxide to remind you what it looked like.



*A sample of iron oxide.*

### **Rust is a form of iron oxide**

When iron is exposed to oxygen in the air, a similar reaction occurs, but much more slowly. The iron is gradually 'eaten away' as it reacts slowly with the oxygen. Under wet conditions iron will rust more quickly.

Rust is actually a mixture of different oxides of iron, but the  $\text{Fe}_2\text{O}_3$  of our earlier example is an important part of that. The rusting of iron is actually a good example of the process of corrosion.

#### **TEACHER'S NOTE**

Remind learners of where else they have heard the term 'corrosive' used before in Matter and Materials. It is used to describe strong acids and bases which learners were first introduced to in Gr. 7 Matter and Materials and will look at again later in this term.



Rusting tends to happen much faster near the ocean. Not only are there water droplets, but these droplets have salt in them and this makes them even more corrosive. Rusting also happens more quickly in the presence of acids. Inside laboratories, or factories where acids are used or stored, the air is also very corrosive. When the air in a specific area contains moisture mixed with acid or salt, we refer to the area as having a **corrosive climate**.

If you live in a corrosive climate, for example near the ocean, it is often better to make the window frames and doors of your house from wood instead of iron and steel, because wood does not rust. Many people also use aluminium as this metal does not rust.



*An abandoned car quickly rusts and corrodes near the sea.*



## The problem with rust



A garden sculpture that was intended to rust to give it more texture.

Rust is a natural process and its effects can be quite beautiful.

However, iron and rust (iron oxide) are completely different materials and therefore have different properties.

### **ACTIVITY:** Why is rust a problem?

#### **TEACHER'S NOTE**

This links to what learners have done in previous grades about the properties of materials.

1. Let's imagine we have manufactured something out of iron. What properties of iron do we want to take advantage of?  
*Iron is a metal, so it is hard, strong and flexible.*
2. What objects do you think we make out of iron where these properties are desirable?  
*Tools, locks, hinges, screws and nails, garage doors... the list of items is almost endless!*



A rusted chain.



A rusted door hinge.

3. When an item is made of iron, we might want to protect it from rust, to prevent it from losing those desired properties. Do you think the rusty chain and door handle in the following photos will be as strong and flexible as when they were new? Why not?  
*No, they will not be as strong. Rust is a different compound to the element iron and so it has different properties. It starts to weaken the objects.*



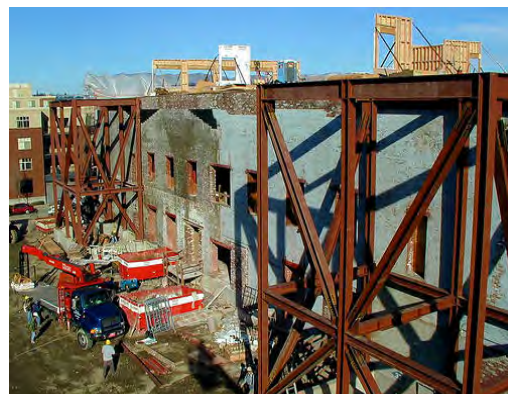


You might have learnt in previous grades that iron can be strengthened, and made more resistant to rust, by mixing it with other elements to turn it into **steel**.

Steel is used in the construction of buildings, because it is very strong. Steel is not completely rust-resistant, however, and needs to be protected against rust, especially in moist and corrosive climates.



*A building under construction. You can see the framework made of steel.*



*Steel reinforcement to support a building. As you can see, steel can also rust.*

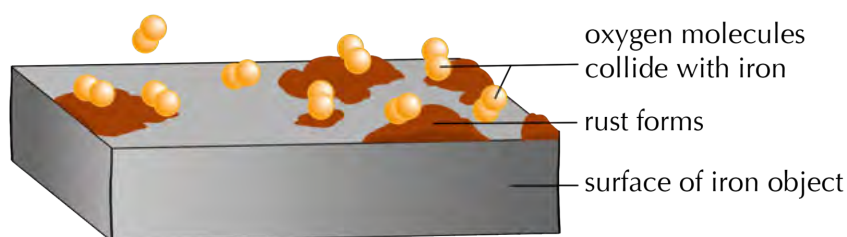
In the next section, we will learn about the different ways in which iron and steel can be protected against rust.

### 3.5 Ways to prevent rust

Rust forms on the surface of an iron or steel object, when that surface comes into contact with oxygen. The oxygen molecules collide with the iron atoms on the surface of the object, and they react to form iron oxide. If we wanted to prevent that from happening, what would we have to do?

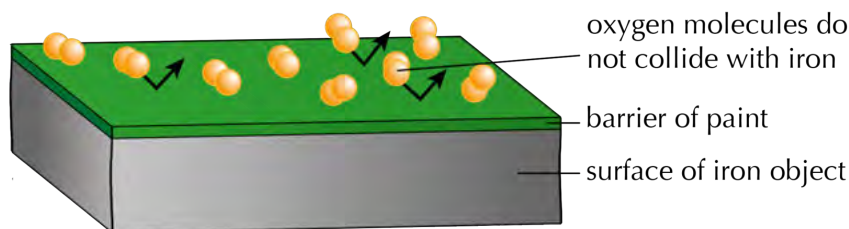
#### TEACHER'S NOTE

We would need to put something between the oxygen and iron so they cannot make contact.



#### Paint provides a barrier to rust

If we wanted to prevent the iron atoms and oxygen molecules from making contact, we would need to place a barrier between them. That is what we are doing when we paint an iron surface to protect it from rust.



Paint is not the ultimate barrier, though. If the paint surface is scratched, or it starts to peel off, the metal will be exposed and rust can still form.

### Other metals as barriers to rust

Rust is a porous material. This means that air and water can penetrate through the rust on the surface of the object to reach the iron underneath. The iron will continue to corrode even if it has a thick layer of rust covering it. So even though the iron surface is covered, it is not protected, because the oxygen molecules can still reach the iron to react with it.

There are a number of other ways to stop or slow down rust. One way to protect the iron surface is to cover it with a metal that does not corrode, like chromium, for instance. Taps and bathroom fittings are often made of iron that has been 'chromed'. They have been covered with a layer of chromium to protect the iron surface from contact with the air.

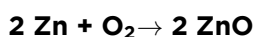


*Chromed taps in a basin.*

#### TEACHER'S NOTE

Ask learners why they think it is especially important for taps in bathrooms and basin to be protected from rust. This is because they are in a moist, humid environment and water makes iron more prone to rust.

Zinc also reacts with oxygen to form zinc oxide:



What group is zinc in?

#### TEACHER'S NOTE

Group 12.

Zinc oxide (ZnO) is not a porous oxide, but forms a dense protective layer that cannot be penetrated by oxygen or water. Iron can be coated with a thin layer of zinc in a process called **galvanising**. The zinc layer quickly reacts with

#### VISIT

Corrosion and rust (video)  
[bit.ly/168tsJx](https://bit.ly/168tsJx)

#### VISIT

Rust formation and how to prevent it (video)  
[bit.ly/19YitDO](https://bit.ly/19YitDO)

#### TAKE NOTE

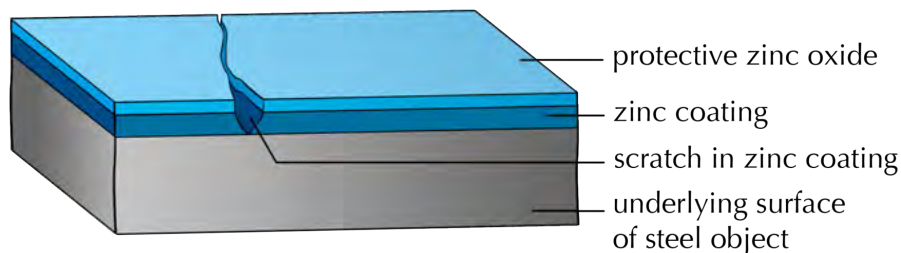
Zinc is in a different group to iron on the Periodic Table. This tells us that it does not react the same way as iron does with oxygen.

oxygen to become zinc oxide. This layer protects the zinc underneath it from being further oxidised. It also protects the iron underneath the zinc from contact with oxygen.

The following diagram shows a segment of galvanised steel, with a scratch in the protective coating. What do you think will happen to the steel that is exposed to the air by the scratch in the coating?

### TEACHER'S NOTE

The exposed steel will rust over time.



*A segment of galvanised steel, showing damage to the zinc coating.*

### VISIT

Why do apples turn brown?  
(video) [bit.ly/17iQvh2](https://bit.ly/17iQvh2)

Iron that is galvanised is used for many different purposes. You would most probably have seen it being used as galvanised roof panels or other galvanised building materials, such as screws, nails, pipes, or floors.



*Galvanised panels used for walls or roofs.*



*A galvanised watering can.*



*Galvanised nuts and bolts.*



*Galvanised flooring.*

In this chapter we learnt how metal oxides form. We saw two demonstrations of reactions in which metals oxides formed as products. Finally, we learnt about a metal oxide (iron oxide or rust) from our everyday experience as well as ways to prevent objects from rusting, especially those used in buildings and industry.

### TEACHER'S NOTE

If you would like to read more about why apples turn brown to explain this to your learners in more detail, visit this website: [bit.ly/13unyg1](http://bit.ly/13unyg1)

## SUMMARY:

### Key Concepts

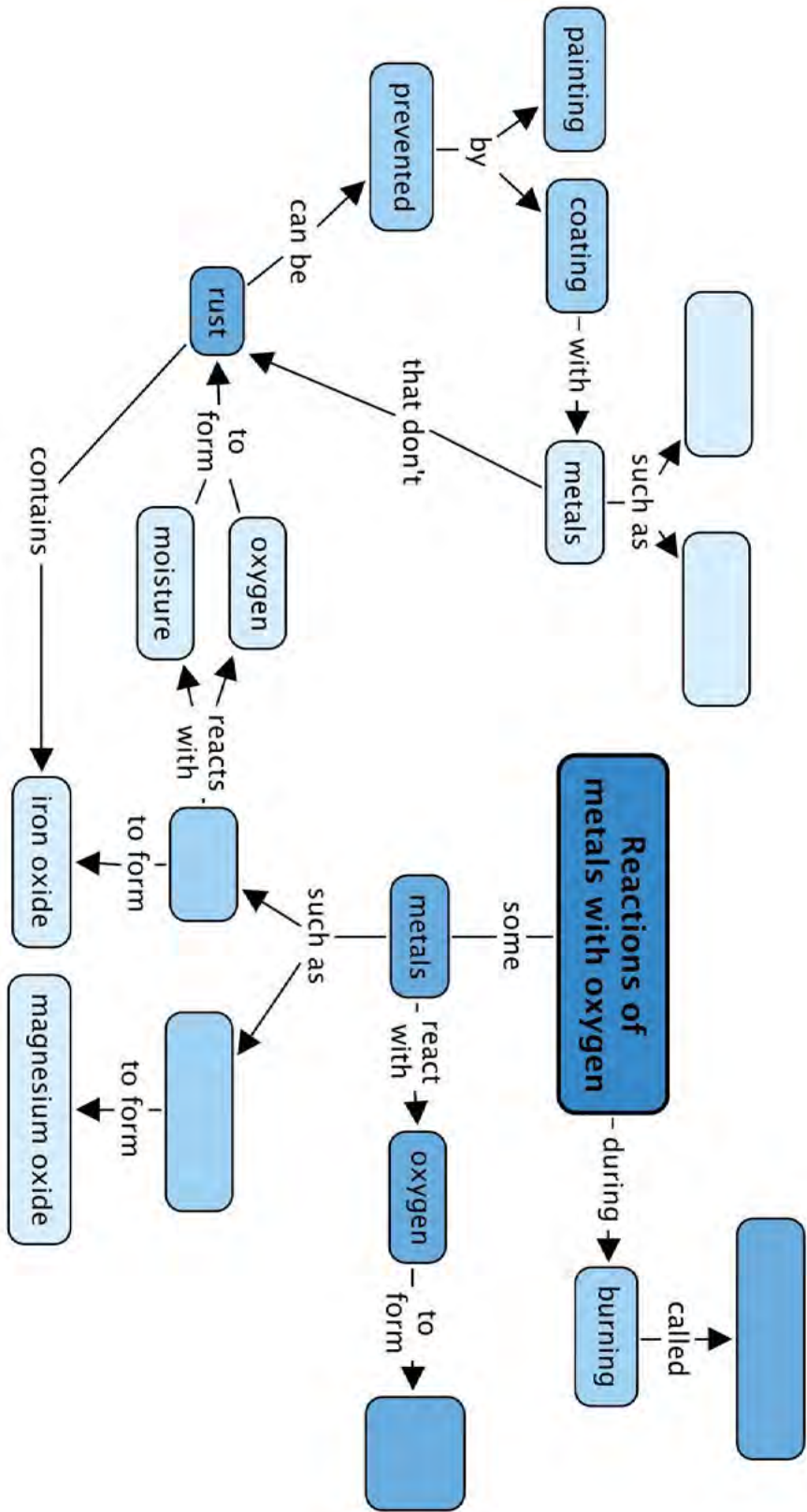
- When a metal reacts with oxygen, a metal oxide forms.
- The general equation for this reaction is: metal + oxygen → metal oxide.
- Some metals will react with oxygen when they burn. These reactions are called combustion reactions. Two examples of combustion reactions are:
  - Iron reacts with oxygen to form iron oxide:  
 $4 \text{Fe} + 3 \text{O}_2 \rightarrow 2 \text{Fe}_2\text{O}_3$
  - Magnesium reacts with oxygen to form magnesium oxide:  
 $2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO}$
- Rust is a form of iron oxide and it forms slowly when iron is exposed to air.
- Iron can be transformed to steel (an alloy), which is more resistant to rust.
- Rust can be prevented by coating iron surfaces with paint, or with rust-resistant metals such as chromium or zinc.

### Concept Map

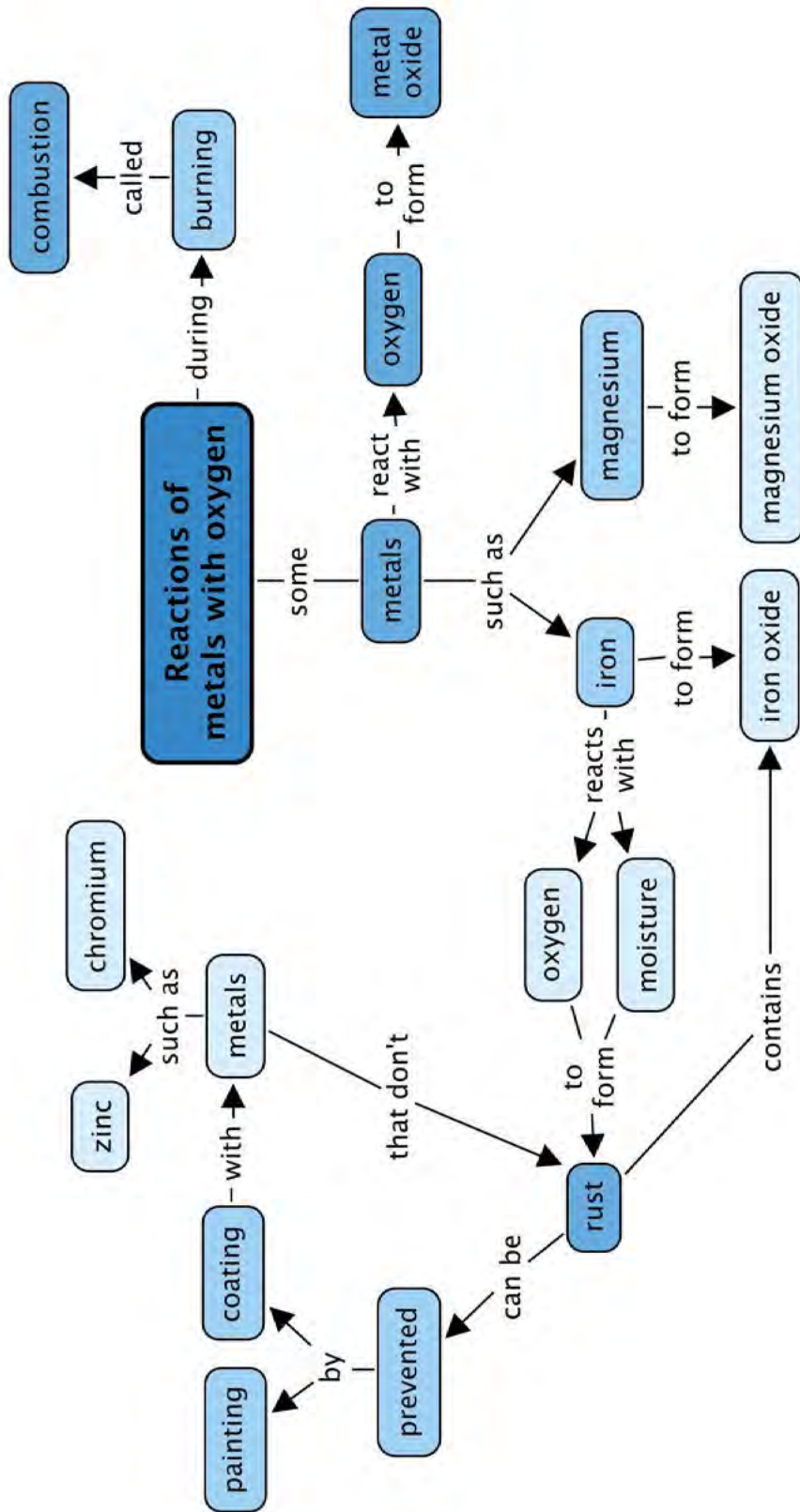
What is the proper name for 'burning'? Fill this into the concept map. Fill in the examples of the metals that you studied in this chapter. You will have to look at the products formed to know where to put which one. Lastly, give two examples of metals that you learnt about in this chapter which do not rust.

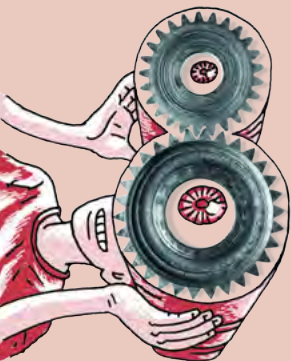












## REVISION:

- Read the sentences and fill in the missing words. Write the missing word on the line below. [9 marks]
  - A chemical reaction where a compound and oxygen react during burning to form a new product is called a \_\_\_\_\_ reaction.
  - Magnesium + \_\_\_\_\_ → magnesium oxide
  - \_\_\_\_\_ + oxygen → iron oxide
  - copper + oxygen → \_\_\_\_\_
  - Another word for iron oxide is \_\_\_\_\_.
  - Metal that is covered by a thin layers of zinc and zinc oxide is called \_\_\_\_\_ metal.
  - The gradual destruction of materials (usually metals) by chemical reaction with the environment is called \_\_\_\_\_.
  - When the air in a specific area contains moisture mixed with acid or salt, we refer to the area as having a \_\_\_\_\_ climate.
  - The product of the reaction between a metal and oxygen is called a \_\_\_\_\_.

- combustion*
- oxygen*
- Iron*
- copper oxide*
- rust*
- galvanised*
- corrosion*
- corrosive*
- metal oxide*

- List three materials that can be used to protect iron or steel from corrosion. [3 marks]

- paint*
- chromium*
- zinc*

- Complete the table by providing the missing equations for the reaction between iron and oxygen [4 marks]

<i>Word equation</i>	<i>iron + oxygen → iron oxide</i>
<i>Chemical equation</i>	$4 \text{Fe} + 3 \text{O}_2 \rightarrow 2 \text{Fe}_2\text{O}_3$
<i>Picture equation</i>	

- Complete the table by providing the missing equations for the reaction between magnesium and oxygen [4 marks]

<i>Word equation</i>	<i>magnesium + oxygen → magnesium oxide</i>
<i>Chemical equation</i>	$2 \text{Mg} + \text{O}_2 \rightarrow 2 \text{MgO}$
<i>Picture equation</i>	

5. Complete the table by providing the missing equations for the reaction between copper and oxygen [4 marks]

<i>Word equation</i>	<i>copper + oxygen → copper oxide</i>
<i>Chemical equation</i>	$2 \text{Cu} + \text{O}_2 \rightarrow 2 \text{CuO}$
<i>Picture equation</i>	

6. Complete the table by providing the missing equations for the reaction between zinc and oxygen [6 marks]

<i>Word equation</i>	<i>zinc + oxygen → zinc oxide</i>
<i>Chemical equation</i>	$2 \text{Zn} + \text{O}_2 \rightarrow 2 \text{ZnO}$
<i>Picture equation</i>	

Total [30 marks]



**TEACHER'S NOTE****Chapter overview**

1 week

In this chapter learners encounter the reactions of the non-metals, carbon and sulfur [Note: the internationally accepted spelling is now 'sulfur', not 'sulphur',] with oxygen. Once again, the translation between word equation, picture equation and chemical equation is reinforced with exercises and examples.

There are no demonstrations prescribed by CAPS for this chapter, but we have included colourful photographs to provide learners with some experience of the splendour of these reactions. Since chemical reactions can seem quite abstract to learners and learning about them in isolation may seem to them as if it lacks relevance, we have also attempted to provide some real-world context to the examples in this chapter.

At the end of the chapter a few additional non-metals and their reactions with oxygen have been included as enrichment. You may choose to omit these, but they do highlight an important point, namely that not all non-metals form non-metal dioxides when they react with oxygen. Since both central examples of this chapter result in non-metal dioxides (viz.  $\text{CO}_2$  and  $\text{SO}_2$ ), one should be mindful of the possible introduction of a misconception in this regard.

4.1 The general reaction of non-metals with oxygen (0.5 hours)

4.2 The reaction of carbon with oxygen (1 hour)

Tasks	Skills	Recommendation
Activity: Coal burning in air	Drawing, balancing chemical equations	Optional (Suggested)

4.3 The reaction of sulfur with oxygen (1 hour)

Tasks	Skills	Recommendation
Activity: The reaction between sulfur and oxygen	Analysing, balancing chemical equations, drawing, modeling	CAPS suggested

4.4 Other non-metal oxides (0.5 hours)

This is an optional, extension section.

## KEY QUESTIONS:

- What happens when a non-metal and oxygen react?
- What is the product called?
- How should we write equations for the reactions of carbon and sulfur with oxygen?
- Do all non-metals form dioxides with oxygen?



Oxygen is all around us in the air we breathe. It is a very **reactive** element. When an element is reactive, it means that it will readily react with many other substances. We saw evidence of the reactive nature of oxygen when we observed how it reacted with iron and magnesium to form metal oxides.

In this chapter we look at a few reactions of non-metals with oxygen. Where do we find non-metals on the Periodic Table?

### TEACHER'S NOTE

On the right.

## 4.1 The general reaction of non-metals with oxygen

When a non-metal burns in oxygen, a **non-metal oxide** forms as product. Here is the word equation for the general reaction:

**non-metal + oxygen → non-metal oxide**



Can you see that it looks similar to the word equation for the reaction between a metal and oxygen? The only difference is that the word 'metal' has been replaced with 'non-metal' on both sides of the equation. Non-metal oxides have different chemical properties to metal oxides. We will learn more about this later on in the term.

### TEACHER'S NOTE

An important chemical difference between metal and non-metal oxides is that when metal oxides dissolve in water, they form basic solutions and when non-metal oxides dissolve in water, they form acidic solution.

Let's look at a few specific examples of reactions in which non-metals react with oxygen. The first one is one that you are already familiar with, namely the reaction of carbon and oxygen.



## 4.2 The reaction of carbon with oxygen

### TAKE NOTE

Substances that are not reactive are called unreactive or **inert**.

Have you ever seen coal burning in air?

Coal is a form of carbon that is used as **fuel** for many different purposes. It is one of the primary **fossil fuels** that humans use to **generate** electricity for powering our industries, our activities and our living spaces. We will look at this in more detail next term in Energy and Change.



*Coals burning in a fire.*



*A coal-powered power station.*

### TEACHER'S NOTE

Learners should have encountered the topics coal, fossil fuels, renewable and non-renewable energy sources and electricity generation in previous grades (specifically in Gr 6 and 7 Energy and Change) and they will also look at it again next term.



### ACTIVITY: Coal burning in air

The energy in coal comes from the energy stored in plants and other organisms that lived hundreds of millions of years ago. Over the millennia, layers of dead plants and other biological waste were covered by layers of water and soil. The heat and pressure from the top layers caused the plant remains to turn into energy-rich coal.



The energy released by burning coal is used to generate electrical energy in coal-powered power stations.

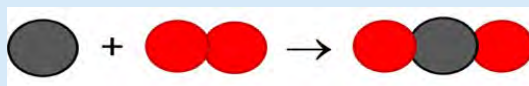
Coal is a form of carbon and when it burns in oxygen we can represent the reaction with the following word equation:

**carbon + oxygen → carbon dioxide**

Draw a picture equation for this reaction in the space below.

#### TEACHER'S NOTE

In the picture equation here, the black atoms are carbon (C) and the red atoms are oxygen (O). If learners do not have coloured pens or pencils, they can use patterns and shading to differentiate between different atoms.



Convert the picture equation into a chemical equation. Is it balanced?

#### TEACHER'S NOTE

The chemical equation is  $C + O_2 \rightarrow CO_2$ . This equation is already balanced.

What group is carbon in on the Periodic Table?

#### TEACHER'S NOTE

Group 14.

The other elements in the same group as carbon will react in the same way as carbon with oxygen.

Since coal is a **non-renewable** energy source as well as one that causes pollution and other environmental problems, scientists and engineers continue to look for alternative fuels and energy sources to eventually replace coal as an energy source. Can you think of the names of some **alternative, renewable** energy sources?

**TEACHER'S NOTE**

Wind energy, solar energy, biofuels, nuclear energy (the latter is not strictly renewable). This content is not included in CAPS (as part of the Grade 9 Matter and Materials requirements). The question has been included in an attempt to create some relevance. The topic of chemical reactions is an abstract one and it often helps to provide some real-world applications to link it to other, less abstract including learners' own experience. This will also link to what learners will cover next term in Energy and Change.

In the next section, we are going to look at the formation of another, less well-known, non-metal oxide named sulfur dioxide. Which non-metal do you think reacts with oxygen to form sulfur dioxide? See if you can write down the formula for sulfur dioxide before we carry on. Here is a hint: What does the *di-* in *dioxide* mean?

**TEACHER'S NOTE**

The non-metal is Sulfur (S). To write the formula, you may need to guide learners to realise there are 2 oxygen atoms in one molecule of sulfur *dioxide*: SO<sub>2</sub>

### 4.3 The reaction of sulfur with oxygen

What is the name of the product of the reaction between sulfur and oxygen? Use the name of the product and the general equation given at the start of the chapter to complete the following word equation:

**sulfur + oxygen** →

**TEACHER'S NOTE**

The equation should read: sulfur + oxygen → sulfur dioxide

**VISIT**

A video on sulfur burning in oxygen [bit.ly/15tuqdl](http://bit.ly/15tuqdl)

Sulfur burns in oxygen to form sulfur dioxide. Your teacher will not demonstrate this reaction, because the sulfur dioxide that forms is a poisonous gas that you and your classmates should not be exposed to.



*Sulfur is a yellow substance and it burns with a blue flame in oxygen.*



*Sulfur mining is very dangerous to the miners who inhale the toxic sulfur dioxide gas.*

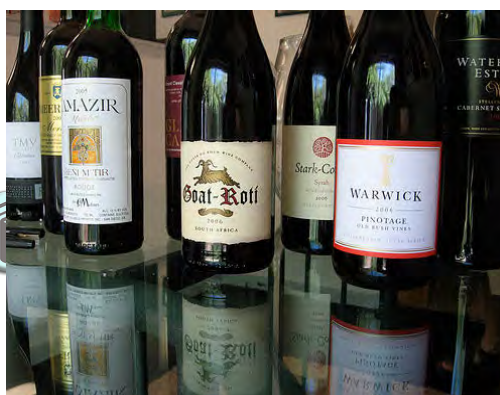
#### VISIT

A video [bit.ly/14CAGmJ](https://bit.ly/14CAGmJ)  
and a photo essay  
[bit.ly/1bofGSI](https://bit.ly/1bofGSI) on sulfur  
mining.

Sulfur dioxide is sometimes used as a **preservative** for dried fruits, such as dried peaches and apricots and the guava rolls that so many of us love to eat. The fact that it is **toxic** means that very small quantities of it can be added to food to preserve it. In very small quantities  $\text{SO}_2$  does not permanently harm a large organism such as a human being, but bacteria cannot survive when it is present. Sulfur dioxide is also an important preservative in many South African wines.



*Dried fruit, such as apricots, are preserved with sulfur dioxide.*



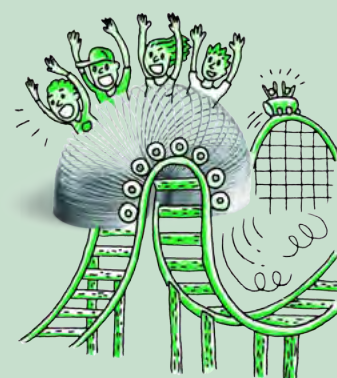
*Many South African wines are preserved with sulfur dioxide.*

### ACTIVITY: The reaction between sulfur and oxygen

In the following activity we are going to review word equations, picture equations and chemical equations, using the reaction between sulfur and oxygen as our context.

You wrote the word equation for the reaction between sulfur and oxygen above. Did you write the following?

**sulfur + oxygen → sulfur dioxide**

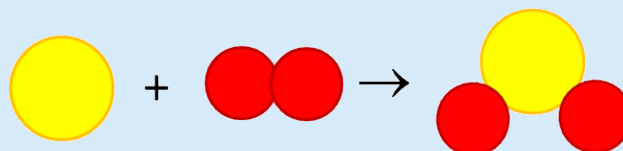


**QUESTIONS:**

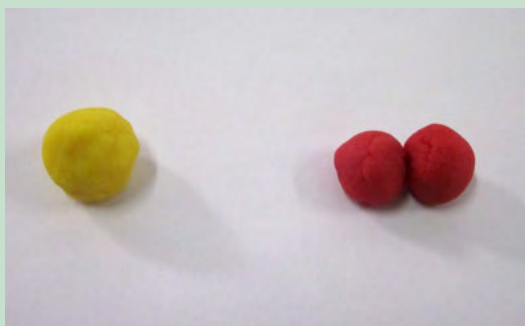
1. What group is sulfur in on the Periodic Table?  
*Group 16*
2. What are the reactants of this reaction? Write their names and formulas.  
*Sulfur (S) and oxygen (O<sub>2</sub>)*
3. What is the product of the reaction? Write its name and formula.  
*Sulfur dioxide (SO<sub>2</sub>)*
4. Now, use the formulas of the reactants and products to write a chemical equation.  
*S + O<sub>2</sub> → SO<sub>2</sub>*
5. When is a reaction balanced?  
*When both sides of the reaction have the same number of the same types of atoms.*
6. Is your reaction above balanced? Why do you say so?  
*The reaction is balanced because it has the same number of S and O atoms on either side of the equation.*
7. Draw a picture equation for the reaction, using the example of carbon above as guide.

**TEACHER'S NOTE**

The picture equation for the reaction is shown below. Colours are not important as long as all atoms of the same element have the same colour. In our example, the sulfur atoms are yellow and the oxygen atoms are red. Chemists have evidence that the actual shape of the SO<sub>2</sub> molecule is not linear; in other words, the atoms do not all lie in a straight line as they do in CO<sub>2</sub>. Rather, the SO<sub>2</sub> molecule is believed to have a bent shape, as it appears in the picture equation. Since the explanation for this shape requires some understanding of bonding models, which are beyond the scope of this level of the curriculum, we recommend that you do not 'go there', but accept 'linear' drawings of the SO<sub>2</sub> molecule as correct.



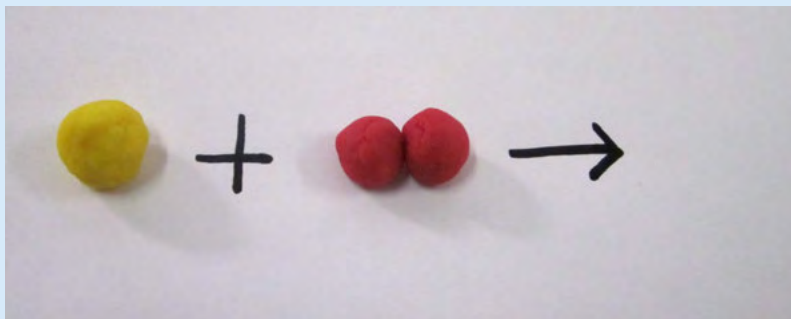
8. Use play dough or clay to build models of the reactants and products of the reaction. This is what your starting reactants could look like:



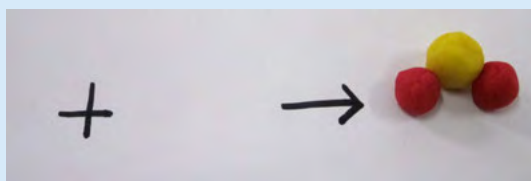


### TEACHER'S NOTE

Provide play dough or modelling clay for this part of the activity. You can also get learners to construct the equation by using sheets of white paper and drawing a '+' and '→'



And then they must rearrange the atoms to form the product as shown here:



You can also repeat this exercise with the other reactions covered so far.

1. **Challenge question:** How many bonds were broken and how many bonds were formed during this reaction?  
*1 bond was broken (between the oxygen atoms) and 2 bonds were formed (1 between each of the oxygen atoms and the sulfur atom)*

### TEACHER'S NOTE

This is an extension question.

## 4.4 Other non-metal oxides

### TEACHER'S NOTE

**Important note:** This is not required by CAPS but is offered as enrichment.

### TAKE NOTE

You might not cover this section in class as it is an extension.

We have looked at two examples of non-metals reacting with oxygen to form non-metal oxides. Both of our examples had a **dioxide** as product (carbon dioxide and sulfur dioxide). Do all non-metals form non-metal dioxides when

they react with oxygen? What do you think?

#### TEACHER'S NOTE

Get learners to discuss this for a moment. You may want to ask if water (H<sub>2</sub>O) is a non-metal oxide. Point out that hydrogen (H) is a non-metal and that water should be a non-metal oxide. Is it a dioxide? No, because it contains only one oxygen. This is important in highlighting how the non-metals in different groups react differently with oxygen.

Not all non-metal oxides are dioxides, as the following examples show.

### The reaction between phosphorus and oxygen

Phosphorus is a very **reactive** non-metal. Can you remember what reactive means?

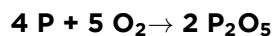
#### VISIT

Video on phosphorus  
burning in oxygen  
[bit.ly/11YyPaD](http://bit.ly/11YyPaD)

#### TEACHER'S NOTE

Ask your learners this question to see what they can remember. Compounds that are *reactive* will readily react with many other substances.

When phosphorus reacts with oxygen the chemical equation for the reaction is the following:



How many phosphorus atoms are in P<sub>2</sub>O<sub>5</sub>? How many oxygen atoms are in P<sub>2</sub>O<sub>5</sub>?

#### TEACHER'S NOTE

There are 2 phosphorus and 5 oxygen atoms.

What is the **systematic name** of the product of this reaction? (If you are unsure how to name it, sneak a peek at the first chapter!)

#### TEACHER'S NOTE

Diphosphorus pentoxide

Can you write a word equation for this reaction?

#### TEACHER'S NOTE

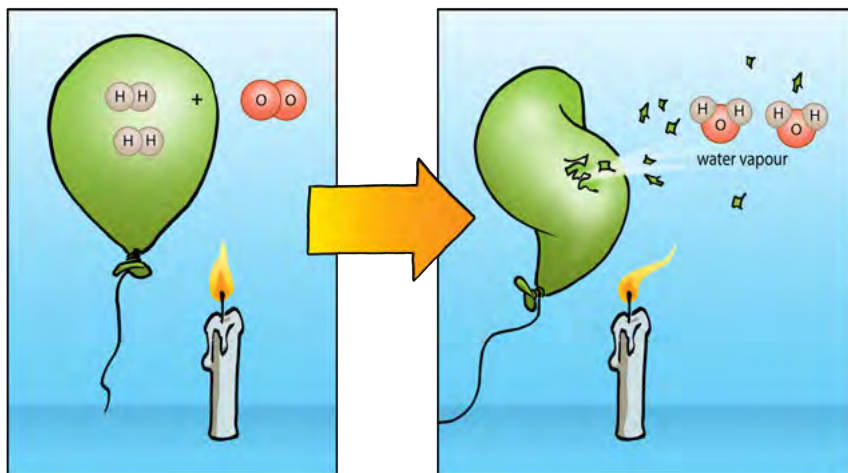
phosphorus + oxygen → diphosphorus pentoxide

Our final example is a compound that you should be very familiar with!

## The reaction between hydrogen and oxygen

Hydrogen and oxygen also react spectacularly. The reaction between a large quantity of hydrogen and oxygen in the air produces a beautiful orange fireball and a very loud boom! (You can watch the video in the visit box to see this in slow motion.)

Here is a diagram to show what is really happening to the compounds in this reaction. The purpose of the candle shown in the picture is to set the hydrogen gas alight, in other words: to provide enough energy for the reaction to start.



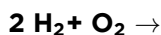
### VISIT

A slow motion video of a hydrogen-filled balloon exploding in air  
[bit.ly/19n32pC](https://bit.ly/19n32pC)

### TEACHER'S NOTE

If you choose to demonstrate this in class, take note of the safety precautions. This is a very explosive reaction and everyone present should wear safety goggles.

Can you complete the following chemical equation? The reaction is between hydrogen and oxygen. Write the product where it belongs.



### TEACHER'S NOTE

$2 \text{H}_2 + \text{O}_2 \rightarrow 2 \text{H}_2\text{O}$ . You can also get learners to practice rearranging the atoms with this equation, making sure they have a balanced equation.

What is the common name of the product of this reaction? What is the systematic name of the product of this reaction? (If you are unsure how to name it, sneak a peek at the first chapter!)

### TEACHER'S NOTE

The common name is water and the systematic name is dihydrogen monoxide.



*In 1937, a German airship exploded and fell to the ground in a huge fireball as the hydrogen gas which kept it floating ignited and reacted with the oxygen in the air.*

**VISIT**

The reaction of hydrogen with oxygen (video)  
[bit.ly/1bofMcl](http://bit.ly/1bofMcl)

In this chapter we learnt about some of the reactions between non-metals and oxygen. Some of the skills that we practised during this chapter were: writing equations (word, picture and chemical equations) and naming compounds.



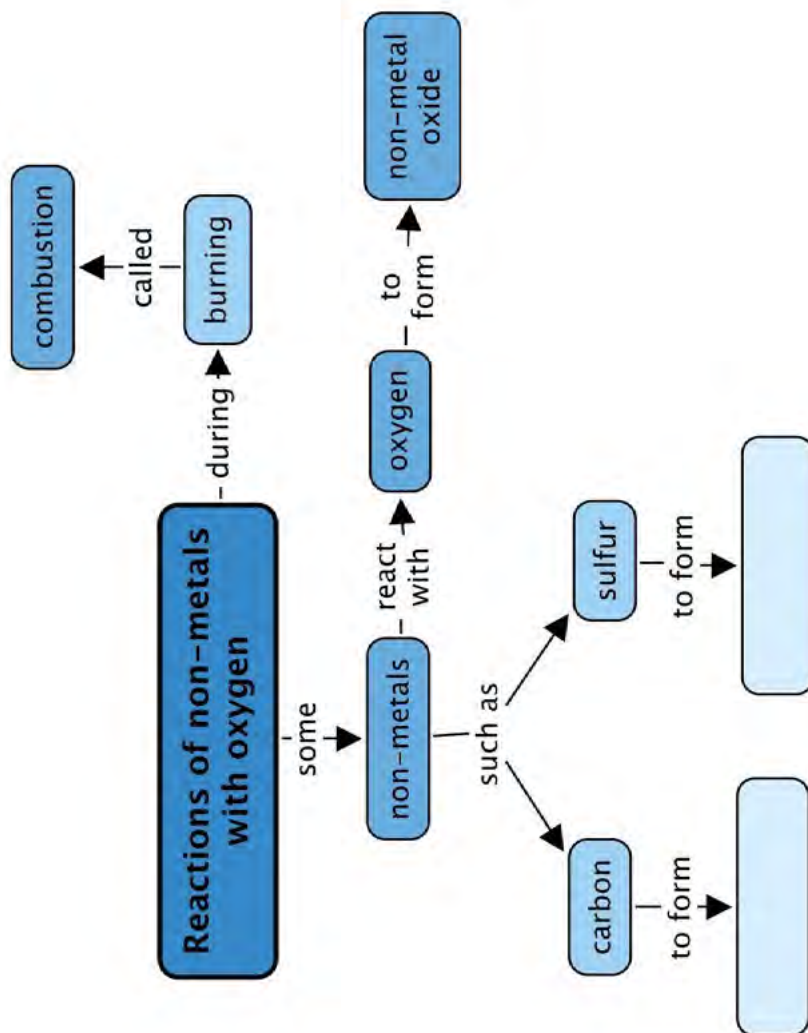
**SUMMARY:**

**Key Concepts**

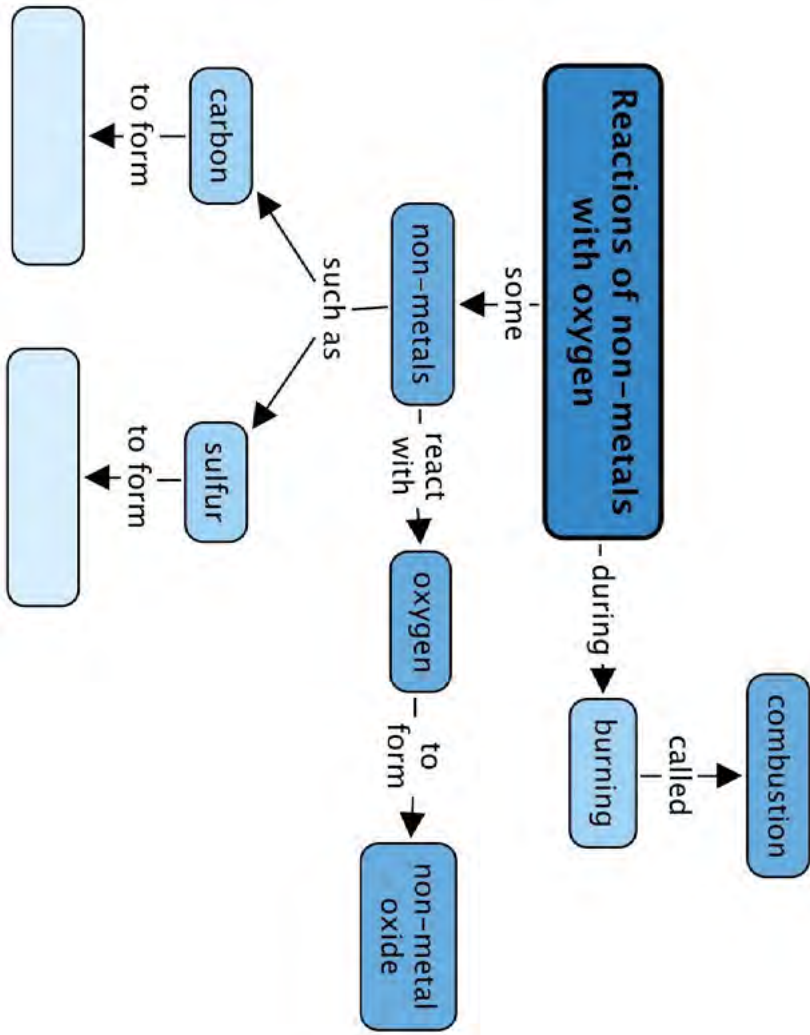
- Non-metals react with oxygen to form non-metal oxides.
- The non-metal and oxygen gas ( $O_2$ ) are the *reactants* in this type of reaction, and a non-metal oxide is the *product*.
- The reactions of carbon and sulfur with oxygen are examples of non-metals reacting with oxygen.
- Carbon and sulfur both form dioxides with oxygen, but this is not true of all non-metals.

**Concept Map**

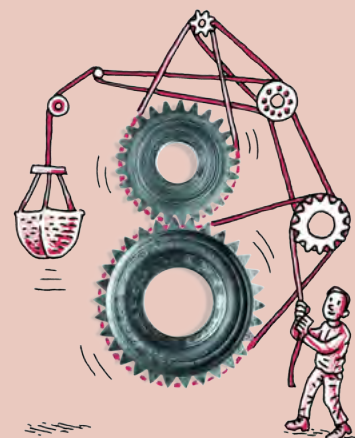
Complete the concept map below. What will you fill in for the products when the two different non-metals react with oxygen during combustion?







## REVISION: Revision questions



1. Fill in the missing words in these sentences. Write the word on the line below. [5 marks]
- A substance that will react readily with many other substances is called a \_\_\_\_\_ substance.
  - Substances that do not react with other substances and do not change into other compounds are called \_\_\_\_\_ or \_\_\_\_\_.
  - When a non-metal reacts with oxygen the product of the reaction is a \_\_\_\_\_.
  - When a compound reacts with oxygen, we say it has become \_\_\_\_\_.
    - reactive
    - unreactive or inert
    - non-metal oxide
    - oxidised
2. Write a short paragraph (3 or more sentences) to explain what you understand each of the following terms to mean, in your own words. [3 x 3 = 9 marks]
- systematic name

*Learner's paragraph should contain at least the following ideas:*

    - The systematic name of a compound is the name that is recognised by IUPAC.*
    - IUPAC refers to the International Union of Pure and Applied Chemistry.*
    - The systematic name of any given compound should be unique so that the compound cannot be confused with any other compound.*
  - preservative

*Learner's paragraph should contain at least the following ideas:*

    - A preservative is a chemical compound that is added to a product (such as a foodstuff or a beverage) to make it last longer.*
    - Most preservatives are poisonous to microorganisms, but are added in such small quantities that they are not harmful to humans.*
    - SO<sub>2</sub> is used as a preservative in many foods, including dried fruit and wine.*
  - non-renewable energy source

*Learner's paragraph should contain at least the following ideas:*

    - Non-renewable energy sources refer to sources that can be used up, such as fossil fuels.*
    - Coal, oil and natural gas are examples of non-renewable fuels.*
    - The energy in these energy sources comes from the energy stored in plants and other living organisms that were fossilised over millions of years.*

3. For each of the following reactions, complete the tables by providing the missing equations.  
 a) The reaction between carbon and oxygen [6 marks]

<i>Word equation</i>	<i>carbon + oxygen → carbon dioxide</i>
<i>Chemical equation</i>	$C + O_2 \rightarrow CO_2$
<i>Picture equation</i>	

- b) The reaction between sulfur and oxygen [6 marks]

<i>Word equation</i>	<i>sulfur + oxygen → sulfur dioxide</i>
<i>Chemical equation</i>	$S + O_2 \rightarrow SO_2$
<i>Picture equation</i>	

Total [26 marks]





**TEACHER'S NOTE****Chapter overview**

1 week

In this chapter, learners are introduced to the pH scale and learn how to measure and interpret pH values. There are two activities around pH measurement in this chapter: One is a paper activity and one is an investigation using indicators. There is an introductory activity on measurement - this helps to link this content to what learners might be doing in other subjects, such as Mathematics and Technology, and also to what they already know about measurement.

The investigation uses universal indicator paper and red cabbage paper to measure the pH of a selection of household products. If you do not have universal indicator paper, but have universal indicator solution, you could easily adapt the activity in the following way: Instead of using paper, learners should add 2 - 3 drops of universal indicator solution to their test solutions, note and record the resulting colours. Red cabbage solution can also be used instead of paper. It would be best to add approximately 1 ml of each test solution to 2 ml portions of the red cabbage water.

To make red cabbage indicator paper, follow the instructions below:

1. Cut a large red cabbage into thin slices and place it in a pot.
2. Add just enough water to cover the cabbage slices.
3. Boil it over low heat for approximately 30 minutes, adding water to keep the cabbage covered if necessary.
4. Remove the pot from the heat and let it cool completely.
5. Strain the juice off the cabbage slices into a large shallow dish. The boiled cabbage slices can be eaten (or placed in the compost).
6. Place sheets of absorbent paper (kitchen towel, coffee filters or filter paper) in the cabbage water.
7. After 30 minutes, remove the paper and leave it in a warm place to dry. You can also dry the paper with a hair dryer, but do not leave it in direct sunlight.
8. When the paper has completely dried, cut it into strips (approximately 1 cm wide). The strips will keep for a long time if stored in a dry place.

The time indicated for this chapter is 1 week and so a suggested 1.5 hours has been allocated to each section. However, as there are only two key tasks in this chapter, you might progress through it at a faster rate than 1 week, and then move onto the next chapter dealing with the reactions of acids with bases, which requires more time.



### 5.1 What is the pH value? (1.5 hours)

Tasks	Skills	Recommendation
Activity: Measuring instruments and units	Identifying, observing,	Optional (Suggested)
Activity: The pH scale	Observing, identifying, remembering	Optional (Suggested)

### 5.2 Indicators (1.5 hours)

Tasks	Skills	Recommendation
Investigation: Universal indicator paper and red cabbage indicator paper	Testing, observing, measuring, recording, analysing, interpreting	CAPS suggested

## KEY QUESTIONS:

- What measurement can we use to decide whether something is an acid or a base?
- What does 'the pH scale' refer to?
- How can we measure the pH of a substance?
- What does it mean if a substance has a pH below 7?
- What does it mean if a substance has a pH above 7?
- What does it mean when a substance has a pH equal to 7?
- How does a universal indicator respond to substances that are acidic, basic, or neutral?



## 5.1 What is the pH value?

In Grade 7 we learnt about acids and bases. Can you remember how to distinguish between them? Here is a table that highlights the main characteristics of acids and bases.

Acids	Bases
Taste sour	Taste bitter
Feel rough between your fingers	Feel slippery between your fingers
Can be corrosive	Can be corrosive
Can make bases lose their basic character	Can make acids lose their acidic character
Turn blue litmus red	Turn red litmus blue

We used the criteria in the table above to classify a number of substances as either acids, bases, or neutral substances. The table below contains some examples and shows their classification.

Acids	Bases	Neutral substances
Orange juice Vinegar Lemon juice Citric acid Gastric acid (stomach acid)	Bicarbonate of soda (baking soda) Soaps Bleach Ammonia solution	Water Table salt solution Cooking oil

Finally, we learnt that there are substances that we can use that will show whether we have an acid or a base. Can you remember what they were called? Hint: They *indicate*, or show, whether we have an acid or base.

### TEACHER'S NOTE

Indicators

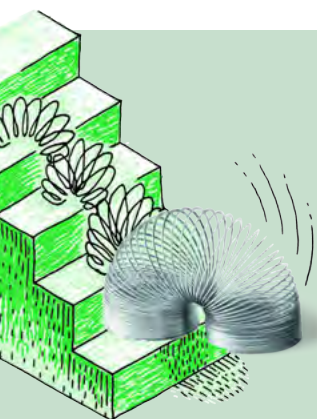
Indicators can show us if a substance is an acid or a base. In this chapter we are going to link some important new learning to what we already know about acids and bases.

### A word or two on measurement

### TEACHER'S NOTE

This section briefly creates the link between what learners might have done in other subjects and in previous grades about measurement and scales, especially Mathematics. It is used to show that many things can be measured and is used to introduce the idea of measuring how acidic or basic a substance is, as before this we only ever classified a substance as an acid or a base and did not make reference to a scale.

Let us talk briefly about 'measuring'.



## ACTIVITY: Measuring instruments and units

What would you measure with each of the measuring instruments below?

The measuring tape and ruler measure...



*Measuring tapes and a ruler*

**TEACHER'S NOTE**

length or distance

The balance measures...

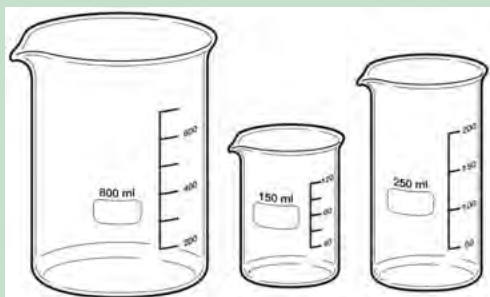


*A triple beam balance.*

**TEACHER'S NOTE**

Mass. Make sure learners do not say 'weight'. This is a misconception.

These measuring beakers measure...



*Different size beakers.*

**TEACHER'S NOTE**

volume

The thermometer measures...



*A thermometer.*

**TEACHER'S NOTE**

temperature

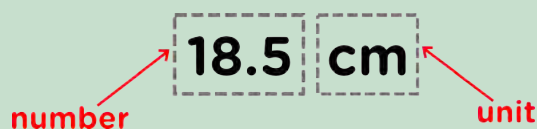
A measurement always consists of two things: a number and a **unit**. To explain what this means, let's imagine we are measuring the length of a pencil.



What is the length of the pencil in the picture?

**TEACHER'S NOTE**

18.5 cm



The unit is a very important part of the measurement because it shows the relative size of the measurement. If you said: "The pencil is 18.5 long", people would not be sure if you meant centimeters, millimeters, or even meters!

What unit would you use to measure the length of your classroom?

**TEACHER'S NOTE**

Meter (m). Centimeter is also acceptable. What learners need to realise is that the unit needs to be made explicit.

What unit would you use to measure your mass?

**TEACHER'S NOTE**

kilogram (kg)

What unit would you use to measure temperature?

**TEACHER'S NOTE**

degrees Celsius (°C)

Can we 'measure' how acidic or basic a substance is?

## Measuring acidity and basicity

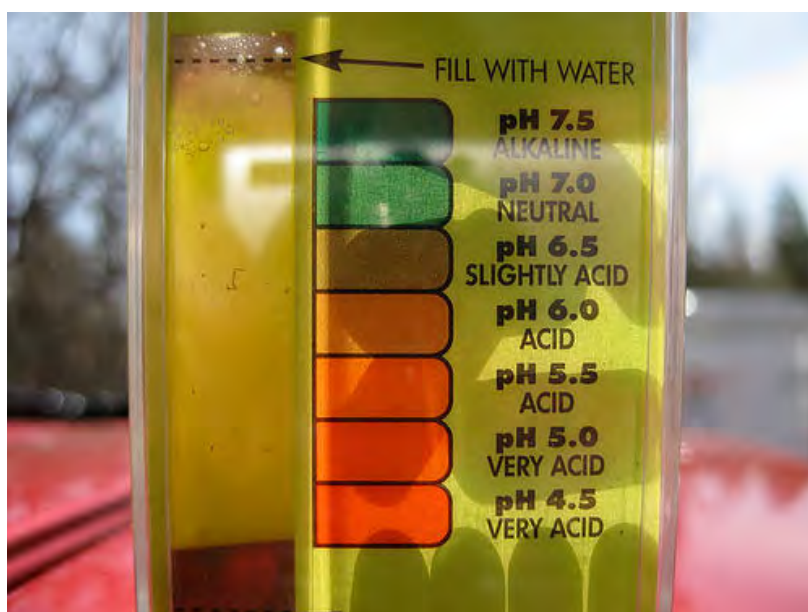
The unit that we use to measure the **acidity** of a substance (how acidic that substance is) is called **pH**. We pronounce the two letters, 'p' and 'H' separately when we say pH.

Have you ever heard the term pH?

### TEACHER'S NOTE

Get learners to discuss this in class for a few minutes. Perhaps they have seen adverts on TV claiming that a certain brand of shampoo or skin soap is 'pH balanced'. Ask them what they think this means.

Perhaps you have heard of a certain shampoo being 'pH balanced', or a skin soap that is 'neutral'. Perhaps you have heard that it is important for the water in a swimming pool to have 'the right pH'?



*A kit for testing swimming pool water pH.*

The pH scale ranges between the values of 1 and 14.

In science and in everyday life, we measure the acidity of substances in pH **units**. We could say that the 'acidity' of a specific shampoo has a pH of 5.5. pH is the unit of measurement and 5.5 is the number indicating the relative acidity on the pH scale. It has become acceptable, however, for us to rather say: "The pH of this shampoo is 5,5."

In the next activity, we are going to get to know the pH scale a little better.

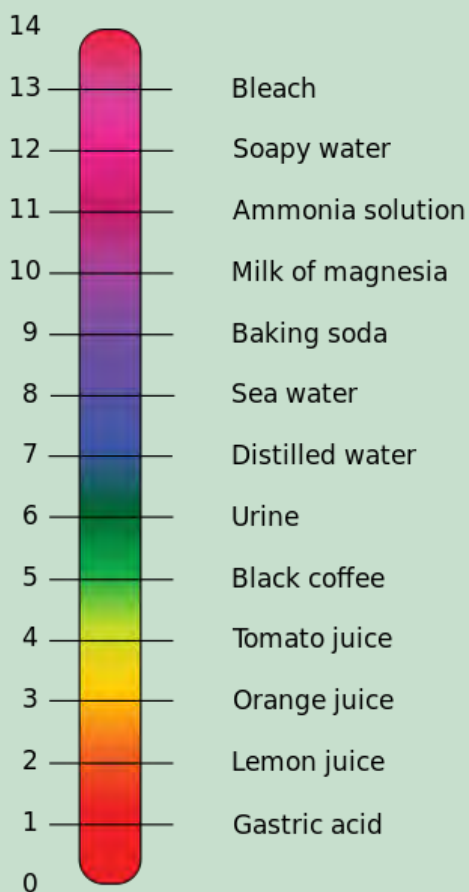




## ACTIVITY: The pH scale

### INSTRUCTIONS:

1. In the following picture the pH values of a variety of substances are shown on the pH scale
2. Use the picture to answer the questions.



*The pH scale.*

### QUESTIONS:

1. Which of the substances in the table at the start of this chapter can you find on the pH scale above? Write their names and approximate pH values in the table below.

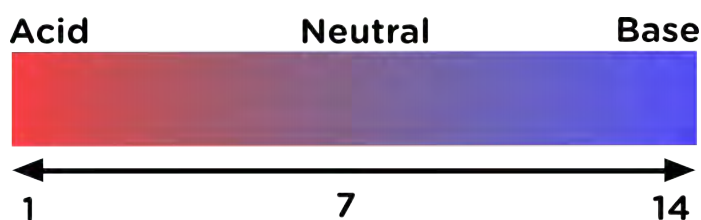
Name of substance	Approximate pH
Gastric acid	1
Lemon juice	2
Orange juice	3
Distilled water	7
Baking soda (solution)	9
Ammonia solution	11
Soapy water	12
Bleach	13

- Circle the names of all the acids in the table above with a red pen or koki.  
*Learners should circle orange juice, lemon juice and gastric acid in red.*
- Write the lowest and highest pH values of these acids. This represents the pH range of the acids on our list.  
*Lowest value: 1 (gastric acid); Highest value: 3 (orange juice)*
- Does this range lie below or above pH 7?  
*Below 7*
- Circle the names of all the bases in the table above with a blue pen or koki on the pH scale above.  
*Learners should circle bicarbonate of soda, soapy water, bleach and ammonia solution in blue.*
- Write the lowest and highest pH values of these bases below. This represents the pH range of the bases on our list.  
*Lowest value: 9 (baking soda); Highest value: 13 (bleach)*
- Does this range lie below or above pH 7?  
*Above 7*
- Find water on the scale and circle it with a green pen or koki. Is water an acid or a base? Or is it perhaps something else?  
*Water is neither an acid nor a base. Water is a neutral substance.*
- What is the pH of water?  
*Water has a pH equal to 7.*
- Which do you think is more acidic: orange juice or lemon juice? If you are not sure, ask yourself this question: Which one is more sour?  
*Lemon juice is more acidic.*
- Which one has the lower pH: orange juice or lemon juice?  
*Lemon juice has a lower pH.*

In the above activity we learnt a number of important things:

- Acids have pH values below 7;
- Bases have pH values above 7; and
- Neutral substances have pH values equal to 7.

This information has been summarised visually in the following diagram.



We saw in the activity that lemon juice, which is more sour than orange juice,

has a lower pH than orange juice. Does that mean that the relative pH of a substance will tell us *how* acidic or basic it is?

### Can we measure how acidic or basic something is?

When we compared orange juice and lemon juice earlier, we learnt something important: The lower the pH of a substance, the more acidic it is. For bases we can state the following: The higher the pH of a substance, the more basic it is.

Here is a summary:

- The closer to pH 1, the more strongly acidic the solution;
- The closer to pH 14, the more strongly basic the solution; and
- pH 7 is a neutral substance.

We have learnt that the pH value of a substance tells us if it is an acid or a base. But how do we measure pH? One way to measure pH is with the help of acid-base indicators. Can you remember what they are? The next section will refresh your memory.

**VISIT**  
Now that you have learnt about pH, test your knowledge with this fun online game  
[bit.ly/13dHNnm](http://bit.ly/13dHNnm)

## 5.2 Indicators

### What is an acid-base-indicator?

We know that some substances change colour when they react with an acid or a base. These substances are called acid-base **indicators**, which can show us if a substance is an acid or a base.

Different indicators change colour at different pH values. The table below shows a selection of acid-base indicators and the colours they will have at different pH values.



Indicator	Colour in acid (pH < 7)	Colour at pH = 7	Colour in base (pH > 7)
Red cabbage water	red, pink	purple	blue, green, yellow
Red onion water	red	violet	green
Turmeric water	yellow	yellow	red
Phenolphthalein	colourless	colourless	pink, red
Bromothymol blue	yellow	green	blue
Red litmus	red	red	blue
Blue litmus	red	blue	blue
Universal indicator	red, orange, yellow	green	Blue, violet, purple

In Grade 7 we made an indicator from red cabbage and even made some **red cabbage indicator** paper. Can you find red cabbage water on the table above? In acids, the red cabbage water will turn red or pink. In neutral solutions it will be purple or violet. Which colours will the red cabbage indicator be when it is mixed with a base?

## TEACHER'S NOTE

Blue, green or yellow

### VISIT

Red cabbage chemistry  
[bit.ly/17lpPoQ](http://bit.ly/17lpPoQ)

If red cabbage indicator is mixed with something that is only slightly basic, it will turn blue. If it is mixed with something that is strongly basic, it will turn yellow.

When you look at the table above and you compare the information given for red cabbage water with the picture below, the colour changes you observed in the red cabbage water (in Grade 7) will make sense!



Red cabbage water mixed with base (left) and with acid (right). The blue drop at the top is the juice in a neutral solution (water).

### VISIT

Cabbage juice indicator  
[bit.ly/17lBR8](http://bit.ly/17lBR8)



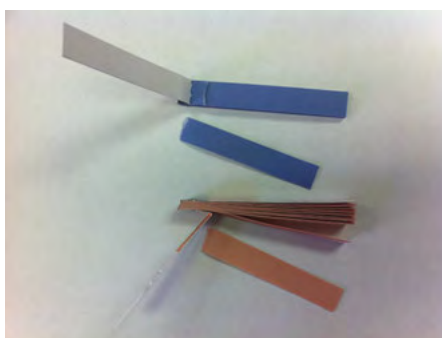
You may recall that we also learnt about **litmus**, the most widely used of all acid-base indicators. Can you find litmus on the table of indicators?

Litmus does not change colour in the presence of a neutral substance, but responds to acids and bases in the following way:

- litmus is red in the presence of an acid; and
- litmus is blue in the presence of base.

Litmus can be bought as a solution or as litmus paper, although the paper is more commonly used.

By changing to different colours in the presence of an acid or a base, indicators can show us if a substance is an acid or a base. In the next section we are going to learn about a special indicator that is so sensitive that it not only tells us whether a substance is an acid or a base, but also what its approximate pH is!



Blue and red litmus paper

**VISIT**

Video showing universal indicator [bit.ly/168rf05](http://bit.ly/168rf05)

**Universal indicator**

Unlike litmus, **universal indicator** can show us much more accurately how acidic or basic a solution is. Can you find universal indicator on the previous table of indicators? Universal indicator can change into a whole range of colours, depending on the pH of the solution. In the following picture, solutions of increasing pH were mixed with universal indicator to show its full range of colours.



*Universal indicator can have many different colours, from red for strong acids to dark purple for strong bases. The liquid inside the middle test tube is neutral (pH = 7) and this is shown by the green colour of the indicator.*

Like litmus, universal indicator also comes in paper form, with the pH colour range of the indicator printed on the packaging.

In the next investigation we will test a number of household substances with red cabbage indicator paper and with universal indicator paper.



**INVESTIGATION:** Universal indicator paper and red cabbage indicator paper

The purpose of this investigation is to determine whether universal indicator and red cabbage can be used to show whether one substance is more acidic or basic than another.

**INVESTIGATIVE QUESTION:**

What question are we trying to answer with this investigation?





### TEACHER'S NOTE

Learners can formulate their own question, but it should be something along the following lines: Can universal indicator paper and red cabbage indicator paper show us whether one substance is more acidic or basic than another?

### HYPOTHESIS:

What do you think the answer to the investigative question is? You should try to make a prediction.

### TEACHER'S NOTE

Learners should make their own prediction/hypothesis.

### IDENTIFY VARIABLES:

1. What will you be changing in this investigation? What is this variable called?  
*We will change the substances that we are testing. The independent variable is the one that is changed.*
2. What will you be measuring in this investigation? What is this variable called?  
*We will measure the pH. This is the dependent variable.*
3. What will you keep the same? What is this variable called?  
*The controlled variable is the type of indicator that we are using in the measurement, namely the universal indicator paper or the red cabbage paper.*

### MATERIALS AND APPARATUS:

- small containers (test tubes or yoghurt tubs) containing the following substances:
  - clean water
  - soda water
  - vinegar
  - lemon juice
  - sugar solution (1 tablespoon dissolved in a cup of water)
  - baking soda (bicarbonate of soda) (1 tablespoon dissolved in a cup of water)
  - Handy Andy (1 tablespoon dissolved in a cup of water)
  - aspirin (Disprin) (1 tablet in 2 tablespoons of water)
  - dishwashing liquid (1 teaspoon dissolved in a cup of water)
  - any other substances commonly used at home that are not dangerous. Do not use strong acids or bases, or bleach. Suggestions include: tea, coffee, rooibos tea, milk, tartaric acid, salt water, Sprite.
- universal indicator paper
- red cabbage indicator paper
- glass or plastic rods (plastic teaspoons or straws will also work well).
- white tile or sheet of A4 printer paper.

### METHOD:

1. Use a small strip (1 cm long) of universal indicator paper for each substance that you will be testing. Place them on a sheet of printer paper or a white tile.

2. Dip the glass rod or straw into the first solution and transfer a drop of it to the first piece of universal indicator paper. Does the paper change colour? Write the colour of the paper with each substance in your table, in the appropriate place.
3. Compare the colour of the test strip with the colour range on the packaging of the universal indicator paper roll to find the pH of the solution. Write this in your table as well.
4. Rinse the straw very thoroughly with tap water before testing the next solution. Do so every time you move from one solution to the next.
5. Test all the solutions and record their colours.
6. Save the solutions to now test them again with red cabbage indicator paper.
7. Use a small strip (2 cm long) of red cabbage paper for each substance that you will be testing.
8. Dip a fresh piece of paper into each of the test solutions and place it on the tile or white paper to dry. For each test solution, write the colour of the red cabbage paper in the table in the appropriate place.

**RESULTS AND OBSERVATIONS:**

Record your observations in the table.

Substance	Colour with universal indicator paper	pH of the substance	Colour with red cabbage paper
Water			
Soda water			
Vinegar			
Lemon juice			
Sugar water			
Baking soda			
Handy Andy			
Aspirin			
Dishwashing liquid			

1. Sequence the substances that you tested according to the colour change of the universal indicator, from the most acidic (darkest red) to the most basic (purple).

*The answer here depends on the results and the substances used.*

**QUESTIONS:**

1. Which of the test substances are acids?  
*Learners should list all the substances that gave pH measurements below 7.*
2. Which of the test substances are bases?  
*Learners should list all the substances that gave pH measurements above 7.*

3. Which of the test substances are neutral substances?  
*Learners should list all the substances that gave pH measurements equal to 7.*
4. Which substance is the strongest acid?  
*Activity-dependent answer.*
5. Which substance is the strongest base?  
*Activity-dependent answer.*
6. Count all the different colours that were possible with the red cabbage.  
*Activity-dependent answer.*
7. What colour(s) did the red cabbage paper turn in the test substances that were acids?  
*The red cabbage paper should turn a red-pink colour in an acid.*
8. What colour(s) did the red cabbage paper turn in the test substances that were bases?  
*The red cabbage paper should turn a blue-green colour in a base.*
9. What colour(s) did the red cabbage paper turn in the test substances that were neutral?  
*The red cabbage paper should turn (or remain) purple with neutral substances.*
10. Do you think red cabbage indicator can be used to actually *measure* pH? Why or why not?  
*Learner-dependent answer. Allow learners to express an opinion here, backed by one or two sentences as motivation.*

#### CONCLUSIONS:

1. What is your conclusion(s)? (Here you should answer the investigative question.)  
*Learner-dependent answer. They should note that universal indicator allows them to measure the pH of individual substances. By arranging the substances in order of increasing pH, they can rank the substances from most acidic to most basic. They should note that red cabbage indicator does give a range of colours with varying pH, but that it is not as effective as universal indicator for measuring pH.*

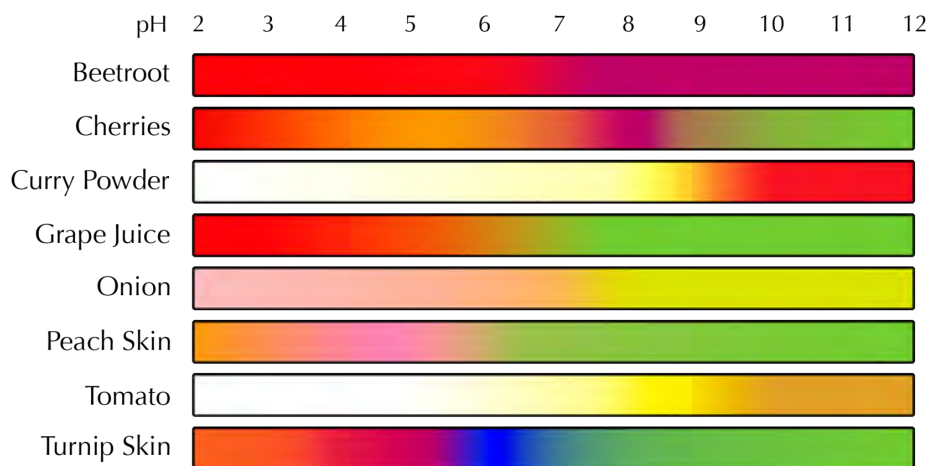
#### Something to think about: Extension question

1. What could we do to make red cabbage indicator suitable for measuring pH?  
*Learners could discuss this question in class if there is time. The important thing here is that each of the colours of the red cabbage indicator needs to be standardised/linked to a specific pH value or range of values. Hence, if we had a range of samples of known pH, we could 'calibrate' the red cabbage solution, by mixing it with each of the pH standards and carefully noting the colour. This would allow us to produce a colour chart, that we could then use in the same way as the one that is available for universal indicator and other commercial indicators.*

In the last investigation we explored whether or not universal indicator paper or red cabbage indicator paper could tell us whether a substance is more acidic or basic than another. The advantage of using universal indicator over other indicators is that universal indicator can give us more accurate pH measurements. This is because it has different colours for different pH values. Most other indicators change colour only once or twice over the entire pH



Many other colourful foods can be used to make acid-base indicators. Check out the diagram below for some examples. You could even try out a few of them at home!



*pH indicators made from edible substances.*

**TAKE NOTE**

Universal indicators give a range of colours that can be used to determine the pH of a solution. Litmus paper can only indicate whether a solution is acidic, neutral or basic.

Measuring pH with indicator solutions or paper is easy, economical and convenient if we have only a few measurements to make. If we have many pH measurements to make, tearing and dipping paper strips and matching them up with a colour chart can become quite tedious and time-consuming.

What other quick and easy ways are there to measure pH?

**How else can we measure pH?**



Scientists use a pH meter to quickly and accurately measure the pH of a substance. While they are much more expensive to purchase than indicator paper or solution, they are a worthwhile investment for a laboratory that has to make many pH measurements daily and need these measurements to be done quickly.



*A portable pH meter.*

A pH meter is an electronic instrument with a special sensor at the end that is sensitive to acids and bases. This is more accurate than the universal indicator. Help the scientist to read the pH of the solutions in the photos and classify them as acidic, neutral or basic!

## TEACHER'S NOTE

The solution on the left has a pH of 7.053 so it is neutral. The solution on the right has a pH of 10.33 so it is basic.

pH meters work as follows: When the sensor is dipped into the test solution, it sends a signal to the electronic circuitry of the pH meter, which is converted to a pH reading on a small LCD screen.

In this chapter we have learnt about the pH scale. We have also learnt how to make pH measurements and how to interpret pH values.



## SUMMARY:

### Key Concepts

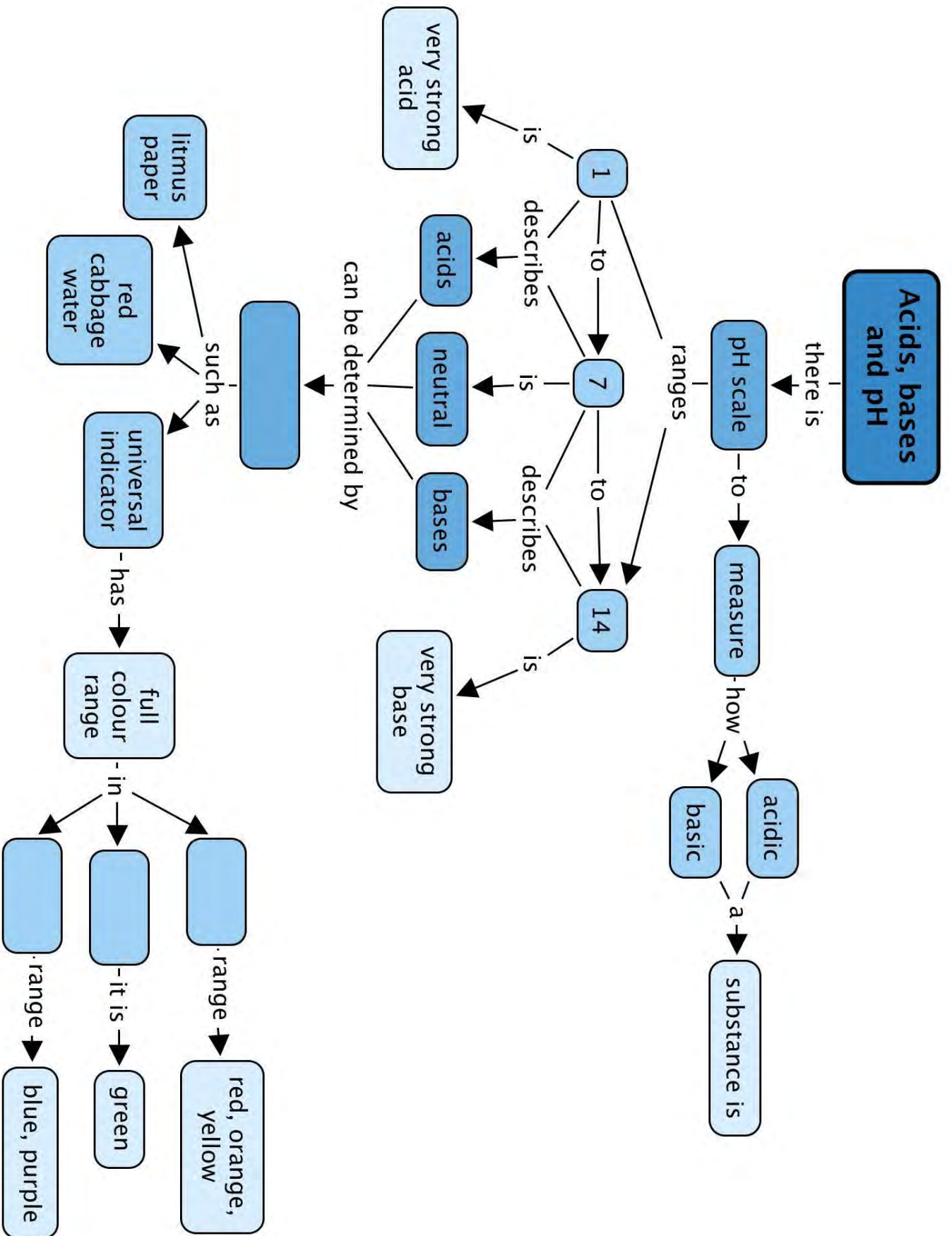
- When we want to decide whether a solution (in water) is acidic or basic, we can measure its pH.
- One of the ways pH can be measured, is with an acid-base indicator, such as universal indicator.
- An acid-base indicator is a substance that changes its colour depending on the pH of the solution that it is added to.
- The pH scale ranges between 1 and 14:
  - Acids have pH values lower than 7;
  - Bases have pH values higher than 7; and
  - Neutral substances have pH values approximately equal to 7.
- How acidic or basic a solution is, depends on its relative pH value:
  - The more acidic a solution is, the closer its pH value will be to 0; and
  - The more basic a solution is, the closer its pH value will be to 14.

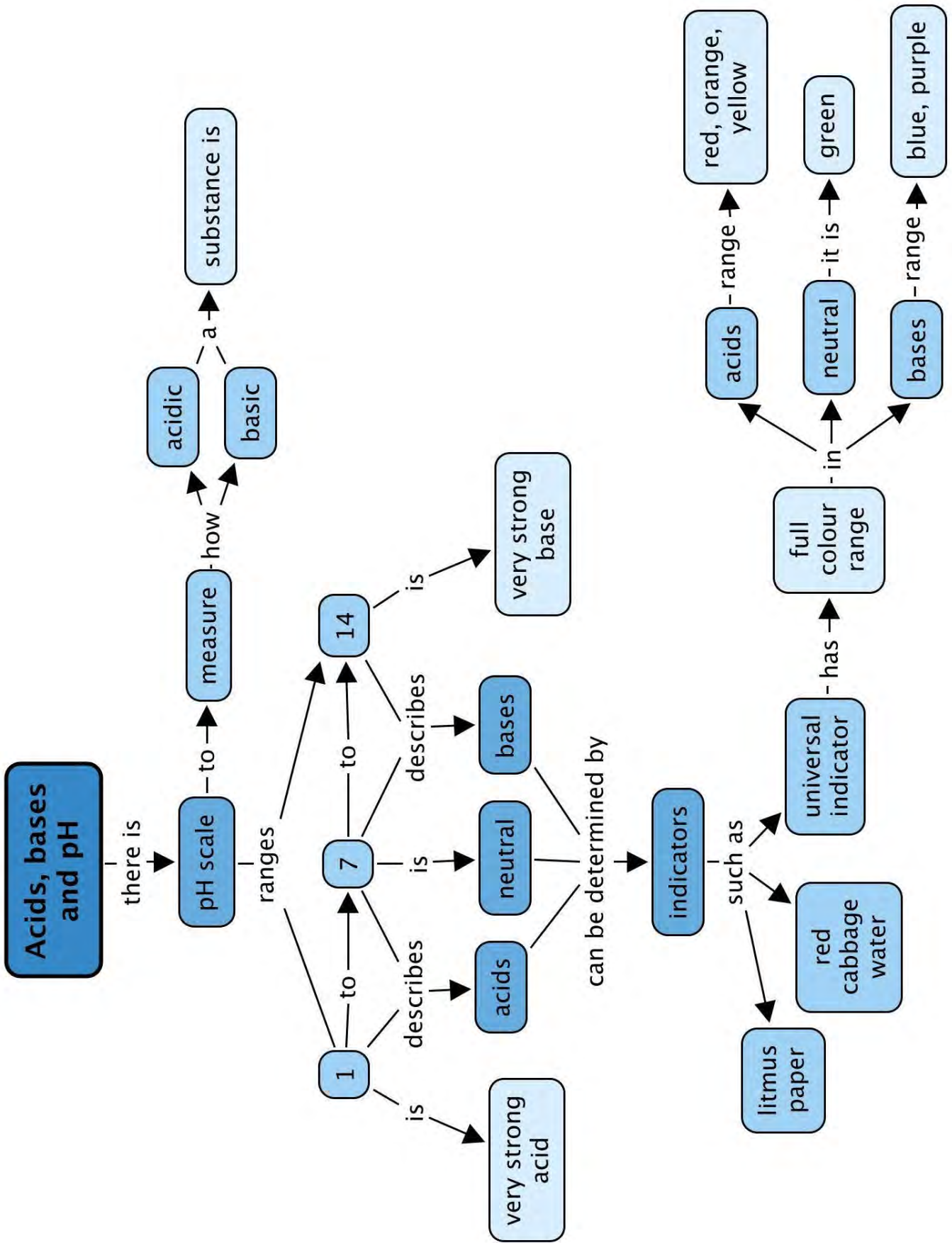
### Concept Map

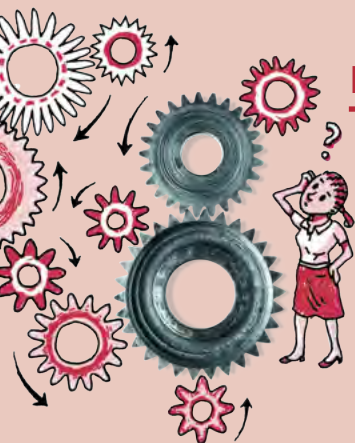
What can you use to determine whether a substance is an acid, base or neutral? Fill this in on the concept map. Finally, complete it by completing the information for the universal indicator. Fill in acid, base or neutral, depending on the colours listed.





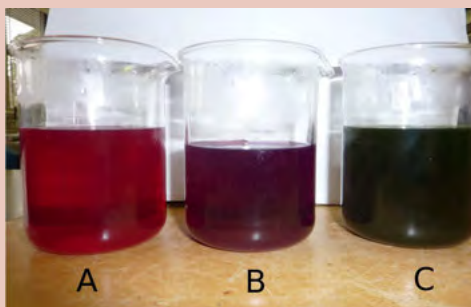






## REVISION:

- Fill in the missing words in these sentences. Write the word on the line below. [6 marks]
  - Something which shows whether a substance is an acid or a base, by changing colour when we add it to that substance, is called an \_\_\_\_\_.  
*indicator or acid-base indicator*
  - The pH scale ranges between the values \_\_\_\_\_ and \_\_\_\_\_.  
*0; 14*
  - \_\_\_\_\_ have pH values less than 7.  
*Acids*
  - Bases have pH values ranging between \_\_\_\_\_.  
*7 and 14*
  - \_\_\_\_\_ substances have pH values approximately equal to 7.  
*Neutral*
- Imagine we start with a beaker of clean, distilled water. Answer the following questions. [4 marks]
  - What will be the pH of the clean, distilled water?  
*The pH will be equal to 7.*
  - How will the pH change if we add a small amount of acid to the water?  
*The pH will decrease.*
  - How could we get the pH to increase?  
*We would have to add a base.*
  - How could we get the pH to increase to a higher value, for example 13?  
*We would have to add a large amount of a strong base.*
- In the following picture, the three beakers contain three different solutions. Red cabbage water was added to each of the beakers. Answer the following questions. [4 x 2 = 8 marks]



- Which solution, A, B or C, is the most acidic? Motivate your answer.  
*Solution A is most acidic. Red cabbage water turns red in acidic solutions.*
- Which solution, A, B or C, is the most basic? Motivate your answer.  
*Solution C is most basic. When red cabbage water turns green we know we have a basic solution.*

- c) Which solution, A, B or C, is neutral? Motivate your answer.  
*Solution B is neutral, because the colour of the red cabbage water is purple in the solution. This is the colour red cabbage water will have in neutral solutions.*
- d) What do you think would happen to the colour of solution A if we mixed it with solution B? Motivate your answer.  
*The red colour of the solution would change. When we add a base to an acid, the acid loses some of its power. The acid makes the base lose some of its potency too. The mixture will be less acidic than solution A and less basic than solution C. If we added enough base for the mixture of the two solutions to be neutral, the solution will turn purple.*

4. A scientist is given 6 solutions labelled A to F. The scientist tests each solution with universal indicator and records her results as follows:

Solution	Colour of universal indicator
A	Yellow
B	Blue
C	Green
D	Red
E	Purple
F	Orange



Use the results in the table and the colour guide for universal indicator underneath the table, to answer the following questions:

- a) Which solutions are acidic? Write their labels below. [2 marks]  
*A, F and D*
- b) Which solutions are basic? Write their labels below. [2 marks]  
*B and E*
- c) Which solution is neutral? Write its label below. [2 marks]  
*C*
- d) Arrange the solutions in order from most acidic to most basic in the table below. Also write the colour and the approximate pH range of each solution in the table. [6 marks]

Solution	Colour of the solution	Approximate pH range of the solution
<i>D</i>	<i>Red</i>	<i>1 - 3</i>
<i>F</i>	<i>Orange</i>	<i>4 - 5</i>
<i>A</i>	<i>Yellow</i>	<i>5 - 6</i>
<i>C</i>	<i>Green</i>	<i>7</i>
<i>B</i>	<i>Blue</i>	<i>8 - 10</i>
<i>E</i>	<i>Purple</i>	<i>11 - 14</i>

Total [30 marks]



**TEACHER'S NOTE****Chapter overview**

2 weeks

The central challenge of this chapter is to establish that acid-base reactions are *exchange* reactions. A fragment of the acid is exchanged with a fragment of the base and a salt and water are the resulting products of the reaction. The type of salt that forms depends on the identities of the acid and the base that were combined during the reaction.

Once learners understand this, they have taken an important step to understanding acid-base chemistry. We will spend some time developing a frame for explaining this at the start of the chapter, to which we will return frequently.

In light of the fact that learners have yet to learn about cations and anions, we have considered it pedagogically justifiable to make the following simplifications to currently accepted acid-base theory, in order to bring the concept of *exchange* across to the learners:

- Acids can be thought of as contributing H (instead of  $H^+$ ); and
- Bases can be thought of as contributing O or OH (instead of  $O^{2-}$  and  $OH^-$ ).
- Water ( $H_2O$ ) is a combination of 2 H and 1 O, or alternatively 1 H and 1 OH.

We are well aware that writing  $H + OH \rightarrow H_2O$  has no meaning in science and for this reason we have avoided this usage in the text. But we do consider the use of simplified symbols (H instead of  $H^+$  and so forth) to have an advantage over their scientifically correct (but potentially confusing) counterparts in this context.

There is also a danger that misconceptions and sloppy usage of symbols may result further down the line, when simplifying in this way. However, we feel these risks are counterbalanced by the greater likelihood of learners *understanding the concept of exchange* if the symbols they work with are not cluttered with additional information - like the charges on the ions - that have no meaning for them yet.

Other skills that will be reinforced in this chapter are:

- writing chemical formulae;
- converting between word equations and chemical equations; and
- balancing chemical equations.

A word of caution: Acid-base reactions are *neutralisation* reactions. However, this does not mean that the mixture of an acid with a base will be a neutral solution and you should avoid language that reinforces this notion. Even if equivalent quantities (stoichiometric quantities) of the acid and base are mixed - which would imply that both have been *neutralised* - the resulting solution will only be neutral (i.e.  $pH = 7$ ) under very special circumstances. The reason is that not all salts are 'neutral substances'; in fact most salts have acid-base properties of their own. The chemistry required for learners to understand this is beyond them at this stage and will only be dealt with in Physical Sciences in Grade 12.



Our suggestion is that you simply refrain from calling salts 'neutral substances'. If questions arise around the issue you could point out that the salts they will encounter in this chapter may be neutral substances, but that this is not true of all salts.

Take note that although there is no section specifically named 'Applications' as indicated in CAPS, this content has rather been dealt with under other sections where it is more appropriate.

### 6.1 Neutralisation and pH (1.5 hours)

Tasks	Skills	Recommendation
Investigation: The reaction between vinegar and baking soda	Hypothesising, measuring, preparing, observing, comparing, recording, plotting graphs	CAPS suggested
Activity: CO <sub>2</sub> bubbled through water	Observing, measuring, comparing	Optional
Activity: What is acid rain?	Observing, reading, researching, interpreting, analysing, summarising	CAPS suggested

### 6.2 The general reaction of an acid with a metal oxide (1.5 hours)

Tasks	Skills	Recommendation
Investigation: The reaction between magnesium oxide and hydrochloric acid	Hypothesising, preparing, observing, measuring, recording, plotting graphs	CAPS suggested
Activity: Writing the chemical equation	Writing and balancing chemical equations	Optional (Suggested)

### 6.3 The general reaction of an acid with a metal hydroxide (1.5 hours)

Tasks	Skills	Recommendation
Investigation: The reaction between sodium hydroxide and hydrochloric acid	Hypothesising, preparing, measuring, observing, measuring, recording, plotting graphs	CAPS suggested
Activity: Writing the chemical equation	Writing and balancing chemical equations	Optional (Suggested)

## 6.4 The general reaction of an acid with a metal carbonate (1.5 hours)

Tasks	Skills	Recommendation
Investigation: The reaction between calcium carbonate (chalk) and hydrochloric acid	Hypothesising, preparing, comparing, measuring, recording, plotting graphs	CAPS suggested
Activity: Writing the chemical equation	Writing and balancing chemical equations	Optional (Suggested)

**KEY QUESTIONS:**

- What is the reaction between an acid and a base called?
- What happens to the pH when an acid and a base are mixed?
- Does the reaction between an acid and a base always give a neutral mixture, in other words a mixture with pH = 7?
- Which factors will determine the pH of the final solution when an acid and a base are mixed?
- Is there a way to predict which classes of compounds will tend to be acids and which will tend to be bases?
- Are metal oxides, metal hydroxides and metal carbonates acidic or basic? Which pH range will their solutions fall into?
- What products can we expect when a metal oxide, a metal hydroxide or a metal carbonate react with an acid?
- Are there general equations to explain these reactions?
- How does acid rain form?

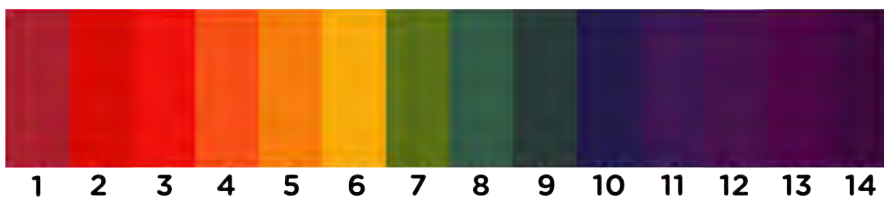
**6.1 Neutralisation and pH**

In the previous chapter we learnt about a new concept, namely pH. If we want to know whether something is an acid or a base, we can measure its pH:

- Acids have pH values below 7. The lower the pH value, the more strongly acidic the substance.
- Bases have pH values above 7. The higher the pH value, the more strongly basic the substance.
- Neutral substances have pH equal to 7.

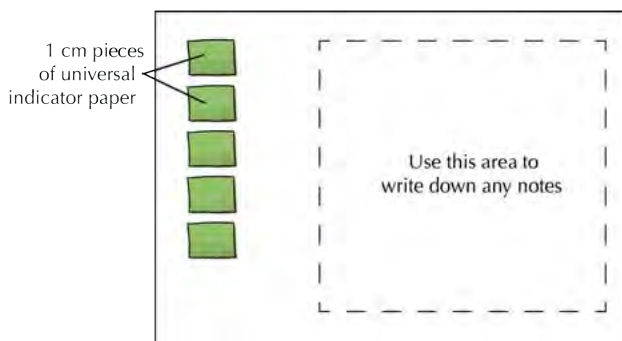
Another useful thing we learnt in the previous chapter is that we can use universal indicator to measure the pH of a solution. Universal indicator has different colours at different pH values. Below is a colour chart showing the range of colours for universal indicator and the pH values they correspond to. You will need it for all the activities of this chapter, because we are going to do lots of pH measurements!





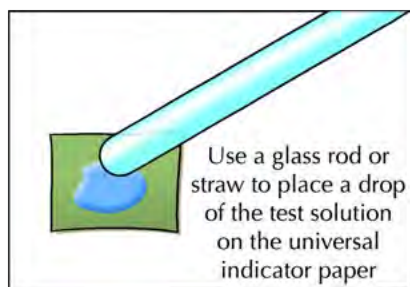
Can you remember how we used the universal indicator paper in the previous chapter? Here are some suggestions for the investigations of this chapter:

1. Before you start, place 1-cm lengths of universal indicator paper on a sheet of white paper, like this:



Later, if you want to write down a note or an observation, you can do so directly on the paper and copy it to your workbook afterwards.

2. Instead of dipping the paper in the solutions you are testing, use a glass rod or drinking straw to transfer a drop of the test solution to the indicator paper.



#### TEACHER'S NOTE

For some of the investigations in this chapter, you will be using droppers or syringes to measure out quantities. Tell learners that they may not use droppers or syringes to squirt water at other learners! There are many reasons why this is not a good idea. The most important reason is that the dropper or syringe **may contain acid**, that could end up in someone's eye where it could cause permanent damage or even blindness. So, squirting each other with the droppers or syringes **is not allowed**.

### What is neutralisation?

What do you think would happen if we mixed an acid and a base?

**TEACHER'S NOTE**

Get learners to discuss this in class or in small groups. Allow them to speculate and guide them to recall their Grade 7 learning: An acid will lose its potency when it is mixed with a base and vice versa. So the acid will be weakened by the base and the base will be weakened by the acid. 'Weaken', however, is a term best avoided, because 'weak' and 'strong' have very specific meanings when speaking about acids and bases. In a sense their acid-base properties will be destroyed, because they will be converted to products that won't be acids or bases. (Often the salt that results from the reaction between an acid and a base will have acid-base properties of its own, but we will not be discussing that now.)

We are going to do an investigation to find out. We are going to mix vinegar with baking soda. But first, a little revision: is vinegar an acid or a base? If you are not sure, imagine putting a drop of vinegar on your tongue. What would it taste like?

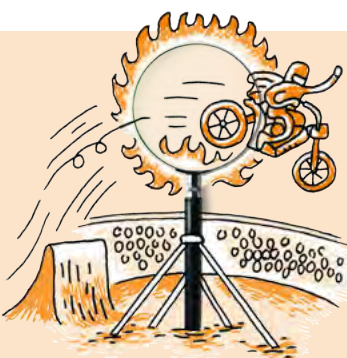
**TEACHER'S NOTE**

It would taste sour, therefore it is an acid.

Is baking soda an acid or a base? If you are not sure, turn back to the previous chapter and look at the activity '*The pH scale*'.

**TEACHER'S NOTE**

Baking soda is a base.



**INVESTIGATION:** The reaction between vinegar and baking soda

**TEACHER'S NOTE**

Quantities for this investigation are as follows: Every 1 g of baking soda will require approximately 15 ml of vinegar for complete neutralisation. We recommend that you measure out 1 teaspoon of baking soda and approximately 50 ml vinegar for each group.

The purpose of this experiment is to investigate how the pH changes when vinegar is added to baking soda.

### INVESTIGATIVE QUESTION(S):

1. What question do you hope to answer with this investigation?  
*A possible answer is: What will happen to the pH of the solution if we add vinegar to baking soda?*

### OVERVIEW OF THE INVESTIGATION:

1. We will measure the pH of a solution of baking soda with universal indicator paper to confirm whether it is acidic or basic. What range do you expect the pH of this solution to fall in?  
*In the range  $pH > 7$*
2. We will add vinegar to the baking soda solution in small portions and measure the pH after each portion has been added. What changes do you expect to observe? Will the pH increase, decrease or stay the same?  
*The pH will decrease.*

### HYPOTHESIS:

1. What is your prediction? Your hypothesis should be a prediction of the finding(s) of the investigation. You should write it in the form of a possible answer to the investigative question.  
*When we add vinegar to baking soda, the pH of the mixture will decrease.*

### MATERIALS:

- baking soda
- vinegar
- water
- glass beaker or small yoghurt tub
- universal indicator paper (cut into 1 cm strips)
- sheet of white printer paper
- plastic teaspoon

### METHOD:

1. Prepare the universal indicator paper by neatly placing five 1-cm pieces underneath each other on the sheet of paper.
2. Place one teaspoon of baking soda in the beaker or yoghurt tub.
3. Add approximately 10 teaspoons of water to the baking soda.
4. Use the teaspoon to stir the solution until all the baking soda has dissolved. We will be calling this the 'test solution' from now on.
5. Transfer one drop of the test solution to the first piece of universal indicator paper using the teaspoon or a straw.
6. Compare the colour of the paper with the colour guide given at the start of the chapter, to find the pH of the solution. Record this pH in your results table.
7. Add 1 teaspoon of the vinegar to the test solution. Stir it gently and transfer another drop of the solution to a fresh strip of the universal indicator.
8. Read the pH of the solution off the colour guide and record it in your results table.
9. Repeat steps 6 and 7 until the pH of the test solution drops below 7. You may need more than 5 pieces of universal indicator paper.



**RESULTS:**

Present your results in a neat table. Use appropriate headings for your table. 'Number of teaspoons of vinegar added' and 'Colour of the universal indicator paper' and 'pH of the test solution' are suggested headings for your columns.

Draw a line graph to illustrate your results. What will be on the x-axis and what will be on the y-axis? Give your graph a heading.

**TEACHER'S NOTE**

Learners must draw a graph with the 'number of teaspoons of vinegar added' on the x-axis (independent variable) and the pH of the solution on the y-axis (dependent variable).

**CONCLUSIONS:**

What conclusions can be made from the results of your investigation? Here you can rewrite your hypothesis, but change it to reflect your findings if they are different from what you predicted earlier.

Were you able to confirm or reject your hypothesis?

In this investigation, you probably noticed that the pH of the mixture dropped every time you added more vinegar to the baking soda! Why did this happen?

When an acid and a base are mixed (in the right amounts), they will **neutralise** each other. That means that, together, they will change into something that is neither an acid nor a base. So, the acid will lose its 'acidity' and the base will lose its 'basicity'.

What have we learnt so far? We have learnt that acids and bases neutralise each other:

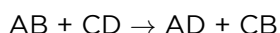
- If we add a base to an acid, the pH of the resulting solution will increase, because the acid will lose some of its **potency**.
- If we add an acid to a base, the opposite will happen. The pH will decrease, because the base will lose some of its potency.

What are the products of an acid-base reaction? Can we predict what they will be?

**The products of acid-base reactions**

In order to understand how an acid-base reaction works, we have to take a quick **detour** and say something about **exchange reactions**. Acid-base reactions are exchange reactions.

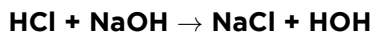
In the reaction below, two substances AB and CD are undergoing an exchange reaction:



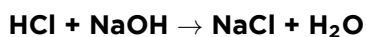
Can you see that A and C have exchanged partners so that A is now combined with D, while C combined with B?

What does this have to do with acids and bases? Well, acids and bases undergo exchange reactions too. Here are some examples. See if you can figure out which parts have exchanged with which.

### Example 1



In the above equation HOH should actually be written:  $\text{H}_2\text{O}$ . The reaction equation becomes:



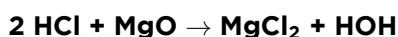
or, in words:

**hydrochloric acid + sodium hydroxide → sodium chloride + water**

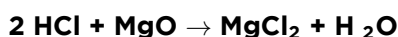
In this example, the following happened:

- the acid gave its H towards making a water molecule;
- the base gave OH towards making a water molecule; and
- the Na from the base and the Cl from the acid combined to form a salt.

### Example 2



In the above equation HOH should actually be written:  $\text{H}_2\text{O}$ . The reaction equation becomes:



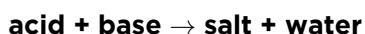
or, in words:

**hydrochloric acid + magnesium oxide → magnesium chloride + water**

In this example, the following happened:

- the acid gave 2 H's towards making a water molecule;
- the base gave OH towards making a water molecule; and
- the Mg from the base and the 2 Cl's from the acid combined to form a salt.

Acid-base reactions always produce water and a salt. In both of the examples above the general equation was:



There is one class of acid-base reactions that produces an additional product, but we will learn more about that later.

## Which laboratory acids should we know about?

When we investigated acids and bases in the previous chapter, we considered only household acids like lemon juice and vinegar. There are a few **laboratory acids** that you should know the names and formulae of and they have been listed in the following table:

#### TAKE NOTE

In Grade 11 you will learn that the mechanisms of these reactions are actually slightly more complex than this, but for now, understanding it at this level is good enough.

Name of the acid	Formula of the acid
hydrochloric acid	HCl
nitric acid	HNO <sub>3</sub>
sulfuric acid	H <sub>2</sub> SO <sub>4</sub>

These acids are very **corrosive**, even when they have been diluted with water and should always be handled with great care.

**VISIT**  
 What happens if you put a burger in concentrated hydrochloric acid? (video)  
[bit.ly/14CO0MG](http://bit.ly/14CO0MG)



eBooks

Look out for this label on bottles which contain corrosive substances, such as strong acids.

*Hydrochloric acid is the acid we will be using in our investigations in this chapter.*

In the next sections will discuss the classes of substances that are typically acids or bases. Two important things to remember are the following:

- Non-metal oxides form acidic solutions when they are dissolved in water.
- Metal oxides, metal hydroxides and metal carbonates all form basic solutions when they are dissolved in water.

First, we will look at the non-metal oxides.

### Non-metal oxides form acidic solutions

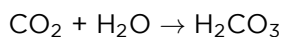
Can you name a few non-metal oxides? Write down their formulae. If you are not sure you can take a peek at the Periodic Table and pick a few non-metals from the right-hand side of the table. Add oxygen and you have a non-metal oxide!

#### TEACHER'S NOTE

CO<sub>2</sub> and SO<sub>2</sub>

How do we know that non-metal oxides form acidic solutions? Experiments have shown this.

You may not know this, but when CO<sub>2</sub> gas is bubbled through water some of it dissolves in the water to form carbonic acid. Here is the reaction equation:



To see this happen, try the following quick activity.

## **ACTIVITY:** CO<sub>2</sub> bubbled through water

### **TEACHER'S NOTE**

A variation of this activity is if you have liquid universal indicator, you can add it to the tap water at the start to show the pH is 7 (it should be green). Then as you blow into the water, the universal indicator will change colour. Make sure you use a clear glass so learners can observe the colour change as it becomes more yellow. This links to the next activity on acid rain and how it forms.



### **MATERIALS:**

- tap water
- glass
- straw
- indicator paper

### **INSTRUCTIONS:**

1. Test the pH of clean tap water. It should be approximately 7. How would you do that?

*We could measure the pH of the water with universal indicator paper.*

2. Now exhale into the water using a straw. Your breath contains CO<sub>2</sub> and some of this will dissolve in the water if you carry on doing this for a few minutes.



1. If you measure the pH of the solution now, you will see that it has decreased! What do you think the pH will be?

*The pH will be below 7.*

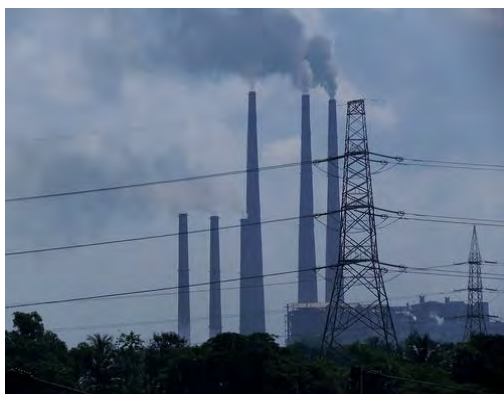


The pH of the solution is now below 7 because it contains carbonic acid ( $\text{H}_2\text{CO}_3$ ). Carbonic acid is not a very strong acid, but still acidic enough to have a pH lower than 7.

When sulfur dioxide (a gas) is bubbled through water it dissolves in the water to form an acid called sulfurous acid:

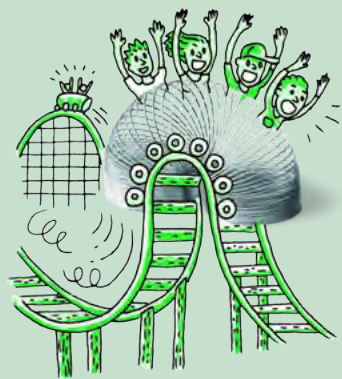


These are two of the reactions that produce a phenomenon called **acid rain**.  $\text{SO}_2$  and  $\text{CO}_2$  are released as waste products from factories and power stations. For example, burning wood and fossil fuels releases carbon dioxide and sulfur dioxide into the atmosphere. These gases then dissolve in water droplets in the atmosphere to form acids, in a similar way that the  $\text{CO}_2$  in your breath dissolved in the water in the last activity to produce an acidic solution. When it rains, these acids are present in the raindrops that fall back to earth. Sulfurous acid ( $\text{H}_2\text{SO}_3$ ) is strong enough to damage plant life and to acidify water sources.



Acid rain forms when  $\text{CO}_2$  and  $\text{SO}_2$  from factories and other air pollutants combine with water in the atmosphere.

A forest that has been destroyed by acid rain.



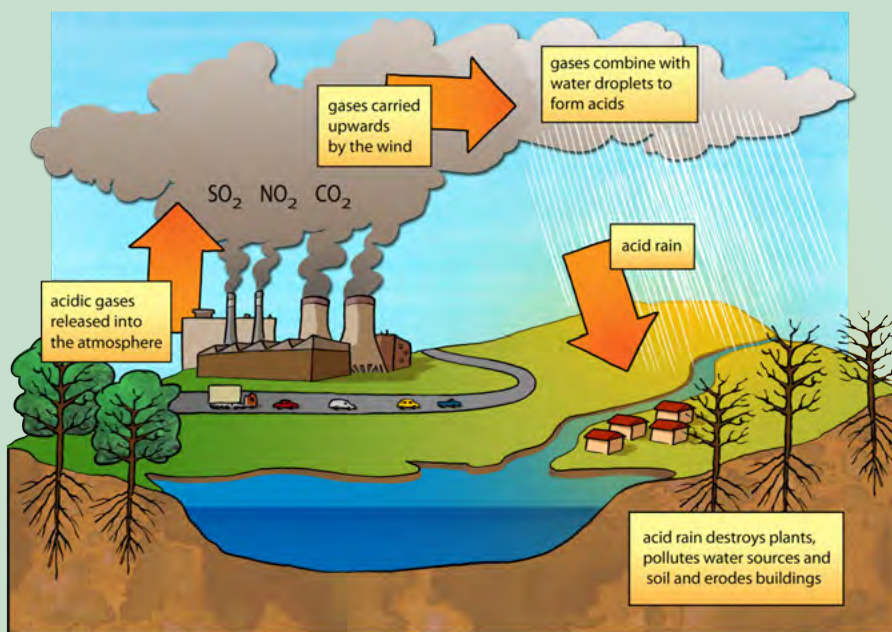
### **ACTIVITY:** What is acid rain?

For the next activity, you have to do some research on acid rain.

#### **INSTRUCTIONS:**

1. Study the diagram showing how acid rain forms.
2. Do some extra reading and research about acid rain.
3. Answer the questions about acid rain.





### QUESTIONS:

- Which three gases are shown in the diagram that contribute to the formation of acid rain? Write their names and formulae.  
*They are sulfur dioxide (SO<sub>2</sub>), carbon dioxide (CO<sub>2</sub>) and nitrogen dioxide (NO<sub>2</sub>).*
- What are some of the sources of these gases? You can do some extra reading about this to help you answer this question.  
*The main sources of these gases which contribute to acid rain are from human activity, such as electricity generation in fossil fuel power plants (especially coal), factories emitting smoke and the exhaust fumes from motor vehicles. Acid rain can also occur due to natural phenomena, such as volcanoes which emit sulfur dioxide into the atmosphere. Some processes in the ocean and in wetlands also produce the gases which form acids.*
- Write the equations for how two of these gases which you have learnt about react with the water in the atmosphere to form acids.  
$$\text{SO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{SO}_3$$
$$\text{CO}_2 + \text{H}_2\text{O} \rightarrow \text{H}_2\text{CO}_3$$
- What are the names of these two acids?  
*Sulphurous acid and carbonic acid.*
- What are some of the environmental impacts of acid rain? Study the diagram for some clues and do some extra reading.  
*The impacts include:*
  - damage of plant life, both wilderness areas and also crops, depending on where the rain falls*
  - the rain leaches into soil and makes it more acidic; this kills microorganisms living in the soil, damages plants further by contaminating soil water*
  - the rain can fall into various water sources and also run off into water sources such as rivers, lakes and dams; this causes the water to become more acidic; aquatic animals and plants can die; human water sources become too acidic as well*
- Acid rain can also damage buildings as it 'eats away' the stone. What property of acids allow it to do this?  
*Acids are corrosive and so they can corrode surfaces over time.*

7. Factories used to have quite short funnels to let out the smoke, but it was found that this caused many problems in the local towns and cities near the factory as the gases would combine with water in the immediate environment to cause acid rain. Factories then started to build much higher smoke funnels so that the smoke was let out high enough to be blown further away. Do you think this is an efficient way to help reduce acid rain? Explain your answer.

*Learners need to justify their answers. They may say that it helps the local environment as the gases are carried further away and therefore do not pollute the town or city that the factory is in or near. But this does not do anything to minimize the acid rain that could potentially form as the same amount of gases are still emitted; they are just carried further away. The acid rain therefore can still form and fall on the vegetation and areas outside of the towns and cities.*

8. Do some research to find out about the possible ways to prevent or minimize the formation of acid rain. Write a paragraph to summarize these methods below.

*There are several solutions to minimizing the formation of acid rain. For example, coal-powered stations can use filters and other processes in their smoke towers to remove sulfur gases before the smoke is released into the atmosphere. Countries can take bigger steps by signing treaties to reduce their sulfur and other greenhouse gas emissions. The move towards using renewable energy sources will also help to reduce the reliance on coal and other fossil fuels, thereby reducing the emission of acid-producing gases into the atmosphere.*

We have now learnt about non-metal oxides, but what about metal oxides? What kind of solutions do they form in water? We will find out more about them and other metal compounds in the next section.

## **Metal oxides, metal hydroxides and metal carbonates form basic solutions**

### **Metal oxides**

Do you remember learning about some of the metal oxides in Chapter 3? We already learnt these rules to write the formulae of metal oxides.

- 1. Metal oxides from group 1 on the Periodic Table will have the formula  $M_2O$** , where M stands for any metal in group 1.

Can you write two examples? Look at the Periodic Table at the front of the book, pick any two metals from group 1 and write their formulae using this rule.

#### **TEACHER'S NOTE**

Any two of the following:  $Li_2O$ ,  $Na_2O$ ,  $K_2O$ ,  $Rb_2O$ ,  $Cs_2O$

- 2. Metal oxides from group 2 will have the formula  $MO$** , where M stands for any metal in group 2.

Can you write 2 examples?

**TEACHER'S NOTE**

Any two of the following: BeO, MgO, CaO, SeO, BaO

What do you think the pH will be of a solution of a metal oxide in water?

**TEACHER'S NOTE**

The pH will be above 7.

The next class of compounds that form basic solutions in water are the metal hydroxides.

**Metal hydroxides**

A metal hydroxide forms when a metal reacts with water. A metal hydroxide has the general formula MOH or  $M(OH)_2$ . In the formula, M represents a metal atom, O represents an oxygen atom and H represents a hydrogen atom.

To know whether the MOH or  $M(OH)_2$  will be the correct formula, here are two simple rules for you to remember:

1. **Metal hydroxides from group 1 on the Periodic Table will have the formula MOH.**

Can you write two examples? Look at the Periodic Table at the front of the book, pick any two metals from group 1 and write their formulae using this rule.

**TEACHER'S NOTE**

Any two of the following: LiOH, NaOH, KOH, RbOH, CsOH.

2. **Metal hydroxides from group 2 will have the formula  $M(OH)_2$ .**

Can you write two examples?

**TEACHER'S NOTE**

Any two of the following:  $Be(OH)_2$ ,  $Mg(OH)_2$ ,  $Ca(OH)_2$ ,  $Sr(OH)_2$ ,  $Ba(OH)_2$ .

What do you think the pH will be of a solution of a metal hydroxide in water?

**TEACHER'S NOTE**

The pH will be above 7.

The final class of compounds that forms basic solutions in water is the metal carbonates. Baking soda is a special kind of carbonate, called a **bicarbonate** (or hydrogen carbonate). You may remember that it was one of the bases we tested with universal indicator earlier.

### Metal carbonates

A metal carbonate has the general formula  $MCO_3$  or  $M_2CO_3$ . In the formula, M represents a metal atom, C represents a carbon atom and O represents an oxygen atom.

To know whether the  $MCO_3$  or  $M_2CO_3$  will be the correct formula, there are two simple rules to remember:

1. **Metal carbonates from group 1 on the Periodic Table will have the formula  $M_2CO_3$ .**

Can you write two examples?

#### TEACHER'S NOTE

Any two of the following:  $Li_2CO_3$ ,  $Na_2CO_3$ ,  $K_2CO_3$ ,  $Rb_2CO_3$ ,  $Cs_2CO_3$ .

2. **Metal hydroxides from group 2 will have the formula  $MCO_3$ .**

Can you write two examples?

#### TEACHER'S NOTE

Any two of the following:  $BeCO_3$ ,  $MgCO_3$ ,  $CaCO_3$ ,  $SrCO_3$ ,  $BaCO_3$ .

What do you think the pH will be of a solution of a metal carbonate in water?

#### TEACHER'S NOTE

The pH will be above 7

In the next sections we will be investigating real reactions!

## 6.2 The general reaction of an acid with a metal oxide

In the previous section we learnt about two classes of oxides, namely **metal oxides** and non-metal oxides. Here is what we know about them so far:

- Metal oxides are formed from the reaction between a metal and oxygen. Metal oxides are basic. When we dissolve them in water, they form solutions with pH values above 7.
- Non-metal oxides are formed from the reaction between a non-metal and oxygen. Non-metal oxides are acidic. When they dissolve in water, they form solutions with pH values below 7.

Here is the same summary, in table form, with some examples added:

Metal oxides	Non-metal oxides
metal + oxygen $\rightarrow$ metal oxide	non-metal + oxygen $\rightarrow$ non-metal oxide
basic	acidic
pH > 7	pH < 7
Examples: $\text{Li}_2\text{O}$ , $\text{Na}_2\text{O}$ , $\text{MgO}$ , $\text{CaO}$	Examples: $\text{CO}_2$ , $\text{SO}_2$ , $\text{NO}_2$ , $\text{P}_2\text{O}_5$

In this section, we are going to learn about the reactions between metal oxides and acids.



### INVESTIGATION: The reaction between magnesium oxide and hydrochloric acid



#### TEACHER'S NOTE

This investigation requires magnesium oxide from the reaction when magnesium ribbon burns in oxygen. If you have set some aside from the earlier activity '*The reaction of magnesium with oxygen*' (Chapter 3), learners can use it for this investigation. If you did not, you can easily repeat that demonstration to produce more white magnesium oxide powder for this next investigation. This investigation is also suitable to scale up as a demonstration.

The purpose of this investigation is to:

- test whether a solution of magnesium oxide in water is acidic, basic or neutral; and
- determine whether the reaction between an aqueous solution of magnesium oxide and hydrochloric acid is a **neutralisation reaction**.



### INVESTIGATIVE QUESTION(S):

What are the questions you hope to answer with this investigation? Write them in the space below. There are a few words to start you off.

1. When magnesium oxide is dissolved in water, will the resulting solution...  
*When magnesium oxide is dissolved in water, will the resulting solution be acidic, basic or neutral?*
2. When a solution of magnesium oxide is treated with hydrochloric acid, will the pH of the mixture ...  
*When a solution of magnesium oxide is treated with hydrochloric acid, will the pH of the mixture increase, decrease, or stay the same?*

### OVERVIEW OF THE INVESTIGATION:

1. We will measure the pH of a solution of magnesium oxide (MgO) with universal indicator paper to confirm whether it is acidic or basic. Within what range do you expect the pH of the magnesium oxide solution to fall?  
*In the range  $pH > 7$*
2. We will add hydrochloric acid (HCl) to the magnesium oxide solution in small portions and measure the pH after each portion has been added. What changes do you expect to observe - will the pH increase, decrease or stay the same?  
*The pH will decrease*

### HYPOTHESIS:

What are your predictions? Your hypothesis should be a prediction of the finding(s) of the investigation. You should write it in the form of a possible answer to the investigative question(s). Here are a few words to start you off:

1. When magnesium oxide is dissolved in water, the resulting solution will...  
*When magnesium oxide is dissolved in water, the resulting solution will be basic (have a  $pH > 7$ ).*
2. When a solution of magnesium oxide is treated with hydrochloric acid, the pH of the mixture will...  
*When a solution of magnesium oxide is treated with hydrochloric acid, the pH of the mixture will decrease.*

### MATERIALS:

- magnesium oxide powder
- water
- universal indicator paper (cut into 1 cm strips)
- white tile or sheet of white printer paper
- glass rod (or plastic straw)
- test tube
- dropper
- hydrochloric acid (HCl) solution (0.1 M)

## TEACHER'S NOTE

Notes for the investigation:

- **Learners must not dilute hydrochloric acid themselves** as it reacts strongly with water. Make sure to add the acid slowly to the water and **NOT** the other way around.
- To prepare 0.1 M HCl solution, carefully add approximately 10 ml concentrated hydrochloric acid (33% or 11 M) to 1 liter of tap water. It is recommended that you wear safety goggles and protective gloves during this step and that you rinse away any acid spills with cold tap water. Since this is just a qualitative experiment, it is not necessary to use distilled water for the solution. It is also not required that you measure the volumes with extreme accuracy.
- The following guide will help you to determine quantities: The magnesium oxide prepared from a 1 cm length of magnesium ribbon will require approximately 8 ml of 0.1 M hydrochloric acid for complete neutralisation. If the learners work in small groups and each group dissolves a small quantity of MgO (the size of a match head) in 2 ml of water, they will only need a few drops of HCl solution to neutralise all the MgO.
- If you have universal indicator **solution**, this will work very nicely as you can observe the colour changes as you add the drops.
- If you decide to give the learners droppers to measure out the HCl, you will have to enforce very strict rules for handling the droppers. Learners find the temptation to squirt water at each other very difficult to resist and they must be made aware of the **hazards of accidentally squirting acid** at another learner.
- Remind learners to use the colour guide for universal indicator provided at the start of the chapter. If you have the budget, a good idea would be to make a number of colour photocopies of the chart and to have them laminated so they will last longer.
- Remind learners to prepare a table for their results beforehand.

## METHOD:

1. Prepare the universal indicator paper by neatly placing five 1 cm pieces in a column on the white tile or sheet of printer paper.
2. Place a small quantity (the size of a match head) of the magnesium oxide in a test tube.
3. Add approximately 2 ml of tap water to dissolve most of the magnesium oxide.
4. Use the glass rod (or plastic straw) to stir the solution until most the magnesium oxide has dissolved. We will be calling this the *test solution* from now on.
5. Transfer one drop of the test solution to the first piece of universal indicator paper.
6. Compare the colour of the paper with the colour guide to find the pH of the solution.
7. Record this pH in the table you prepared beforehand.
8. Add 10 drops of the hydrochloric acid solution to the test solution. Stir it gently and transfer another drop of the solution to a fresh strip of the universal indicator.
9. Read the pH of the solution off the colour guide and record it in your table.
10. Repeat steps 3 and 4 until the pH of the test solution drops below 7. You may need more than 5 pieces of universal indicator paper.

**RESULTS:**

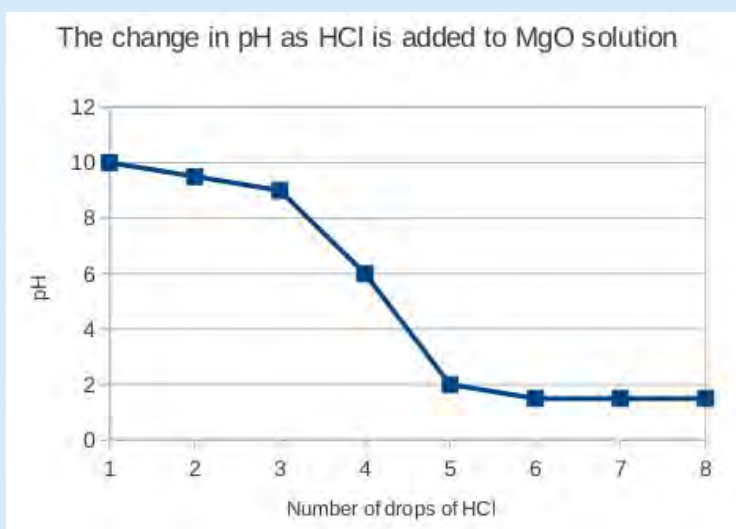
1. Present your results in a table. You should prepare this beforehand. Use appropriate headings for your table. 'Number of drops of HCl added' and 'Colour of the universal indicator paper' and 'pH of the test solution' are suggested headings for your columns.

*Learner-dependent answer*

2. Draw a graph of your results. Here are some hints to help you decide which variable to put on which axis:
  - a) What is your independent variable? (Which variable did you change?)  
This goes on the x-axis.  
*Number of drops of HCl*
  - b) What is your dependent variable? (Which variable did you measure?)  
This goes on the y-axis.  
*pH*

**TEACHER'S NOTE**

The number of drops of HCl should be on the x-axis of the graph and pH should be on the y-axis. There should be a general trend downwards (since acid is added to a base, we can expect the pH to drop), but it should not be linear. This experiment is a very rudimentary 'titration' and an example of a titration curve from this experiment is given here:



It is therefore not expected that learners' curves will be linear, but rather that there will be a gradual decline in pH at first, followed by a rapid drop when all the base has been neutralised. After this the curve levels out again.

**CONCLUSIONS:**

What conclusions can be made from the results of your investigation? Rewrite your hypothesis, but change it to reflect your findings if they are different from what you predicted earlier.

Were you able to confirm or reject your hypotheses?

**VISIT**

A video showing the reaction of copper(II)oxide with hydrochloric acid  
[bit.ly/19ncbyc](https://bit.ly/19ncbyc)

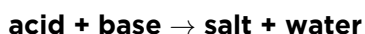
Now that we have investigated a reaction between a metal oxide (MgO) and an acid (HCl), we can write an equation for the reaction. We will begin by writing a general equation and end with one that matches the reaction that we have just investigated.

### General equation for the reaction of an acid with a metal oxide

Can you remember learning that an acid-base reaction is an **exchange** reaction? We learnt that:

- The acid contributes H towards making a water molecule;
- The base contributes O or OH towards making a water molecule; and
- Whatever is left of the the acid and the base after making a H<sub>2</sub>O molecule, combines to form a salt.

The general word equation for the reaction between an acid and a base is:



Since the base in our reaction is a metal oxide we can write:



This is the general word equation for the reaction between an acid and a metal oxide. The type of salt that forms will depend on the specific acid and metal oxide which were used in the reaction.

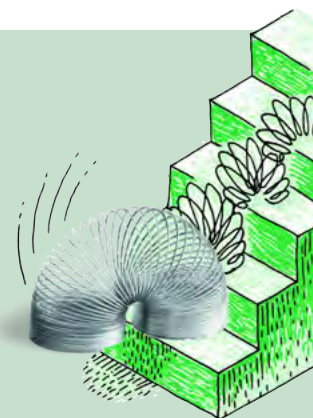
### Equations for the reaction between magnesium oxide and hydrochloric acid

Now we are going to learn how to write equations for our actual reaction.

## ACTIVITY: Writing the chemical equation

#### The following steps will guide you:

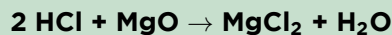
1. The acid of our reaction was hydrochloric acid. Write its chemical formula.  
*HCl*
2. What is the name and formula of the metal oxide we used?  
*Magnesium oxide (MgO)*
3. Now, let's try to predict the products of the reaction. We know that water will be one of the products.
4. Write what remains of the base (MgO) after we have taken away the O (to make water).  
*Mg*
5. Write what remains of the acid (HCl) after we have taken away the H (to make water). (Remember we need two H to make one H<sub>2</sub>O).  
*2 Cl (we used 2 HCl)*



6. Now put the two remaining fragments together. Place the metal first and remember that 2 HCl will leave 2 Cl after the 2 H has been given to O to make water. One Mg and 2 Cl makes...



Now, let's put it all together, first the reactants, then the products:



7. Let's check quickly if the reaction is balanced.
- How many H atoms on the left hand side and on the right hand side?  
Are they balanced?  
*2 H atoms left and 2 H atoms right. The H's are balanced.*
  - How many Cl atoms on the left hand side and on the right hand side?  
Are they balanced?  
*2 Cl atoms left and 2 Cl atoms right. The Cl's are balanced.*
  - How many O atoms on the left hand side and on the right hand side?  
Are they balanced?  
*1 O atoms left and 1 O atoms right. The O's are balanced.*

Since the numbers of each type of atom is the same on either side of the equation, we can confirm that it is balanced.

Finally, let's use the chemical equation to write a word equation for the reaction:

**hydrochloric acid + magnesium oxide** → **magnesium chloride + water**

In the next section we are going to look at the reactions between acids and metal hydroxides.



## 6.3 The general reaction of an acid with a metal hydroxide

We will start this section with an investigation to illustrate the reaction between an acid and a **metal hydroxide**.



## **INVESTIGATION:** The reaction between sodium hydroxide and hydrochloric acid



### **TEACHER'S NOTE**

Notes for the investigation:

- The same cautions regarding droppers and syringes apply to this activity. You will need to enforce very strict rules for handling these items or learners may find the temptation to squirt water at each other very difficult to resist.
- Remember to provide learners with a colour guide for universal indicator, if you have this.
- Remind learners to draw a results table before they start the experiment.

The purpose of this investigation is to:

- test whether sodium hydroxide is acidic or basic; and
- determine whether the reaction between sodium hydroxide and hydrochloric acid is a neutralisation reaction.

### **INVESTIGATIVE QUESTION(S):**

1. What are the questions you hope to answer with this investigation? Write them below. You may use the previous investigation (of the reaction between magnesium oxide and hydrochloric acid) as guideline.

*Here are some ideas:*

- *When sodium hydroxide is dissolved in water, will the resulting solution be acidic, basic or neutral?*
- *When a solution of sodium hydroxide is treated with hydrochloric acid, will the pH of the mixture increase, decrease or stay the same?*
- *Will it be possible to neutralise all the sodium hydroxide by adding hydrochloric acid?*

### **OVERVIEW OF THE INVESTIGATION :**

1. We will measure the pH of a solution of sodium hydroxide (NaOH) with universal indicator paper to confirm whether it is acidic or basic. Within what range do you expect the pH of the sodium hydroxide solution to fall?

*In the range  $pH > 7$*

2. We will add hydrochloric acid (HCl) to the sodium hydroxide solution in small portions and measure the pH after each portion has been added. What changes do you expect to observe? Will the pH increase, decrease or stay the same?

*The pH will decrease*

### **HYPOTHESIS:**

1. What are your predictions? Your hypothesis should be a prediction of the finding(s) of the investigation. You should write it in the form of a possible answer to the investigative question(s). If you are unsure, check the previous investigation.

Some ideas:

- Sodium hydroxide solution will have a pH greater than 7.
- When a solution of sodium hydroxide is treated with hydrochloric acid, the pH of the mixture will decrease.
- By adding hydrochloric acid to the sodium hydroxide solution, it should be able to decrease the pH to 7 and even below 7.

#### MATERIALS:

##### TEACHER'S NOTE

Prepare 0.1 M NaOH solution by dissolving approximately 4 g of NaOH pellets in 1 liter of cold tap water. Wear safety goggles and gloves since there is a chance the sodium hydroxide solution could splash up.

- sodium hydroxide solution (0.1 M)
- universal indicator paper (cut into 1 cm strips)
- white tile or sheet of white printer paper
- glass rod or plastic straw
- test tube or small glass beaker
- plastic syringe (2.5 ml capacity)
- hydrochloric acid (HCl) solution (0.1 M)

##### TEACHER'S NOTE

Instructions for preparation are given with the previous investigation: *The reaction between magnesium oxide and hydrochloric acid*

#### METHOD:

1. Prepare the universal indicator paper by neatly placing five 1 cm pieces in a column on the white tile or sheet of printer paper.
2. Use the syringe to transfer 2 ml of the sodium hydroxide solution into the test tube or small glass beaker. We will be calling this the *test solution* from now on.
3. Rinse the syringe very thoroughly with water and dry it out with a clean tissue. Now fill it with hydrochloric acid solution and set it aside.
4. Transfer one drop of the sodium hydroxide (test solution) to the first piece of universal indicator paper.
5. Compare the colour of the paper with the colour guide to find the pH of the sodium hydroxide solution. Record this pH in your results table.
6. Add 0.5 ml of the hydrochloric acid solution from the syringe to the test solution. Stir it gently with the glass rod or straw and transfer another drop of the test solution to a fresh strip of the universal indicator paper.
7. Read the pH of the solution off the colour guide and record it in your results table.
8. Repeat steps 6 and 7 until the pH of the test solution reaches approximately 7.
9. How much of the hydrochloric acid solution have you used? Write the volume on the line below.

### TEACHER'S NOTE

Learner dependent answer. Should be around 2 ml.

9. If you are quite sure that all the base has been neutralised by the acid (the pH should be 7 and the universal indicator paper should have turned green), pour the test solution into a small glass beaker and leave it in the window sill for a few days. Remember to come back to it later to see what has happened to it.

### TEACHER'S NOTE

NaCl forms in this reaction and the idea is for learners to let it dry out in the window sill and examine it later. It is probably not a good idea to let them taste it, as there is a possibility that not all of the acid or base has been neutralised.

### RESULTS:

1. Present your results in a neat table. Use appropriate headings for your table.

The following are suggested headings for your columns.

- Volume of HCl added
- Colour of the universal indicator paper
- pH of the test solution

*learner-dependent answer*

1. Draw a graph of your results.
  - a) What is your independent variable? (Which variable did you change?)  
*Volume of HCl*
  - b) What is your dependent variable? (Which variable did you measure?)  
*pH*

### TEACHER'S NOTE

The volume of HCl added should be on the x-axis of the graph and pH should be on the y-axis. There should be a general trend downwards (since acid is added to a base, we can expect the pH to drop), but it should not be linear. See comments and graph provided with the previous investigation.

### VISIT

A video illustrating the reaction of magnesium hydroxide with hydrochloric acid in the presence of universal indicator

[bit.ly/1IYInSP](https://bit.ly/1IYInSP)

### CONCLUSIONS:

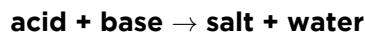
What conclusions can be made from the results of your investigation? Here you can rewrite your hypothesis, but change it to reflect your findings if they are different from what you predicted earlier.

Were you able to confirm or reject your hypothesis?

Now that we have investigated a reaction between a metal hydroxide (NaOH) and an acid (HCl), we can write an equation for the reaction. We will begin by writing a general equation and end with one that matches the reaction that we have just investigated.

### General equation for the reaction of an acid with a metal hydroxide

You learnt that an acid-base reaction can be represented by the following general word equation:



The base in our reaction was a metal hydroxide, so the general equation becomes:



This is the general equation for the reaction between an acid and a metal hydroxide. The type of salt that forms will depend on the specific acid and metal hydroxide which were used in the reaction.

### Equations for the reaction between sodium hydroxide and hydrochloric acid

Now we are going to learn how to write equations for our actual reaction.



### ACTIVITY: Writing the chemical equation

The following steps will guide you:

1. The acid of our reaction was hydrochloric acid. Write its chemical formula.  
*HCl*
2. What is the name and formula of the metal hydroxide we used?  
*Sodium hydroxide (NaOH)*
3. Now, let's try to predict the products of the reaction. We know that water will be one of the products.
4. Write what remains of the base after we have taken away the OH to make water.  
*Na*
5. Write what remains of the acid after we have taken away the H to make water. Remember we need two H to make one H<sub>2</sub>O, but NaOH has already contributed one O *and* one H. Now put the two fragments together. Place the metal from the base first and the non-metal from the acid. One Na and one Cl makes...  
*NaCl*
6. Now, let's put it all together, in the following order: Acid + metal hydroxide  
→ salt + water  
*HCl + NaOH → NaCl + H<sub>2</sub>O*

7. Let's check quickly if the reaction is balanced.
- a) How many H atoms on the left and on the right? Are they balanced?
  - b) How many Cl atoms on the left and on the right? Are they balanced?
  - c) How many O atoms on the left and on the right? Are they balanced?
- a) *2 H atoms on the left and 2 H atoms on the right. The H's are balanced.*  
b) *1 Cl atoms on the left and 1 Cl atoms on the right. The Cl's are balanced.*  
c) *1 O atoms on the left and 1 O atoms on the right. The O's are balanced.*
8. Once you have performed this reaction and you are left with a **neutral solution**, you decide you want to recover the sodium chloride (table salt). How will you do this?  
*You need to evaporate the water so that the salt crystallizes, either by leaving it in a sunny spot or boiling the solution.*

Finally, let's use the chemical equation to write a word equation for the reaction:

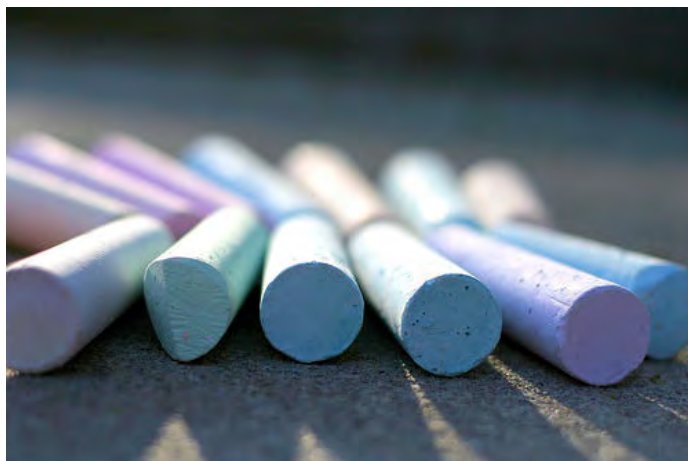
**hydrochloric acid + sodium hydroxide → sodium chloride + water**

In the next section we are going to look at the reactions between acids and metal carbonates.

## 6.4 The general reaction of an acid with a metal carbonate



In this section we will investigate the reaction between an acid and a **metal carbonate**.



*Blackboard chalk is calcium carbonate, a metal carbonate.*





**INVESTIGATION:** The reaction between calcium carbonate (chalk) and hydrochloric acid

**TEACHER'S NOTE**

Grind up a few pieces of white chalk for this experiment. The calcium carbonate will not actually dissolve well in water, but it should be possible to determine that the solution is basic, from the tiny amount of calcium carbonate that will dissolve when the chalk dust is suspended in water.

Learners will need their colour charts and results tables before they start.

The purpose of this investigation is to:

- test whether calcium carbonate is acidic or basic;
- determine whether the reaction between calcium carbonate and hydrochloric acid is a neutralisation reaction; and
- determine the products of the reaction between calcium carbonate and hydrochloric acid.

**INVESTIGATIVE QUESTIONS:**

1. What are the questions you hope to answer with this investigation? Write them on the lines below. You may use your previous investigations as a guideline.

*Some ideas:*

- *When calcium carbonate is dissolved in water, will the resulting solution be acidic, basic or neutral?*
- *When a solution of calcium carbonate is treated with hydrochloric acid, will the pH of the mixture increase, decrease or stay the same?*
- *Will it be possible to neutralise all the calcium carbonate by adding hydrochloric acid? (Be careful not to introduce misconceptions here)*
- *What other products will form when calcium carbonate reacts with hydrochloric acid?*

**OVERVIEW OF THE INVESTIGATION :**

1. We will measure the pH of a suspension of calcium carbonate ( $\text{CaCO}_3$ ) with universal indicator paper to confirm whether it is acidic or basic. Within what range do you expect the pH of the calcium carbonate to fall?  
*In the range pH > 7*
2. We will add hydrochloric acid (HCl) to the calcium carbonate in small portions and measure the pH after each portion has been added. What changes do you expect to observe? Will the pH increase, decrease or stay the same?  
*The pH will decrease*

**HYPOTHESIS:**

1. What are your predictions? Your hypothesis should be a prediction of the finding(s) of the investigation. You should write it in the form of a possible answer to the investigative question(s). If you are unsure, check the

previous investigation.

*Some ideas:*

- Calcium carbonate solution will have a pH greater than 7
- When calcium carbonate is treated with hydrochloric acid, the pH of the mixture will decrease
- By adding hydrochloric acid to the calcium carbonate, it should be able to decrease the pH to 7 and even below 7

#### **MATERIALS:**

- chalk dust (calcium carbonate) suspended in a small quantity of water.
- universal indicator paper (cut into 1 cm strips)
- white tile or sheet of white printer paper
- glass rod or plastic straw
- test tube or small glass beaker
- plastic syringe (2.5 cm capacity) or dropper
- hydrochloric acid (HCl) solution (0.1 M)

#### **METHOD:**

1. Prepare the universal indicator paper by neatly placing five 1 cm pieces in a column on the white tile or sheet of printer paper.
2. Place approximately 2 ml of the calcium carbonate suspension into the test tube or small glass beaker. We will be calling this the *test solution* from now on.
3. Rinse the syringe very thoroughly with water and dry it out with a clean tissue. Now fill it with hydrochloric acid solution and set it aside.
4. Transfer one drop of the calcium carbonate (test solution) to the first piece of universal indicator paper.
5. Compare the colour of the paper with the colour guide below, to find the pH of the calcium carbonate solution. Record this pH in your results table.
6. Add 0.5 cm of the hydrochloric acid solution from the syringe to the test solution. Watch very carefully what happens. Do you see anything interesting? (Hint: Look for bubbles!) Stir the test solution gently with the glass rod and transfer another drop of it to a fresh strip of the universal indicator.
7. Read the pH of the solution off the colour guide and record it in your table.
8. Repeat steps 6 and 7 until the pH of the test solution reaches approximately 7. How much of the hydrochloric acid solution have you used? Write the volume in the space below.
9. Your teacher will repeat the experiment as a demonstration and will collect the gas that formed during the reaction, for testing with clear limewater.
10. Can you remember which gas we are testing for with clear limewater? Write its name and formula below.

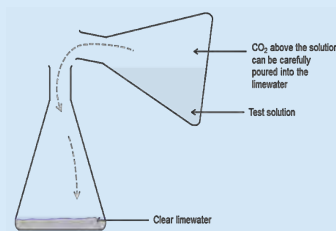
#### **TEACHER'S NOTE**

Carbon dioxide, CO<sub>2</sub>

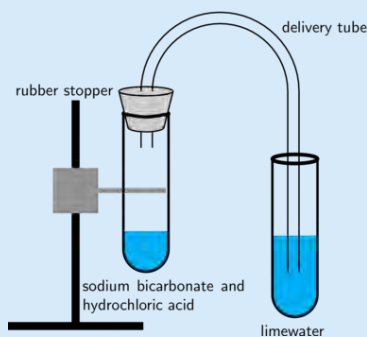
**TEACHER'S NOTE**

Perform the experiment in a conical flask, as follows:

- $\text{CO}_2$  into another conical flask containing lime water (see diagram below). The  $\text{CO}_2$  gas should be poured out. Shake the conical flask containing the lime water and  $\text{CO}_2$  to facilitate mixing. Allow the learners to make their observations.  $\text{CO}_2$  is denser than air and will remain in the conical flask for a few minutes before diffusing into the air. It is during this time that you should pour it over into the lime water. Be careful not to let any of the test solution flow over into the clear lime water. Only the  $\text{CO}_2$



Alternatively, you could use a setup like the one shown in the diagram below:



These experiments can also be done using combo plates.

**RESULTS:**

1. Present your results in a neat table. Use appropriate headings for your table. Suggested headings for your columns are as follows:

- Volume of HCl added
- Colour of the universal indicator paper
- pH of the test solution

2. Draw a graph of your results.
- What is your independent variable? (Which variable did you change?)  
*Volume of HCl*
  - What is your dependent variable? (Which variable did you measure?)  
*pH*

### CONCLUSIONS:

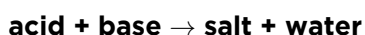
What conclusions can be made from the results of your investigation? Here you can rewrite your hypothesis, but change it to reflect your findings if they are different from what you predicted earlier.

Were you able to confirm or reject your hypothesis?

Now that we have investigated a reaction between a metal carbonate ( $\text{CaCO}_3$ ) and an acid (HCl), we can write an equation for the reaction. We will begin by writing a general equation and end with one that matches the reaction that we have just investigated.

### General equation for the reaction of an acid with a metal carbonate

The general equation for the reaction between an acid and a base is as follows:



If we replace 'base' with 'metal carbonate', we get



But wait, there was a third product in our reaction! Can you remember what it was? (Hint: Bubbles formed, so it was a gas.)

#### TEACHER'S NOTE

$\text{CO}_2$

We need to make it clear that  $\text{CO}_2$  was a product of the reaction, so the correct general word equation would be:



The type of salt that forms will depend on the specific acid and metal carbonate which were used in the reaction.

### Equations for the reaction between calcium carbonate and hydrochloric acid

Now we are going to learn how to write equations for our actual reaction.

#### VISIT

A video showing the reaction between metal carbonates and acids  
[bit.ly/17yN5N](https://bit.ly/17yN5N)



## ACTIVITY: Writing the chemical equation

The following steps will guide you:

- The acid of our reaction was hydrochloric acid. Can you write its chemical formula?  
*HCl*
- What is the name and formula of the metal carbonate we used?  
*Calcium carbonate (CaCO<sub>3</sub>)*
- Now, let's try to predict the products of the reaction. We know that water and carbon dioxide will be two of the products.
- Write what remains of the base after we have taken away the CO<sub>3</sub> to make CO<sub>2</sub> and leave one O to make water.  
*Ca*
- Write what remains of the acid after we have taken away the H to make water. Remember we need two H to make one H<sub>2</sub>O and CaCO<sub>3</sub> has only contributed one O.  
*2 HCl are needed, so 2 Cl will remain.*
- Now put the two fragments together. Place the metal from the base first and the non-metal from the acid Ca and 2 Cl makes...  
*CaCl<sub>2</sub>*
- Now, let's put it all together, first the reactants, then the products:  
**2 HCl + CaCO<sub>3</sub> → CaCl<sub>2</sub> + H<sub>2</sub>O + CO<sub>2</sub>**
- Let's check quickly if the reaction is balanced.
  - How many H on the left and right? Are they balanced?  
*2 H left and 2 H right. The H's are balanced.*
  - How many Cl on the left and right? Are they balanced?  
*2 Cl left and 2 Cl right. The Cl's are balanced.*
  - How many O on the left and right? Are they balanced?  
*3 O left and 3 O right. The O's are balanced.*
  - How many C on the left and right? Are they balanced?  
*1 C left and 1 C right. The C's are balanced.*

Finally, let's use the chemical equation to write a word equation for the reaction:

**hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide**

### Applications for calcium carbonate

Calcium carbonate is found in many places outside of the laboratory. It is found in different types of rocks around the world, for example limestone, chalk and marble.





*The Cango Caves near Oudtshoorn, South Africa, are situated in a limestone ridge and contain spectacular limestone formations. Such caves are the result of water high in carbonic acid acting upon limestone deposits in ancient rock layers.*

Calcium carbonate is also the main part of shells of various marine organisms, snails, pearls, oysters and bird eggshells. It is also found in the exoskeletons of crustaceans (such as crabs, prawns and lobsters).



*Chunks of calcium carbonate from various shells.*



Calcium carbonate also has many applications. In industry, the main application is in construction as it is used in various building materials and in cement. Calcium carbonate is used in many adhesives, paints and in ceramics. It is also used in swimming pools to adjust the pH. When do you think it would be added? If the pool was too acidic and you wanted to make it more basic, or if the pool was too basic and you wanted to make it more acidic?

#### **TEACHER'S NOTE**

$\text{CaCO}_3$  forms a basic solution in water so it is used if the pH is too low (too acidic) and you want to make the pool water more basic.

Calcium carbonate is also used in agriculture in the form of lime powder. Agricultural lime is made by grinding up limestone or chalk. It is added to the soil if the soil is too acidic to increase the pH. It also provides plants with a source of calcium.



*This tractor is busy depositing agricultural lime onto a field. This is called liming.*

In this chapter we have investigated a number of reactions of acids with bases. We have learnt to write word equations for these reactions and practised converting between word and balanced chemical equations.



## **SUMMARY:**

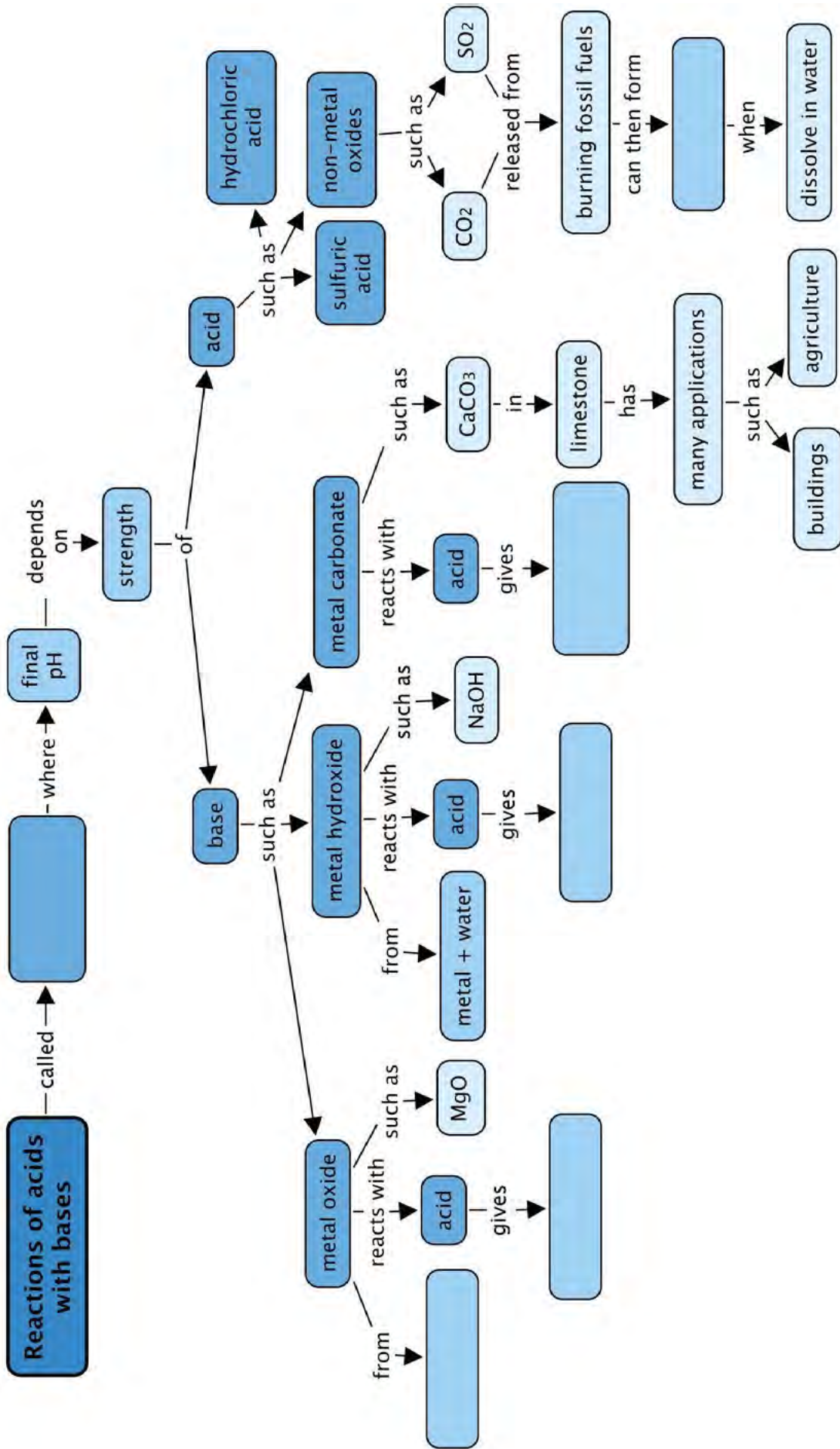
### **Key Concepts**

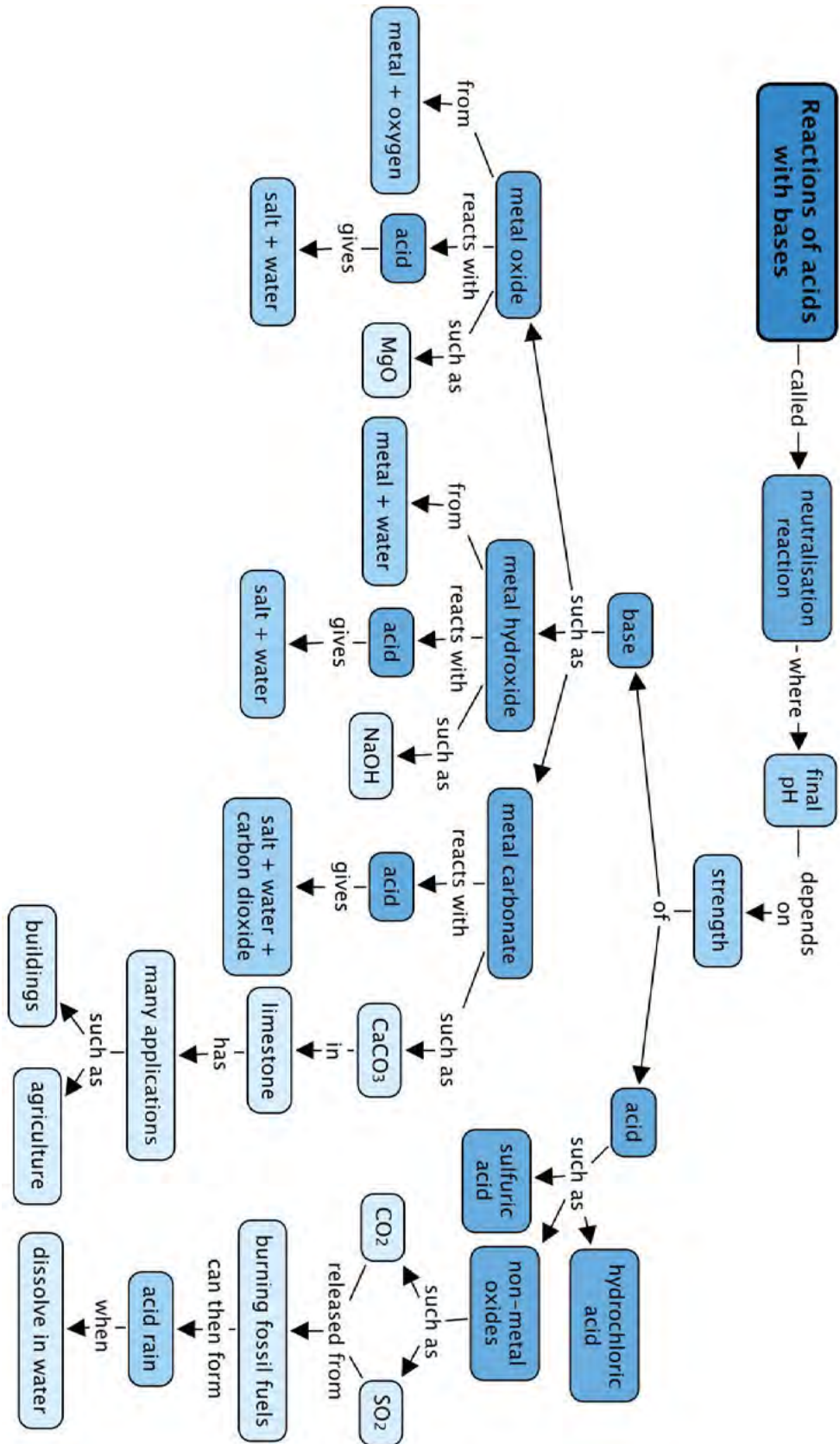
- The reaction of an acid with a base is called a neutralisation reaction.
- When an acid ( $\text{pH} < 7$ ) is added to a base ( $\text{pH} > 7$ ), the pH of the resulting mixture will lie somewhere between that of the acid and the base. Even though the acid and base will be neutralised, the resulting solution will not necessarily be neutral.
- Some common laboratory acids are sulfuric acid ( $\text{H}_2\text{SO}_4$ ), nitric acid ( $\text{HNO}_3$ ) and hydrochloric acid ( $\text{HCl}$ ).
- Non-metal oxides tend to form acidic solutions when they dissolve in water. These solutions will have pH values below 7.
- Metal oxides, metal hydroxides and metal carbonates form basic solutions in water; these will have pH values above 7.
- When a metal oxide, or a metal hydroxide reacts with an acid, a salt and water form as products.
- When a metal carbonate reacts with an acid, a salt, water and carbon dioxide form as products.
- The general word equations for the reactions of this chapter are the following:
  - acid + metal oxide  $\rightarrow$  salt + water
  - acid + metal hydroxide  $\rightarrow$  salt + water
  - acid + metal carbonate  $\rightarrow$  salt + water + carbon dioxide

### **Concept Map**

Complete the concept map by filling in the blank spaces..









## REVISION:



1. Fill in the missing words in these sentences. Write the word on the line below. [10 marks]
- a) To know if something is an acid or a base, we measure its \_\_\_\_\_.  
*pH*
- b) The name of the laboratory acid with the formula  $\text{H}_2\text{SO}_4$ , is \_\_\_\_\_.  
*sulfuric acid*
- c) The formula of the laboratory acid named hydrochloric acid, is \_\_\_\_\_.  
*HCl*
- d) When a metal oxide reacts with an \_\_\_\_\_, a salt and water will be formed.  
*acid*
- e) When a metal hydroxide reacts with an acid, a salt and \_\_\_\_\_ will be formed.  
*water*
- f) When a metal carbonate reacts with an acid, a salt, water and \_\_\_\_\_ will be formed.  
*carbon dioxide*
- g) Metal oxides, metal hydroxides and metal carbonates all dissolve in water, forming \_\_\_\_\_ solutions. This means the solutions will have pH values \_\_\_\_\_ than 7.  
*basic; greater*
- h) The reaction of an acid with a base is called a \_\_\_\_\_ reaction.  
*neutralisation*
- i) Non-metal oxides tend to form \_\_\_\_\_ solutions when they dissolve in water.  
*acidic*
2. Write a short paragraph (3 or more sentences) to explain what you understand each of the following terms to mean, in your own words. [2 x 3 = 6 marks]
- a) neutralisation  
*Learner's paragraph should contain at least the following ideas:*
- When an acid and a base are mixed, the acid will lose some of its 'acidity' and the base will lose some of its 'basicity'.
  - If they are mixed in the right amounts, they will **neutralise** each other.
  - The products of the reaction will be a salt and water.
- b) acid rain  
*Learner's paragraph should contain at least the following ideas:*
- Certain industries (and even some natural phenomena like volcanic eruptions) produce non-metal oxides as waste products.
  - Non-metal oxides form acidic solutions when they dissolve in atmospheric water droplets.
  - These acidic solutions rain down onto the Earth's surface and can cause damage to buildings, plant life and acidify water sources.



3. For each of the following reactions, complete the tables by providing the missing equations.

a) The reaction between hydrochloric acid and magnesium oxide [4 marks]

<i>Word equation</i>	<i>hydrochloric acid + magnesium oxide → magnesium chloride + water</i>
<i>Chemical equation</i>	<i><math>2 \text{HCl} + \text{MgO} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}</math></i>
<i>General equation</i>	<i>acid + metal oxide → salt + water</i>

b) The reaction between hydrochloric acid and sodium hydroxide [6 marks]

<i>Word equation</i>	<i>hydrochloric acid + sodium hydroxide → sodium chloride + water</i>
<i>Chemical equation</i>	<i><math>\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}</math></i>
<i>General equation</i>	<i>acid + metal hydroxide → salt + water</i>

c) The reaction between hydrochloric acid and calcium carbonate [4 marks]

<i>Word equation</i>	<i>hydrochloric acid + calcium carbonate → calcium chloride + water + carbon dioxide</i>
<i>Chemical equation</i>	<i><math>2 \text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{H}_2\text{O} + \text{CO}_2</math></i>
<i>General equation</i>	<i>acid + metal carbonate → salt + water + carbon dioxide</i>

d) The reaction between hydrochloric acid and magnesium hydroxide [4 marks]

<i>Word equation</i>	<i>hydrochloric acid + magnesium hydroxide → magnesium chloride + water</i>
<i>Chemical equation</i>	<i><math>2 \text{HCl} + \text{Mg}(\text{OH})_2 \rightarrow \text{MgCl}_2 + 2 \text{H}_2\text{O}</math></i>
<i>General equation</i>	<i>acid + metal hydroxide → salt + water</i>

e) The reaction between hydrochloric acid and calcium oxide [4 marks]

<i>Word equation</i>	<i>hydrochloric acid + calcium oxide → calcium chloride + water</i>
<i>Chemical equation</i>	$2 \text{HCl} + \text{CaO} \rightarrow \text{CaCl}_2 + \text{H}_2\text{O}$
<i>General equation</i>	<i>acid + metal oxide → salt + water</i>

f) The reaction between hydrochloric acid and potassium hydroxide [6 marks]

<i>Word equation</i>	<i>hydrochloric acid + potassium hydroxide → potassium chloride + water</i>
<i>Chemical equation</i>	$\text{HCl} + \text{KOH} \rightarrow \text{KCl} + \text{H}_2\text{O}$
<i>General equation</i>	<i>acid + metal hydroxide → salt + water</i>

g) The reaction between hydrochloric acid and sodium carbonate [4 marks]

<i>Word equation</i>	<i>hydrochloric acid + sodium carbonate → sodium chloride + water + carbon dioxide</i>
<i>Chemical equation</i>	$2 \text{HCl} + \text{Na}_2\text{CO}_3 \rightarrow 2 \text{NaCl} + \text{H}_2\text{O} + \text{CO}_2$
<i>General equation</i>	<i>acid + metal carbonate → salt + water + carbon dioxide</i>

Total [48 marks]



**TEACHER'S NOTE****Chapter overview**

0.5 week

This is a short chapter to conclude the series of reactions that learners will have been exposed to this term. The last reactions to look at are those between an acid and a metal. At the end of this chapter, there is a short activity on some of the careers in the chemical industry. Although this is not for assessment purposes, if you do not have time to do it in class, we encourage you to encourage or get your learners to do it as a homework activity. Seeing the real world application for what they learn in the classroom is a very important part of the learning process and in discovering what is possible through science and technology.

7.1 The reaction of an acid with a metal (1.5 hours)

Tasks	Skills	Recommendation
Activity: Testing for hydrogen gas	Remembering, balancing chemical equations	Optional
Investigation: The reaction between magnesium and hydrochloric acid	Hypothesising, preparing, measuring, observing, interpreting	CAPS suggested
Activity: Writing the chemical equation	Writing and balancing chemical equations	Optional (Suggested)
Activity: Other careers in chemistry	Researching, comparing, describing	Optional

**KEY QUESTIONS:**

- What do we get when a metal reacts with an acid?
- What is the general equation for the reaction between a metal and an acid?
- How do we write the word equation and the balanced chemical equation?
- How can we test for the presence of hydrogen gas?



## 7.1 The reaction of an acid with a metal

In the previous chapter we learnt about the reactions of acids with a variety of bases: metal oxides, metal hydroxides and metal carbonates. We learnt how to write general equations, word equations and chemical equations for those reactions.

In this chapter we will investigate one final type of reaction, namely the reaction between an acid and a metal.

First, we will do an investigation to observe the reaction and then we will write equations to represent it. Before we do this, however, we have to take a quick detour to learn something interesting about hydrogen gas.

### ACTIVITY: Testing for hydrogen gas

#### TEACHER'S NOTE

This activity introduces the test for hydrogen gas. It is **optional**, however, the test will be used in the following investigation so if you do not do this activity in class, a suggestion is for learners to do it in their own time, or to just explain the hydrogen test briefly before proceeding to the investigation.

1. What do you know about hydrogen gas? Perhaps you know its formula? Write it below.

$H_2$

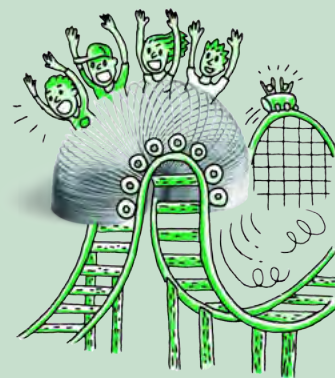
2. Hydrogen gas is a **diatomic** gas. What does this mean?  
*That means each molecule of hydrogen gas consists of two H atoms.*
3. What do you know about the position of hydrogen in the periodic table? Write what you know below.  
*Hydrogen can be found in the top left hand corner of the periodic table.*
4. The position of hydrogen in the periodic table tells us that it is the lightest of all the elements. It has the smallest atomic mass. Because the element hydrogen is a gas (even though it is a diatomic one), it has one of the lowest densities of any substance. Can you remember what **density** means? Write your own definition below.

*Density is the mass of a substance in a given space (volume).*

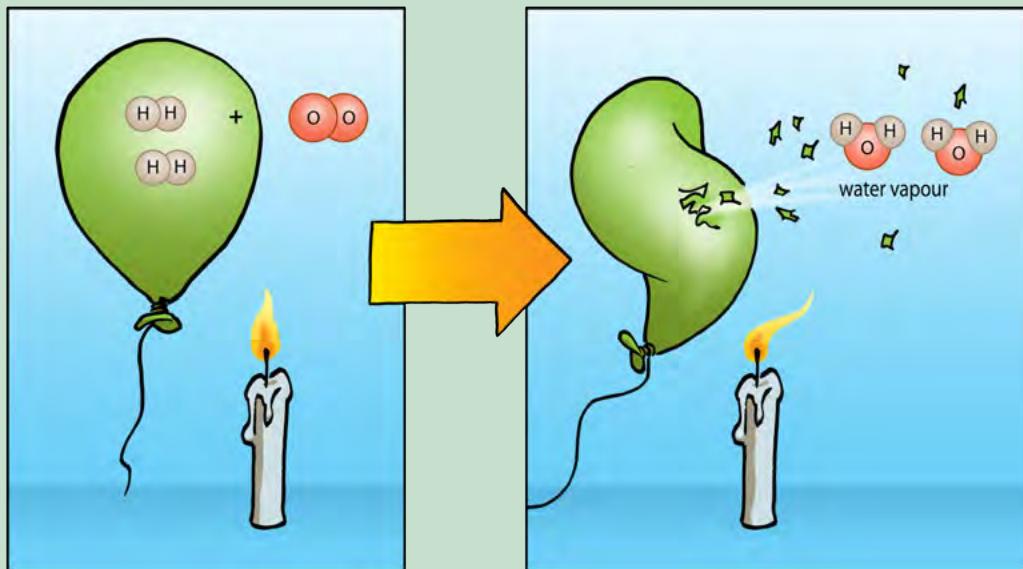
When hydrogen gas is released in a reaction it will immediately rise up, because **hydrogen is less dense than air**. If you filled a balloon with hydrogen, it would float up and you would need to tie a string to it to prevent it from floating away!



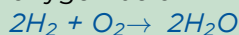
*This man is about to launch a weather balloon filled with hydrogen gas. It will float upwards to collect information about the weather in Antarctica.*



Another interesting thing about hydrogen is that it reacts explosively with oxygen if you bring a flame near it. You may remember learning about this in Chapter 4 about the reactions of non-metals with oxygen. The reaction between a large quantity of hydrogen and oxygen in the air produces a beautiful orange fireball and a very loud boom! Do you remember seeing the following diagram?



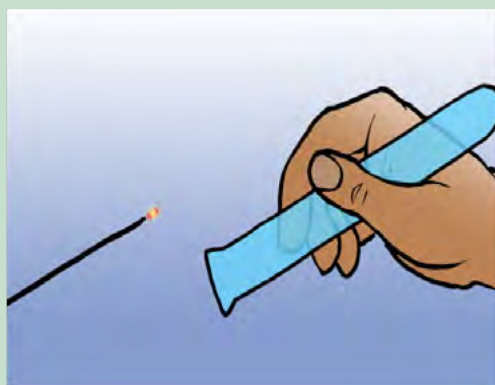
5. Write the balanced equation for the reaction between hydrogen gas and oxygen below.



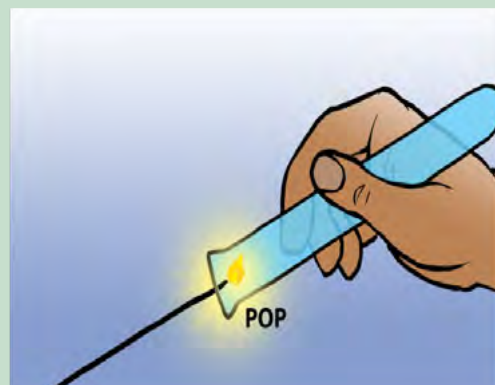
The reaction between a tiny amount of hydrogen and oxygen in the air produces a **characteristic** 'pop' sound and this serves as test for the **presence** of hydrogen. You can watch the short video clip in the visit box in the margin to see this 'pop'.

**VISIT**

Testing for hydrogen gas  
[bit.ly/14CyU4Q](http://bit.ly/14CyU4Q)



When a glowing splint is put into a test tube containing hydrogen gas...

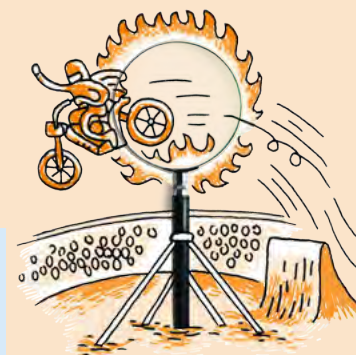


...it makes a 'pop' sound.

Let's now investigate the reaction between an acid and a metal. You should listen carefully for this 'pop' sound during the investigation. If you hear it, it will signal the presence of hydrogen gas!



## **INVESTIGATION:** The reaction between magnesium and hydrochloric acid



### **TEACHER'S NOTE**

It is recommended that you demonstrate this reaction to learners. There are many ways to perform this demonstration and if you have a tried and trusted method, you should use it by all means. For example, a simple method is to place diluted HCl in a test tube, add a piece of magnesium and then bring a glowing splint to the neck of the test tube so that it goes 'pop' in the presence of the hydrogen gas that is produced. The method we have included here does not require anything too complicated and it has the added fun aspect of blowing hydrogen bubbles and popping them with a candle flame.

The purpose of this investigation is to:

- observe the reaction between hydrochloric acid and magnesium; and
- identify the gaseous product of the reaction between hydrochloric acid and magnesium.

Your teacher will demonstrate the reaction between magnesium and hydrochloric acid, while you make observations. Remember to watch carefully and take detailed notes.

### **INVESTIGATIVE QUESTION:**

What question(s) do you hope to answer with this investigation?

*One possible question would be: What products will form when magnesium reacts with hydrochloric acid?*

### **HYPOTHESIS:**

What do you predict will happen? Your hypothesis should be a prediction of the finding(s) of the investigation. You should write it in the form of a possible answer to the investigative question(s).

*Some ideas:*

- *When magnesium reacts with hydrochloric acid, a gas is released.*
- *When magnesium reacts with hydrochloric acid, hydrogen gas is released.*

### **MATERIALS:**

- magnesium ribbon (cut into smallish pieces)
- hydrochloric acid (HCl) solution (1 M)
- large test tube
- retort stand with clamp
- rubber stopper with short length of glass tubing pushed through it
- silicone or rubber tubing (or a glass delivery tube as shown in the set-up below)
- shallow dish filled with soapy water (made by mixing a few teaspoons of dishwashing liquid with water)

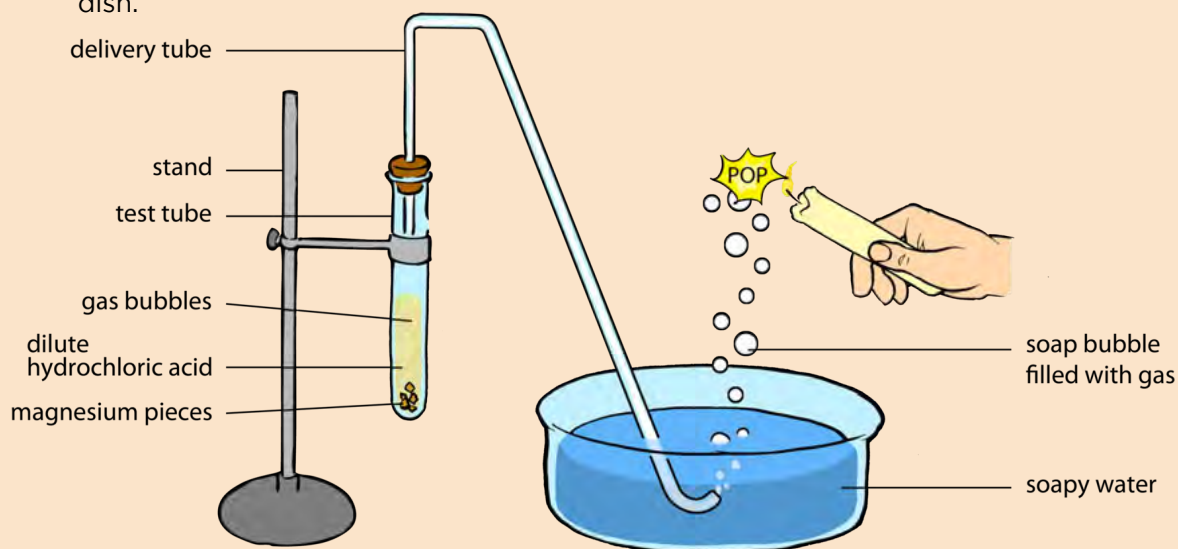
**TEACHER'S NOTE**

To prepare dilute hydrochloric acid solution, slowly and carefully add approximately 100 ml concentrated hydrochloric acid (33% or 11 M) to 900 ml of cold tap water. It is recommended that you wear safety goggles and protective gloves during this step and that you rinse away any acid spills with cold tap water. Since this is just a qualitative experiment, it is not necessary to use distilled water for the solution. It is also not required that you measure the volumes with extreme accuracy. Be careful when handling this solution; even though it is dilute it can still cause burns.

The quantities for this experiment are as follows: 1 g of magnesium will require approximately 42 ml of 1 M hydrochloric acid to be consumed. Just more than 900 ml of hydrogen gas will be produced by these quantities of reactants.

**METHOD:**

1. Use a piece of universal indicator paper to test the pH of the hydrochloric acid solution. Record its pH.  
*The pH of the 1 M HCl solution will be below 1. Since this solution is still very corrosive, it is recommended that you choose one responsible learner to perform the pH measurement on behalf of the class.*
2. Set up the experiment as shown in the following diagram. Ensure that the end of the delivery tube is below the surface of the soap solution in the dish.

**TEACHER'S NOTE**

A possible extension is to hold a cold piece of metal or glass above the place where you burst the bubbles so that the water vapour that forms during the reaction condenses on the metal or glass.

3. Place approximately 1 g of the magnesium pieces in the test tube, but do not add the hydrochloric acid until everything else is ready to be assembled.
4. Add approximately 40 ml of hydrochloric acid and immediately place the stopper on the test tube. The first few bubbles of gas that are released from the end of the delivery tube will be air.

- When the soap bubbles start to float up, hold a burning candle to them and listen carefully for the sound they make when they pop. Do not hold the candle to the end of the delivery tube.
- When the magnesium stops reacting and no further hydrogen bubbles are released, extinguish the candle and set it aside.
- Disassemble the experiment and test the pH of the reaction mixture. Record the pH value.

### RESULTS AND OBSERVATIONS:

Record your results in the following table:

pH of the 1 M hydrochloric acid before the reaction	
pH of the mixture after the reaction	

Use the following lines to write down any observations that you make during the investigation.

*Learners should note that there is a 'pop' sound when the candle bursts the bubbles. They should note that when HCl is added to the magnesium pieces, the solution bubbles as the gas is produced.*

### CONCLUSIONS:

What conclusions can be made from the results of your investigation? Rewrite your hypothesis, but change it to reflect your findings if they are different from what you predicted earlier.

### QUESTIONS:

- What did you observe in the test tube when the magnesium and hydrochloric acid were mixed?  
*Bubbles formed on the surface of the magnesium pieces.*
- What did you observe at the end of the gas delivery tube after the magnesium and hydrochloric acid were mixed?  
*Bubbles came out of the end of the gas delivery tube.*
- Why do you think the soap bubbles floated upwards?  
*The gas in the soap bubbles is less dense than air. **NOTE:** Learners may say 'lighter' than air; you can use the opportunity to remind them that less dense substances will float on substances of higher density.*
- Which gas do you think was produced by the reaction? Write its name and formula below. What makes you think it was this gas?  
*Hydrogen gas (H<sub>2</sub>). Hydrogen is less dense than air so it made soap bubbles and floated upwards which made the characteristic 'pop' sound when a candle was brought near to the bubbles.*
- What happened to the pH of the hydrochloric acid solution during the reaction?  
*The pH increased.*
- What does the increase in pH mean?  
*When the pH increases, it means there is less acid in the solution. The hydrochloric acid was being used up in the reaction with magnesium.*
- Were you able to confirm or reject your hypothesis?  
*Learner dependent answer.*



In our investigation hydrochloric acid reacted with magnesium (a metal). Our next task is to write an equation for the reaction. We will begin by writing a general equation and end with one that matches the reaction that we have just investigated.

**VISIT**

A video and simulation that teaches you more about the reactions of acids with metals [bit.ly/1eDGii7](http://bit.ly/1eDGii7)

**General equation for the reaction of an acid with a metal**

The general word equation for the reaction between an acid and a metal is:



The type of salt that forms will depend on the specific metal and acid which are used in the reaction.

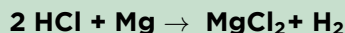
**Equations for the reaction between magnesium and hydrochloric acid**

Now let's write equations for our actual reaction from the last investigation.

**ACTIVITY:** Writing the chemical equation

The following steps will guide you:

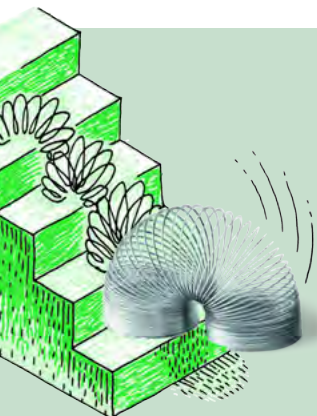
- The acid of our reaction was hydrochloric acid. Can you write its chemical formula?  
*HCl*
- What is the name and formula of the metal we used?  
*Magnesium (Mg)*
- Now, let's try to predict the products of the reaction. We know that hydrogen gas will be one of the products. Write the chemical formula for hydrogen gas.  
*H<sub>2</sub>*
- Write what remains of the acid (HCl) after we have taken away the H to make H<sub>2</sub>. (Remember we need two H to make one H<sub>2</sub>).  
*2 Cl*
- The two Cl and the Mg are exactly what are needed to make magnesium chloride. Write the formula below.  
*MgCl<sub>2</sub>*
- Now, let's write the reaction; first the reactants, then the products:



Let's check quickly if the reaction is balanced.

- How many H on the left and right? Are they balanced?  
*2 H left and 2 H right. The H's are balanced.*
- How many Cl on the left and right? Are they balanced?  
*2 Cl left and 2 Cl right. The Cl's are balanced.*
- How many Mg on the left and right? Are they balanced?  
*1 Mg left and 1 Mg right. The Mg's are balanced.*

Since the numbers of each type of atom is the same on either side of the equation, we can confirm that it is balanced.

**VISIT**

Coke cans made from aluminium (a metal) react with an acid and a base (video) [bit.ly/1IYxBMO](http://bit.ly/1IYxBMO)

7. Finally, let's use the chemical equation to write a word equation for the reaction.



## Chemist or Pharmacist?

### TEACHER'S NOTE

This section is not for assessment purposes and you may be inclined to leave it out. However, we strongly encourage you to give your learners the opportunity to discover the applications of what they are learning in class in the world around them, even if only as a homework exercise. It is very important for learners to realise that what they learn in class extends far beyond the walls of your classroom. Encourage them to be curious!

### VISIT

A useful site to find out more about some chemistry-related careers  
[bit.ly/15tsQ10](http://bit.ly/15tsQ10)

When people hear that someone is a '**chemist**', they often confuse this with being a '**pharmacist**'. In some countries the terms 'chemist' and 'pharmacist' are even used to describe the same kind of person. In South Africa the two words have different meanings. But what is the difference between being a chemist and being a pharmacist?

Look up these careers to identify the main difference between a chemist and a pharmacist and summarise them below:

### Chemists:



*Two chemists working in a laboratory.*

### TEACHER'S NOTE

Chemists are people who have studied chemistry and can use their specialist knowledge of chemical reactions to produce new materials and compounds. These could be new medicines, innovative building materials, new fuels that do not harm the environment and many others.



**Pharmacists:**



*A pharmacist in his dispensary.*

**TEACHER'S NOTE**

Pharmacists also study chemistry, but combine this with other subjects like pharmacology, physiology and biochemistry. Pharmacists are health professionals and have specialist training in the health sciences as well as the chemical sciences. Their key responsibility is to ensure the safe and effective use of pharmaceutical drugs. They use their knowledge of medicines and the human body to dispense prescriptions from a licensed pharmacy. Job opportunities for pharmacists also include clinical services, reviewing medications for safety and efficacy and providing drug information where it is needed.



**ACTIVITY:** Other careers in chemistry

**TEACHER'S NOTE**

This is an **optional** activity, which is not for assessment. A suggestion is that if you do not have time to do it in class, learners should still be encouraged to do it outside of class as it is important that they see how and where chemistry can take them after school.

**INSTRUCTIONS:**

1. Below is a list of different careers that all use chemistry in some way. Have a look through the list and then select the five careers you find most interesting.
2. Do an internet search to find out what each career is.

3. Write a one line description of this career.
4. If there is a career that really interests you, draw a smiley face next to it and be sure to do some extra reading around the topic and where chemistry might take you! Find out what level of chemistry you will need for this particular career.
5. There are many other careers besides the ones listed here which use chemistry in some way, so if you know of something else which is not listed here and it interests you, follow your curiosity and discover the possibilities!

### Some careers involving chemistry:

- Agricultural chemistry
- Biochemistry
- Biotechnology
- Chemical education/teaching
- Dentistry
- Environmental chemistry
- Forensic science
- Food science/technology
- Geneticist
- Geochemistry
- Materials science
- Medicine and medicinal chemistry
- Mining
- Oil and petroleum industry
- Organic chemistry
- Oceanography
- Patent law
- Pharmaceuticals
- Space exploration
- Zoology

#### VISIT

10 reasons to love science!  
(video) [bit.ly/14xWFy](https://bit.ly/14xWFy)

### Your descriptions of the careers you are interested in:

In this chapter we have studied the reaction of hydrochloric acid with magnesium, as an example of a reaction between an acid and a metal.

## SUMMARY:

### Key Concepts

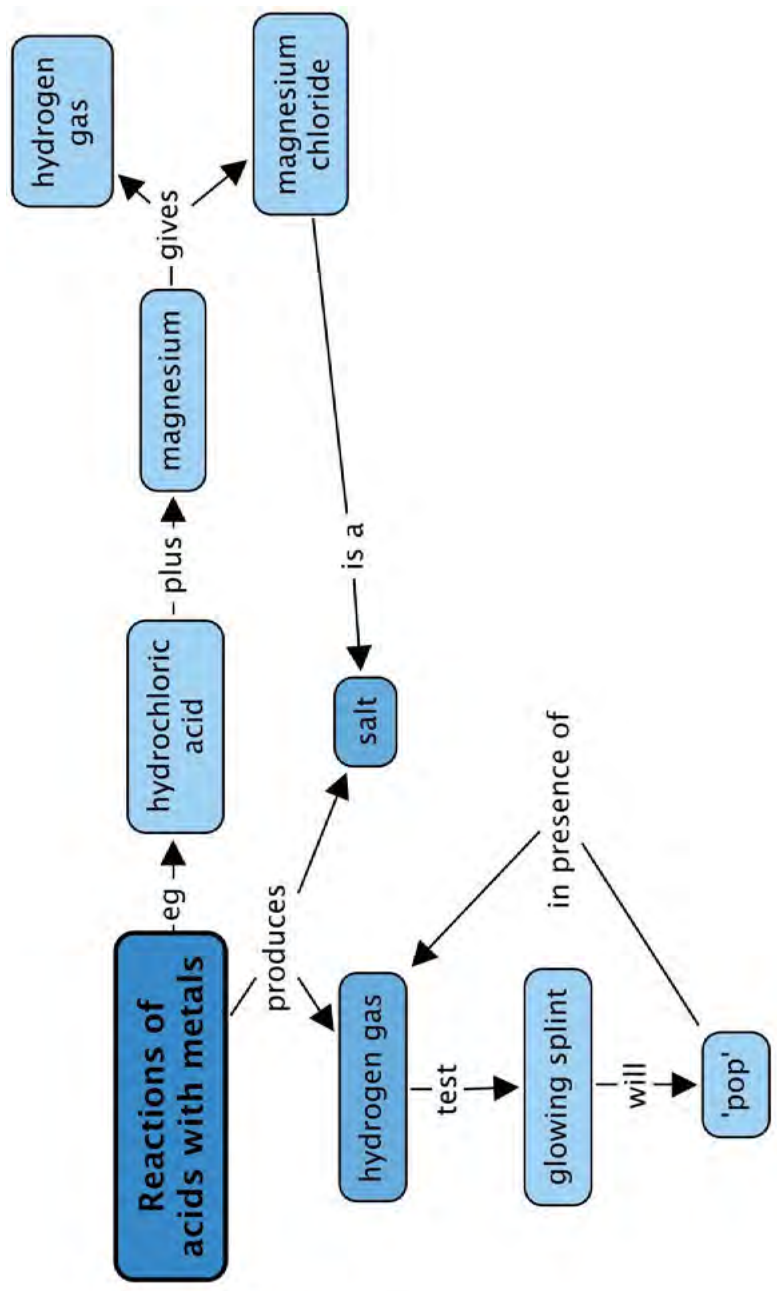
- An acid will react with a metal to form a salt and hydrogen gas.
- The general word equation for the reaction between an acid and a metal is as follows:
  - acid + metal → salt + hydrogen

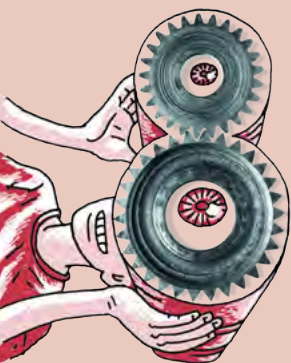
### Concept Map

This was quite a short chapter, so the concept map has been left blank for you to do your own. Be sure to include something about the test for hydrogen.



Reactions of  
acids with metals





## REVISION:

- Fill in the missing words in these sentences. Write the word on the line below. [3 marks]
  - When an acid reacts with a metal, a salt and \_\_\_\_\_ gas forms.
  - A molecule that consists of two atoms bonded together is called a \_\_\_\_\_ molecule.
  - The scientific quantity represented by the mass of a substance in a given volume is called the \_\_\_\_\_ of that substance.
    - hydrogen
    - diatomic
    - density
- Write a short paragraph (2 sentences or more) to explain why a balloon filled with hydrogen will float upwards. [2 marks]  
*Learner's paragraph should contain at least the following:*
  - Hydrogen gas is less dense than air.
  - Substances of lesser density always float on substances of greater density.
- Imagine you are carrying out a reaction and you expect one of the products that will form is hydrogen. Write a short paragraph (2 sentences or more) to describe how you would confirm the presence of hydrogen gas. [2 marks]  
*Learner's paragraph should contain at least the following:*
  - The first sign to look out for is bubbles. The presence of bubbles signals that a gas is formed during the reaction.
  - To confirm whether the gas is hydrogen, collect a small amount in a test tube. Hold a glowing splint at the opening of the test tube when you release the gas. If the gas ignites with a characteristic 'pop' sound, we will know it is hydrogen.
- When an acid reacts with a metal, do you think the pH of the solution will increase, decrease, or stay the same? Motivate your answer briefly. [3 marks]  
*The pH will increase. In the reaction, the acid is changed into something else that is not an acid. That means the pH must increase.*
- Complete the following table by providing the missing equations for the reaction between hydrochloric acid and magnesium [6 marks]

Word equation	hydrochloric acid + magnesium → magnesium chloride + hydrogen gas
Chemical equation	$2 \text{HCl} + \text{Mg} \rightarrow \text{MgCl}_2 + \text{H}_2$
General equation	acid + metal → salt + hydrogen

- Complete the following table by providing the missing equations for the reaction between hydrochloric acid and zinc [4 marks]

Word equation	hydrochloric acid + zinc → zinc chloride + hydrogen gas
Chemical equation	$2 \text{HCl} + \text{Zn} \rightarrow \text{ZnCl}_2 + \text{H}_2$
General equation	acid + metal → salt + hydrogen



7. We have looked at many different chemical reactions this term. As a summary, complete the following table by giving the general equations in words for each of the chemical reactions in the second column, and provide an example for each type as a balanced chemical equation in the third column. [18 marks]

*Only one example has been provided in this table as an example of what learners might write. There are however other suitable reactions which they have also learnt about this term. You must check that the reactions they provide are balanced.*

*The mark allocation is 1 mark for each of the general word equations and 2 marks for the example (only 1 mark if it is not correctly balanced).*

<b>Type of chemical reaction</b>	<b>General word equation</b>	<b>Example (balanced equation)</b>
<i>metals with oxygen</i>	<i>metal + oxygen → metal oxide</i>	$2\text{Mg} + \text{O}_2 \rightarrow 2\text{MgO}$
<i>non-metals with oxygen</i>	<i>non-metal + oxygen → non-metal oxide</i>	$\text{C} + \text{O}_2 \rightarrow \text{CO}_2$
<i>acids with metal oxides</i>	<i>acid + metal oxide → salt + water</i>	$2\text{HCl} + \text{MgO} \rightarrow \text{MgCl}_2 + \text{H}_2\text{O}$
<i>acids with metal hydroxides</i>	<i>acid + metal hydroxide → salt + water</i>	$\text{HCl} + \text{NaOH} \rightarrow \text{NaCl} + \text{H}_2\text{O}$
<i>acids with metal carbonates</i>	<i>acid + metal carbonate → salt + carbon dioxide + water</i>	$2\text{HCl} + \text{CaCO}_3 \rightarrow \text{CaCl}_2 + \text{CO}_2 + \text{H}_2\text{O}$
<i>acids with metals</i>	<i>acid + metal → salt + hydrogen gas</i>	$2\text{HCl} + \text{Mg} \rightarrow \text{MgCl}_2 + \text{H}_2$

Total [38 marks]



## GLOSSARY

<b>acidity:</b>	this word is related to the word 'acid', so is the word 'acidic'; a substance is strongly acidic when it has a high (degree of) acidity
<b>acid rain:</b>	rainwater that is unusually acidic as a result of dissolved non-metal oxides that have entered the atmosphere
<b>alternative:</b>	different
<b>atomic number:</b>	a unique number that represents a given element, and shows its position on the periodic table; the number of protons found in the nucleus
<b>balanced</b>	: a balanced equation reaction has the same numbers of atoms of a particular type on opposite sides of the reaction equation
<b>barrier</b>	: a fence or other obstacle that keeps things apart
<b>bond</b>	: a force between atoms in a compound, holding them together
<b>camera flash:</b>	a device (usually attached to the camera) that provides a quick burst of light at the instant that the photo is taken
<b>characteristic:</b>	a quality or feature of an object or item; for example, one of the characteristics of an acid is that it is corrosive
<b>chemical bond:</b>	a special attractive force that holds the atoms in a molecule together
<b>chemical equation:</b>	an equation that describes a chemical reaction using the chemical formulae of the compounds involved in the reaction
<b>chemical formula:</b>	a combination of element symbols that shows the types and number of atoms in one molecule of a given compound; a unique string of symbols (letters and numbers) that represents a chemical compound
<b>chemical reaction:</b>	a process in which atoms in substances, called reactants, are rearranged to form new substances, called products
<b>chemist</b>	: a person who has studied chemistry and uses this knowledge to do his/her job
<b>chromed metal:</b>	metal that is covered by a thin layer of chromium
<b>coefficient:</b>	a number that is placed <i>in front of</i> a chemical formula in a reaction equation; it shows the number of molecules of that type taking part in the reaction, for example $2 \text{ Mg}$
<b>collide</b>	: to bump into something
<b>combustion</b>	: a type of chemical reaction where a substance and oxygen react during burning to form a new product

<b>compound:</b>	a pure substance in which atoms of two or more different chemical elements are bonded in some fixed ratio
<b>convention:</b>	a way in which something is usually done
<b>corrosion:</b>	the gradual destruction of materials (usually metals) by chemical reaction with substances in the environment
<b>corrosive</b>	: a corrosive substance is something that causes corrosion; substances that are corrosive can cause burns on the skin and damage to certain surfaces
<b>crystal lattice:</b>	in some compounds, the atoms are arranged in a regular pattern in a fixed ratio to form a lattice structure; a lattice looks like a mesh or trellis
<b>density:</b>	the mass of a substance in a given space (volume)
<b>detour:</b>	to take a roundabout route, either to make a visit along the way, or to avoid something
<b>diatomic</b>	: a diatomic molecule consists of two atoms; H <sub>2</sub> , N <sub>2</sub> , O <sub>2</sub> , F <sub>2</sub> , Cl <sub>2</sub> , Br <sub>2</sub> , and I <sub>2</sub> are all examples of elements that consist of diatomic molecules
<b>dioxide</b>	: a compound that contains two oxygen atoms in its chemical formula; examples are carbon dioxide (CO <sub>2</sub> ) and sulfur dioxide (SO <sub>2</sub> )
<b>electrons:</b>	the smallest of the three types of sub-atomic particles; they are negatively charged and are located outside the atomic nucleus
<b>element</b>	: a pure substance that consists of only one type of atom throughout
<b>exchange reaction:</b>	a reaction in which the reactants break up in fragments that are then exchanged, or swapped around
<b>exposed</b>	: when a material is exposed, it is uncovered or unprotected (in this case from oxygen that will react with it)
<b>fossil fuel:</b>	a fuel that was formed from the prehistoric remains of plant and animal life (fossils); it usually has to be extracted from the earth; examples include oil, coal and natural gas
<b>fuel</b>	: a substance that will release energy when it reacts with another substance; in this context that other substance is usually oxygen
<b>galvanised</b>	<b>metal:</b> metal that is covered by thin layers of zinc and zinc oxide
<b>galvanise:</b>	to galvanise iron or steel means to cover it with a thin layer of zinc; the zinc reacts with oxygen to form zinc oxide when it is exposed to air and this forms a strong and impenetrable coating
<b>generate</b>	: to produce something; in this case it refers to some other source of energy being converted to electrical energy (electrical power or electricity)
<b>group</b>	: the vertical columns of the Periodic Table are called <i>groups</i>

<b>identical:</b>	exactly the same in every way
<b>ignite</b>	: to set something on fire
<b>indicator</b>	: a substance that changes colour in the presence of another substance, showing that that substance is present
<b>inert:</b>	unreactive; these substances do not react with other substances and do not change into other compounds
<b>IUPAC:</b>	International Union of Pure and Applied Chemistry (acronym)
<b>IUPAC system:</b>	a system for naming compounds in a way that is unique for each compound
<b>laboratory acids:</b>	acid commonly found in the laboratory
<b>litmus</b>	: a well known acid-base indicator that turns red when mixed with an acid and blue when mixed with a base
<b>macroscopic</b>	: the <i>macroscopic</i> world includes all the things we can observe with our five senses - things we can see, hear, smell, touch and taste
<b>metal:</b>	an element that is shiny, ductile and malleable; metals occur on the left and towards the middle of the periodic table
<b>metal carbonate:</b>	a compound with the the general formula $MCO_3$ or $M_2CO_3$ where M represents a metal atom, C represents a carbon atom and O represents an oxygen atom
<b>metal hydroxide:</b>	a compound with the the general formula $MOH$ or $M(OH)_2$ where M represents a metal atom, O represents an oxygen atom and H represents a hydrogen atom
<b>metal oxide:</b>	the product of the reaction between a metal and oxygen; a compound with the general formula $MO$ or $M_2O$ where M represents a metal atom and O represents an oxygen atom
<b>molecule</b>	: two or more atoms that have chemically bonded with each other; the atoms in a molecule can be of the same kind (in which case it would be a molecule of an element), or they can be of different kinds (in which case it would be a molecule of a compound)
<b>neutralisation reaction:</b>	a reaction in which the reactants neutralise each other
<b>neutralise:</b>	to neutralise something means to take away its potency
<b>neutral solution:</b>	a solution with $pH = 7$
<b>neutrons</b>	: a type of sub-atomic particle similar to protons in mass and size, but neutral (without charge); neutrons together with protons make up the atomic nucleus
<b>non-metal:</b>	an element that does not have metallic properties; non-metals (excluding hydrogen) occur in the top right-hand corner of the periodic table

<b>non-metal oxide:</b>	the product of the reaction between a non-metal and oxygen
<b>non-renewable:</b>	non-renewable energy sources refer to sources that can be used up, such as fossil fuels (coal, oil, or natural gas)
<b>oxidise</b>	: when a compound reacts with oxygen, we say it is oxidised; in chemistry, the word oxidise means much more than this, but in this chapter we will limit ourselves to this simple definition
<b>penetrate</b>	: when liquid or air penetrates into a material, it passes into or through that material (usually because of tiny holes in the material); something that cannot be penetrated is called impenetrable
<b>periodic table:</b>	a table in which the chemical elements are arranged in order of increasing atomic number
<b>period:</b>	the horizontal rows of the Periodic Table are called <i>periods</i>
<b>pharmacist</b>	: a person who has studied pharmacy and uses this knowledge in the field of health science
<b>pH</b>	: pH measures the acidity and alkalinity of a solution as a number on a scale ranging between 0 and 14
<b>picture equation:</b>	an equation that describes a chemical reaction using diagrams of the particles of the compounds involved in the reaction
<b>porous</b>	: material that has tiny holes through which liquid or air may pass
<b>potency</b>	: power
<b>prefix</b>	: a bit added at the start of a word, usually to indicate number, e.g., <i>mono-</i> , <i>di-</i> , or <i>tri-</i>
<b>presence:</b>	the state of something existing or being present in a place
<b>preservative</b>	: a substance that is added to products (usually food or beverages) to make them last longer; most preservatives are toxic to microorganisms, but are added in such small quantities that they do not pose significant harm to humans
<b>product</b>	: a substance that forms during the reaction; it will be present after the reaction has taken place
<b>protons</b>	: sub-atomic particles that are positively charged and occur inside the atomic nucleus along with neutrons
<b>reactant:</b>	the starting substances that undergo change in a chemical reaction
<b>reactive</b>	: elements and compounds that are <i>reactive</i> will readily react with many other substances
<b>red cabbage indicator:</b>	An acid-base indicator made from the sap of red cabbage; red cabbage indicator is also capable of displaying a range of colours, depending on the pH of the solution with which it is mixed
<b>renewable:</b>	a renewable source of energy cannot be used up, such as water, wind, or solar power



<b>rust</b>	: a reddish- or yellowish-brown, often flaky, coating of iron oxide that is formed on iron or steel by oxidation (when it reacts with oxygen in the air)
<b>rust-resistant:</b>	a rust-resistant material; one that does not rust
<b>semi-metal:</b>	an element that has properties of both metals and non-metals; the semi-metals occur in a narrow diagonal strip that separates the metals from the non-metals on the periodic table
<b>steel</b>	: a metal alloy composed of a mixture of iron and other elements (mostly metal); it is very strong and used widely in the construction industry (also in buildings)
<b>submicroscopic:</b>	the submicroscopic world includes things that exist but that we can't see; atoms and molecules can only be 'seen' as mental pictures and when we draw these, we refer to them as 'submicroscopic diagrams'
<b>subscript</b>	: a number that is placed <i>inside</i> a chemical formula; it shows the number of atoms of that type in one molecule of that compound, for example O <sub>2</sub>
<b>suffix</b>	: a bit added at the end of a word, e.g., <i>-ide</i>
<b>symbolic</b>	: the <i>symbolic</i> world includes letters and numbers that we use to represent atoms and molecules
<b>symbol (or element symbol):</b>	a unique letter (or letters) that represent a given element
<b>systematic name:</b>	The unique name that will be generated for a given compound, if the IUPAC system for naming compounds is followed correctly
<b>tarnish:</b>	when a metal surface gets dirty or spotty after reacting with oxygen or other substances in the air, we say it is tarnished
<b>toxic</b>	: poisonous, harmful to living organisms
<b>unique</b>	: the only one of its kind; unlike anything else
<b>unit:</b>	In this chapter, unit means a quantity used as a standard of measurement, e.g. units of time are second, minute, hour, day, week, month, year and decade
<b>universal indicator:</b>	An acid-base indicator that can display a range of colours, depending on the pH of the solution with which it is mixed
<b>word equation:</b>	an equation that describes a chemical reaction using the names of the compounds involved in the reaction



# A Assessment rubrics

The assessment guidelines for Gr 7-9 Natural Sciences are outlined in CAPS on page 85. Provided here are various rubrics as a guideline for assessment for the different tasks which you would like to assess, either **informally** (to assess learners' progress) or **formally** (to record marks to contribute to the final year mark). These rubrics can be photocopied and used for each learner.

The various rubrics provided are:

- **Assessment Rubric 1: Practical activity**
  - To be used for any practical task where learners are required to follow instructions to complete the task.
- **Assessment Rubric 2: Investigation**
  - To be used for an investigation, especially where learners have to write their own experimental report or design the investigation themselves.
- **Assessment Rubric 3: Graph**
  - To be used for any graph or translation task you would like to assess, either on its own or within another activity.
- **Assessment Rubric 4: Table**
  - To be used when learners have to draw their own table and you would like to assess it.
- **Assessment Rubric 5: Scientific drawing**
  - To be used when learners have to do a drawing, particularly in Life and Living.
- **Assessment Rubric 6: Research assignment or project**
  - To be used when learners have to do a research assignment or project, either outside of class or in class time, and either individually or in groups.
- **Assessment Rubric 7: Model**
  - To be used when learners have to design and build their own scientific models.
- **Assessment Rubric 8: Poster**
  - To be used when learners have to make a poster, either individually or in a group.
- **Assessment Rubric 9: Oral presentation**
  - To be used when learners have to give an oral presentation to the class on a selected topic.
- **Assessment Rubric 10: Group work**
  - To be used to assess any work where learners are required to complete the task as a group. This rubric is designed to assess the group as a whole.

## A.1 Assessment Rubric 1: Practical activity

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Following instructions</b>	Unable to follow instructions	Instructions followed with guidance	Able to work independently	
<b>Observing safety precautions</b>	Unable to observe safety precautions	Sometimes does not follow safety precautions	Able to follow safety precautions completely	
<b>Ability to work tidily</b>	Cannot work tidily	Can work tidily		
<b>Cleans up afterwards</b>	Does so once reminded	Does so without reminding		
<b>Organisation</b>	Disorganised	Fairly organised	Organised and efficient	
<b>Use of apparatus, equipment and materials</b>	Always used incorrectly and materials wasted	Sometimes used correctly and aware of material usage	Apparatus and materials used correctly and efficiently	
<b>Results or final product</b>	No result or final product	Partially correct results or product	Results or product correct	
<b>Answers to questions based on activity</b>	No answers provided or most are incorrect	Can answer questions and at least 60% are correct	Can answer application and questions correctly	
			Total	/15

## A.2 Assessment Rubric 2: Investigation

Name:

Date:

Task:

Assessment criteria	0	1	2	3	Comments
<b>Aim</b>	Not stated or incorrect	Not clearly stated	Clearly stated		
<b>Hypothesis or prediction</b>	Not able to hypothesise	Able to hypothesise, but not clearly	Clearly hypothesises		
<b>Materials and apparatus</b>	Not listed or incorrect	Partially correct	Correct		
<b>Method</b>	None	Confused, not in order or incorrect	Partially correct	Clearly and correctly stated	
<b>Results and observations (recorded either as a graph, table or observations)</b>	No results recorded or incorrectly recorded	Partially correctly recorded	accurately recorded but not in the most appropriate or specified way	Correctly and accurately recorded in the most appropriate or specified way	
<b>Analysis or discussion</b>	No understanding of the investigation	Some understanding of the investigation	Understands the investigation	Insightful understanding of the investigation	
<b>Evaluation</b>	No attempt	Partially correct	Correct, but superficial	Critical evaluation with suggestions	
<b>Neatness of report</b>	Untidy	Tidy			
<b>Logical presentation of report</b>	Not logical	Some of report is logically presented	Report is logically presented		
				Total	/25



## A.3 Assessment Rubric 3: Graph

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Correct type of graph</b>	Not correct	Correct		
<b>Appropriate heading, describing both variables</b>	Not present	Present, but incomplete	Complete	
<b>Independent variable on x-axis</b>	Not present or incorrect	Present		
<b>Dependent variable on y-axis</b>	Not present or incorrect	Present		
<b>Appropriate scale on x-axis</b>	Incorrect	Correct		
<b>Appropriate scale on y-axis</b>	Incorrect	Correct		
<b>Appropriate heading for x-axis</b>	Not present or incorrect	Correct		
<b>Appropriate heading for y-axis</b>	Not present or incorrect	Correct		
<b>Units for independent variable on x-axis</b>	Not present or incorrect	Correct		
<b>Units for dependent variable on y-axis</b>	Not present or incorrect	Correct		
<b>Plotting points</b>	All incorrect	Mostly or partially correct	All correct	
<b>Neatness</b>	Untidy	Tidy		
<b>Graph size</b>	Too small	Large		
			Total	/15

## A.4 Assessment Rubric 4: Table

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Appropriate heading, describing both variables</b>	Not present	Present, but incomplete	Complete	
<b>Appropriate column headings</b>	Not present or incorrect	Mostly correct	Correct and descriptive	
<b>Appropriate row headings</b>	Not present or incorrect	At least half correct	All correct	
<b>Units in headings and not in body of table</b>	None present	Present but in the body	Present and in the headings	
<b>Layout of table</b>	No horizontal or vertical lines	Some lines drawn	All vertical and horizontal lines drawn	
<b>Data entered in table</b>	Not correct	Partially correct	All correct	
			Total	/12



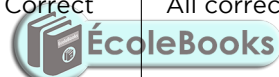
## A.5 Assessment Rubric 5: Scientific drawing

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Appropriate, descriptive heading</b>	Not present	Present, but incomplete	Complete	
<b>Appropriate size of drawing (sufficiently large on page)</b>	Incorrect (too small)	Correct		
<b>Accuracy of drawing (correct shape and proportion of parts)</b>	Incorrect	Somewhat correct	Correct	
<b>Structures or parts placed correctly in relation to each other</b>	Mostly incorrect	Mostly correct, but some misplaced	All correct	
<b>Diagram lines are neat, straight and done with a sharp pencil</b>	Not clear or neat or blunt pencil	Clear and neat		
<b>Label lines do not cross over each other</b>	Incorrect	Correct	All correct	
<b>Parts are labelled</b>	Mostly incorrect	Mostly correct with some missing or incorrectly labelled	All correct and labelled	
			Total	/12



## A.6 Assessment Rubric 6: Research assignment or Project

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Group work (if applicable)</b>	Conflict between members or some did not participate	Some conflict and some members did not always participate	Worked efficiently as a group	
<b>Project layout</b>	No clear or logical organisation	Some parts are clear and logical, while others are not	Clear and logical layout and organisation	
<b>Accuracy</b>	Many errors in content	A few errors in content	Content is accurate	
<b>Resources used (material or media)</b>	No resources used	Some or limited resources used	A range of resources used	
<b>Standard</b>	Poor standard	Satisfactory	Of a high standard	
<b>Use of time</b>	Did not work efficiently and ran out of time	Worked fairly efficiently	Worked efficiently and finished in time	
			Total	/12

## A.7 Assessment Rubric 7: Model

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Scientifically accurate</b>	Model inaccurate or incomplete	Mostly accurate, but with some parts missing or incorrect	Accurate, complete and correct.	
<b>Size and scale</b>	Too big or too small, parts not in proportion to each other	Correct size, but some parts too big or too small	Correct size and proportional scale	
<b>Use of colour or contrast</b>	Dull, with little use of contrast	Somewhat colourful	Creative and good use of colour and contrast	
<b>Use of materials</b>	Inappropriate use or only expensive materials used	Satisfactory use of appropriate materials and recyclables where possible	Excellent use of materials and recyclables where appropriate	
<b>Use of a key or explanation</b>	Not present	Present but incomplete or vague	Clear and accurate	
			Total	/10



## A.8 Assessment Rubric 8: Poster

Name:

Date:

Task:

Assessment criteria	0	1	2	Comments
<b>Title</b>	Absent	Present, but not sufficiently descriptive	Complete title	
<b>Main points</b>	Not relevant	Some points relevant	All points relevant	
<b>Accuracy of facts</b>	Many incorrect	Mostly correct, but some errors	All correct	
<b>Language and spelling</b>	Many errors	Some errors	No errors	
<b>Organisation and layout</b>	Disorganised and no logic	Organisation partially clear and logical	Excellent, logical layout	
<b>Use of colour</b>	No colour or only one colour	Some use of colour	Effective colour	
<b>Size of text</b>	Text very small	Some text too small	Text appropriate size	
<b>Use of diagrams and pictures</b>	Absent or irrelevant	Present but sometimes irrelevant	Present, relevant and appealing	
<b>Accuracy of diagrams or pictures</b>	Inaccurate	Mostly accurate	Completely accurate	
<b>Impact of poster</b>	Does not make an impact	Makes somewhat of an impact	Eye catching and makes a lasting impact	
<b>Creativeness</b>	Nothing new or original	Some signs of creativity and independent thought	Original and very creative	
			Total	/22

## A.9 Assessment Rubric 9: Oral presentation

Name:

Date:

Task:

Assessment criteria	0	1	2	3	Comments
<b>Introducing the topic</b>	Did not do	Present, but with no clear links to content	Present, and links to content being covered	Interesting and catching introduction	
<b>Speed of presentation</b>	Too fast or too slow	Started off too fast or too slow but reaches optimal pace	Good speed throughout		
<b>Pitch and clearness of voice</b>	Too soft or unclear	Started off unclear or too soft, but improved	Speaks clearly and optimal pitch throughout		
<b>Capturing audience's attention and originality</b>	Did not make an impact or no attempt to capture interest	Interesting at times	Sustained interest and stimulating	Sustained interest and stimulating throughout with originality	
<b>Organisation of content during presentation</b>	Illogical or unclear	Clear and mostly logical	Clear and logical throughout		
<b>Factual content</b>	Many errors in content	Some errors in content	All correct		
<b>Concluding remarks</b>	No conclusion or not appropriate	Made a satisfactory conclusion	Insightful/ thought-provoking conclusion		
<b>Answers to educator and class's questions</b>	Was not able to answer questions or gave incorrect answers	Was able to answer recall questions only	Was able to answer recall and application questions		
			Total		/18

## A.10 Assessment Rubric 10: Group work

Name:

Date:

Task:

Assessment criteria	0	1	2	3	Comments
<b>Member participation</b>	Very few members participated or one or two members did most of work	Only some members participated	In the beginning only some members participated but then full participation	Full participation throughout	
<b>Discipline within the group</b>	Lack of discipline	Some members disciplined	Most members disciplined	All members disciplined	
<b>Group motivation</b>	Unmotivated or lack focus	Some members motivated, but others lack focus	Most members motivated and focused	All members motivated and focused	
<b>Respect for each other</b>	Show disrespect to each other	Some members showed disrespect	All members are respectful		
<b>Conflict within the group</b>	Considerable conflict and disagreements which were unresolved	Some conflict which was either resolved or unresolved	No conflict or any issues were resolved maturely		
<b>Time management</b>	Disorganised and unable to stick to time frames	Mostly able to work within the given time	Effective use of time to complete the task		
			Total		/15



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