LIFE SCIENCES

Grade 11 Textbook

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

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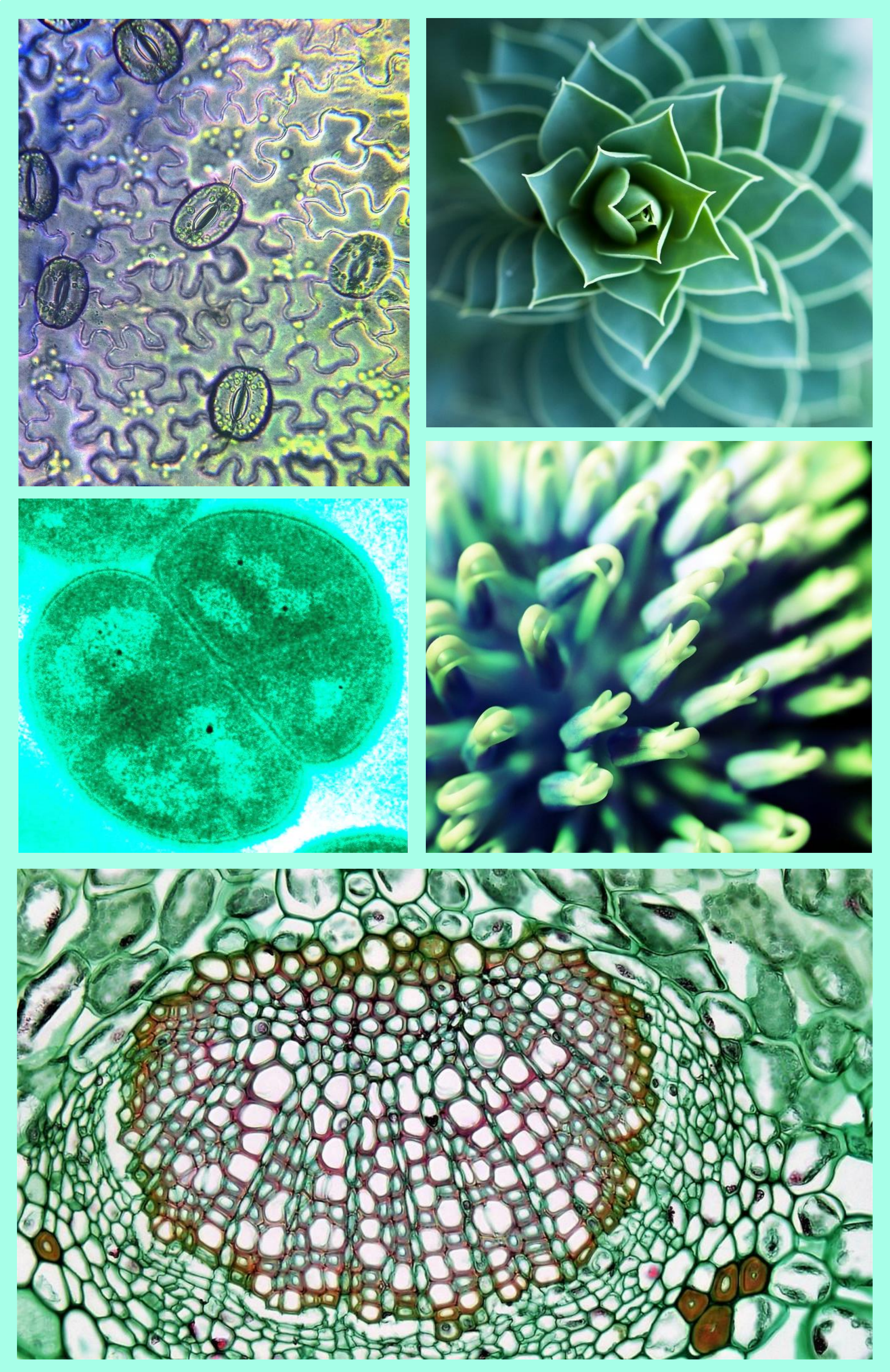

INTRODUCING LIFE SCIENCES

The aim of this textbook is to allow you, the learner, to be an active partner in your learning experience. The text has been designed to cover all the content you need for Grade 11, and to provide it in a readable manner that communicates all concepts simply, clearly and in the necessary amount of detail.

The next few pages will provide you with a broad overview of Life Sciences and hopefully show you its value as a choice for a school subject.

Studying Life Sciences also offers you broader benefits: it will encourage your ability to **think critically**, to **solve problems** and seek to **understand the world around you**.

What are the Life Sciences?

The term 'Life Sciences' indicates clearly the two ideas held together in this subject:

- **Life** refers to all living things – from the most basic of molecules through to the interactions of organisms with one another and their environments.
- **Science** indicates it is necessary to use certain methods in our study of the subject. The two broad aims of any science are to increase existing knowledge and discover new things.

We approach this using careful methods that can be copied by others. These include:

- proposing hypotheses (the predicted outcome of an investigation) and
- carrying out investigations and experiments to test these hypotheses.

Scientific knowledge changes over time as more is discovered and understood about our world; as such, Life Sciences is a constantly growing subject.

Why choose Life Sciences as a subject?

- **First**, to give you knowledge and skills that are helpful in everyday life, even if you do not pursue Life Sciences after school.
- **Secondly**, to expose you to the wide variety of sub-fields within the subject that could encourage or interest you to pursue a career in the sciences.

If you choose to study Life Sciences at school you will be able to study any Life Science specialisations after school - such as microbiology, genetics, environmental studies or biotechnology.

What skills will Life Sciences equip you with?

This subject will teach you important biological concepts, processes, systems and theories, and provide you with the skills to think, read and write about them. Life Sciences will:

- give you the ability to evaluate and discuss scientific issues and processes
- provide an awareness of the ways biotechnology and a knowledge of Life Sciences have benefited humankind
- show you the ways in which humans have impacted negatively on the environment and organisms within it, and show you how to be a responsible citizen in terms of the environment and conservation
- build an appreciation of the unique contribution of South Africa to Life Sciences - both the diversity of the unique biomes within Southern Africa and the contributions of South Africans to the scientific landscape.

Life Sciences Strands for Grade 11

Everything you study this year will fit into one of these three broad strands. These knowledge pathways grow over your three years of FET.

Within each knowledge strand, ideas should not be studied separately; rather seek to discover the links between related topics so that you grow in your understanding of the inter-connectedness of life. As you study each section or chapter, look for the broad strokes that place it under one of these strands:

- Knowledge **Strand 2**: Life Processes in Plants and Animals
- Knowledge **Strand 3**: Diversity, Change and Continuity
- Knowledge **Strand 4**: Environmental Studies

The Purpose of studying Life Sciences

There are three broad purposes, which will expand as we continue:

- **Aim 1 -** knowing the content (theory);
- **Aim 2 -** doing practical work and investigations;
- **Aim 3 -** understanding the applications of Life Sciences in society - both present society (indigenous and western) and within the context of history.

Aim 1: Knowing the content of Life Sciences

Learning content involves understanding and making meaning of scientific ideas, and then connecting these ideas. Theory is not just recalling facts; it is being able to *select important ideas*, *use different sources to learn*, and *describe concepts, processes and theories* important to Life Sciences.

Within this you will learn to *write summaries*, develop your *own diagrams* and *reorganise data* you are given into something meaningful. Additionally, you will learn to *interpret the data* you are working with and *link it to theory* you have studied.

Aim 2: Doing practical work and investigations

Life Science is a fascinating subject and one of the best ways to understand it is for you to see it in action. Therefore, it is important for you to know how to do practical investigations. Within this, you will learn many useful skills like how to *follow instructions* in a safe manner and how to *name*, *recognise* and *handle laboratory equipment*.

During a practical investigation it is important for you to be able to *make observations*. There are many ways this can be done - by making drawings, describing what you see, taking measurements, and comparing materials before and after a certain treatment. After making these observations it is important for you to be able to *measure* and *record them* in a useful way. From here you will *interpret your data* - you will look for the value in what you gathered and discuss the changes, trends, and applications of what you have shown.

Finally, you will learn how to design your own investigations and experiments. An investigation is more straightforward; for example, it could involve observing soil profiles or counting animal populations.

Planning an experiment would begin with identifying a problem, and then hypothesising a solution. In planning, you would identify variables and consider ways to control them, select apparatus and materials to assist you, and then plan an experiment that could be repeated by someone else. It is also important to consider ways of capturing and interpreting your data.

Aim 3: Understanding the history, importance and modern applications of Life sciences

The third aim of Life Sciences is to show you that school science can be relevant to your life and that studying provides enrichment to you, even if you do not pursue it past school level.

As you study you will be exposed to the history of science and indigenous knowledge systems from other times and other cultures. As you learn a certain section of work, you will be introduced to how that knowledge was developed by various scientists across the ages as they pursued a deeper understanding of the world around them.

Our search of knowledge is shaped by our world view. Therefore, an important concept to be aware of is that modern science (and technology) and traditional, indigenous knowledge systems will sometimes differ in their approach to science. These seemingly opposite views can be held together as both bring a certain dynamic; they should not be seen as opposing forces.

Finally, there are many possible career fields branching out of Life Sciences and, as you learn, some of these will be shown through examples. Different sections would open up different careers choices- *in the past* (for example palaeontology), *the present* (like horticulture, game ranch management and preservation) and *the future* (such as biotechnology and genetic engineering).

A final word on using this textbook

The best way to use this textbook to increase your understanding and thereby results would be as follows:

- Remember, good learning begins in the classroom so always pay careful attention as your teacher works through it with you
- Take note of sections you do not understand and revisit them
- Ask questions to make sure you understand
- Consider the end-of-chapter summaries and build on them to create your own point-form summary note
- Practice re-sketching the given diagrams
- Work through all the given questions and answers at the end of the chapter.


Strand
diversity
change
and
continuity

1: Biodiversity and classification of micro-organisms

CHAPTER 1: BIODIVERSITY AND CLASSIFICATION OF MICRO-ORGANISMS

Introduction

Biodiversity in general, refers to the wide variety of plants, animals and micro-organisms on Earth. Organisms which are too small to be seen with the naked eye are referred to as **micro-organisms**. Micro-organisms can be **unicellular** or **multicellular**. Some are harmful and cause diseases whilst others are very useful in the environment and to humans e.g. yeasts are used to make bread.

Key terminology

unicellular	an organism consisting of only one cell
multicellular	an organism made up of many cells
biodiversity	the variety of organisms found in an area or on Earth

The classification of organisms

Scientists have placed all the organisms into specific groups so that it is easier to study them. There are five groups called kingdoms (Figure 1):

- Kingdom Monera – bacteria
- Kingdom Protista
- Kingdom Fungi
- Kingdom Plantae
- Kingdom Animalia

A scientist who is responsible for the placing of an organism within a specific group is called a taxonomist.

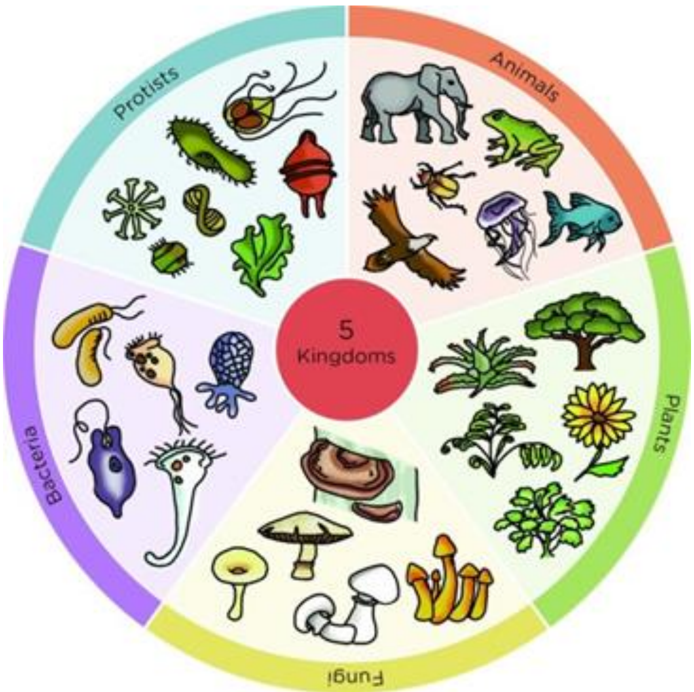

Figure 1: The 5 Kingdoms of Life

Viruses

Viruses are placed in a separate group and not in a kingdom because they display some non-living as well as living characteristics.

Key terminology

capsid	a protein coat surrounding the nucleic material of a virus
acellular	non-cellular
obligate parasite	obligate = forced; a parasitic organism that cannot complete its life-cycle without exploiting a suitable host (if an obligate parasite cannot obtain a host it will fail to reproduce)
host	an organism that harbours a parasite
pathogenic	an organism that causes disease
bacteriophage	a type of virus that infects bacteria; the word "phage" means to eat"
nucleoid	an irregularly shaped region within the cell of a prokaryote that contains all or most of the genetic material

Structure and characteristics of viruses

Introduction to viruses: https://www.youtube.com/watch?v=8FqlTslU22s

- Viruses are **microscopic** (20 – 300 nm) and can only be studied using an electron microscope.
- Viruses consist of a core of either DNA or RNA enclosed by a protein coat called a **capsid** (Figure 2).

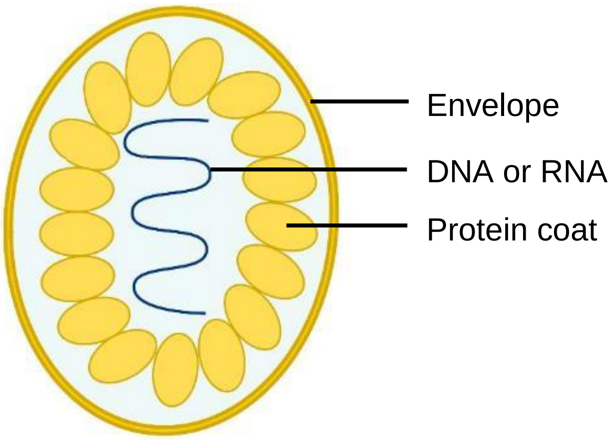

Figure 2: Structure of a typical virus

- Viruses occur in a variety of shapes,
- cannot respire, feed or excrete waste,
- do not have a cytoplasm and do not have any membrane bound organelles such as mitochondria or nuclei.
- Viruses have **either DNA or RNA** which is surrounded and protected by an outer **protein coat or capsid**. All other living organisms have both DNA and RNA.
- Viruses are **acellular**.
- Viruses **do not have chlorophyll** and are therefore unable to make their own food by photosynthesis.
- All viruses are **obligate internal parasites**. This means that they cannot multiply without infecting another living organism or **host**.
- Viruses can infect bacteria, protists, plants and animals. Viruses that infect bacteria are called **bacteriophages**.
- Viruses cause diseases and are said to be **pathogenic**.
- In humans, viruses are responsible for diseases such as HIV/AIDS, poliomyelitis, chickenpox, herpes and influenza.
- If a virus cannot find a host, they can become dormant.

Bacteria

Bacteria belong to the Kingdom Monera. Bacteria are found everywhere on earth. Some are pathogenic and cause diseases such as tuberculosis, while most are useful.

Key terminology

prokaryotic	an organism where the nuclear material is **not enclosed** in a membrane
eukaryotic	any single or multicellular group of organisms that have a **membrane-bound nucleus** containing genetic material
flagellum	a **whip-like**, protruding filaments that help cells or micro-organisms move; plural of flagellum is flagella
autotrophic	organisms which can synthesize their own food e.g. green plants, algae and some bacteria
heterotrophic	any organism that sources food from its environment because it cannot make its own food, e.g. animals, fungi, most bacteria
saprophytic	plant or fungal microorganisms that feeds on dead or decaying tissues of other organisms

binary fission	asexual reproduction of a single cell in which divides by mitosis; the cell regenerates as two or more separate cells having the same chromosomal identities as the parent cell
endospore	a tough, protective, non-reproductive bacteria structure that contains DNA and cytoplasm and lies dormant to survive unfavourable environmental conditions in order that it can germinate once conditions improve
plasmid	a plasmid is a small, circular, double-stranded DNA molecule that is distinct from a cell's chromosomal DNA

Characteristics of bacteria

Bacterial cell structure: https://www.youtube.com/watch?v=4DYgGA9jdlE

- Bacteria are **unicellular** (one celled) organisms.
- Bacteria are larger than viruses and can be seen using a light microscope.
- Bacteria are distinguished from one another by their shape (Figure 3). These shapes include: **coccus** – round, **bacillus** – rod-shaped, **spirillum** – spiral-shaped, and **vibrio** – comma-shaped.

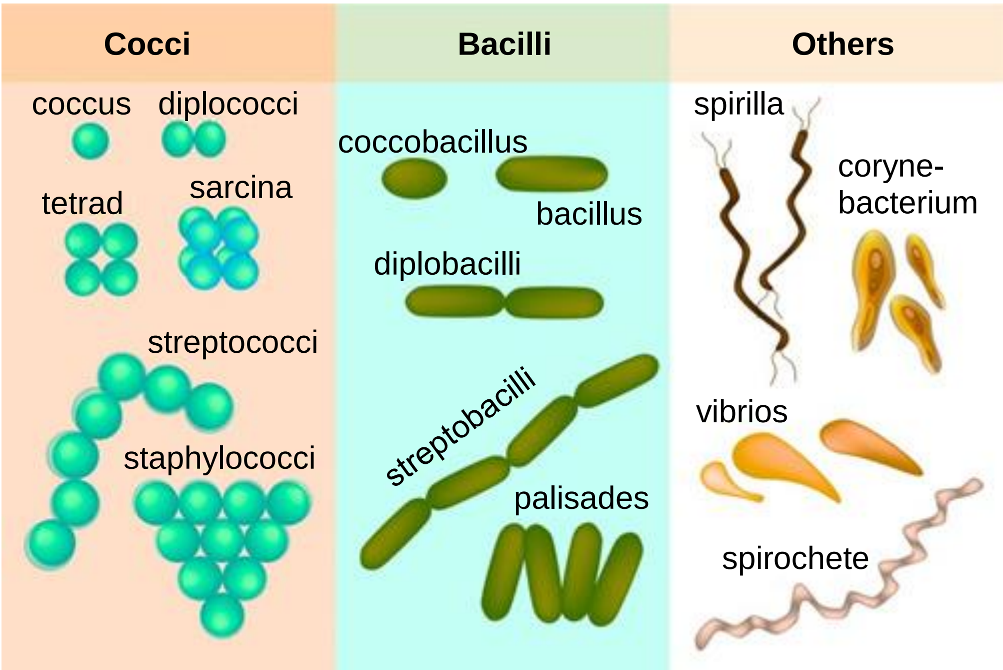

Figure 3: Bacterial shapes

Structural characteristics

All bacteria have the following structural characteristics (Figure 4):

- A cell wall made up of polysaccharides.
- Some bacteria have a **slime capsule** to protect them from drying out.
- Cytoplasm surrounded by a **cell membrane**.
- No membrane-bound organelles.
- The DNA is in the form of an irregular loop and is called a **nucleoid**. Since there is no membrane around the nuclear material, bacteria are said to be **prokaryotic**.
- A **plasmid,** small, circular, double-stranded DNA molecule is also found in the cytoplasm of bacteria.
- Many bacteria have a **whip-like flagellum** which they can use to move in a liquid. The flagella can rotate to propel the organism forwards.

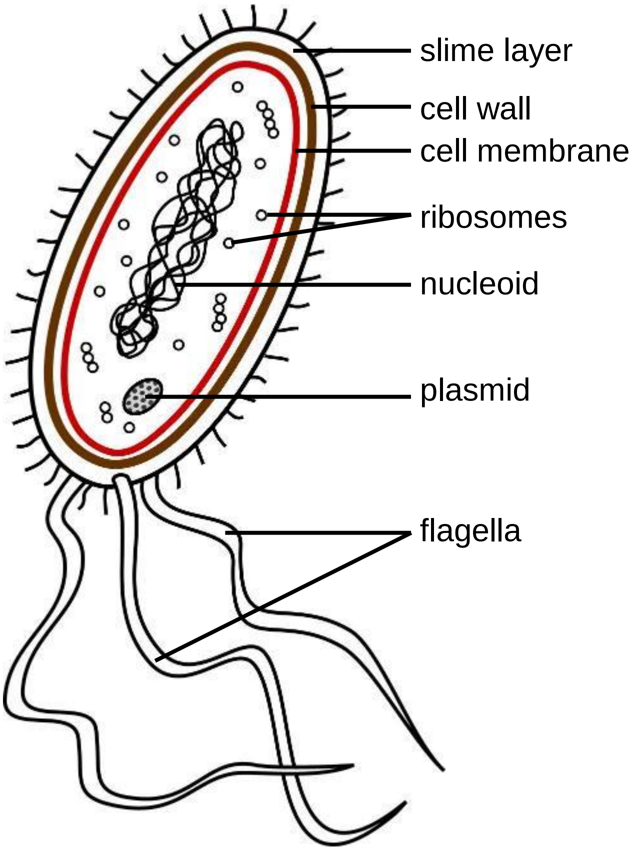

Figure 4: Basic structure of a bacillus shaped bacterium

Nutrition of bacteria

Autotrophic bacteria can manufacture their own food.

- **Photosynthetic bacteria** use sunlight energy, while
- **Chemosynthetic bacteria** get their energy from chemical processes.

Heterotrophic bacteria cannot manufacture their own food. This includes:

- **Parasitic bacteria** that obtain their food from other living organisms.
- **Saprotrophic bacteria** that play an important role as decomposers. They obtain their food from dead organic plants and animals.
- **Mutualistic bacteria** that form a relationship with another organism. Both organisms benefit from the relationship.

Reproduction of bacteria

Bacteria multiply very quickly under favourable conditions. This simple form of cell division is called **binary fission (**Figure 5).

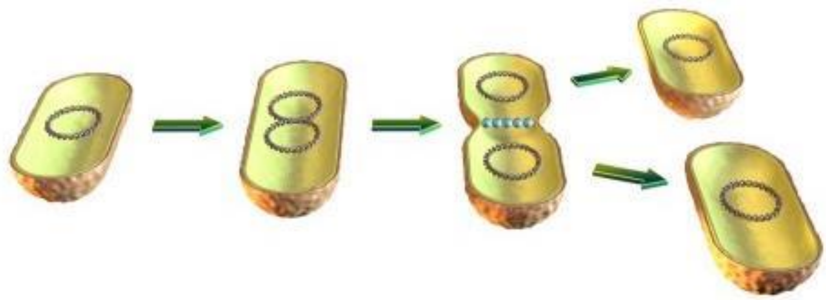

Figure 5: Binary fission in bacteria

Bacteria form **endospores** when conditions are unfavourable for example, when there is a lack of food, extreme heat or a lack of moisture.

Protista

The **Kingdom Protista** is a collection of eukaryotic organisms. Protists do not fit into the plant, animal or fungi kingdoms.

Key terminology

aquatic	living in or around water
phytoplankton	very small plants (algae) that float on or near the surface of water
zooplankton	consisting of small animals and the immature stages of larger animals which float on or near the surface of the water
sessile	sessile organisms are usually permanently attached to something and can cannot move on their own but can move through outside sources (such as water currents)

Characteristics of the Protista

- simple **unicellular** or **multicellular eukaryotic** organisms
- no tissue differentiation
- found mainly in water
- autotrophic or heterotrophic
- usually **microscopic** but can be several meters in length for example the seaweeds
- some are **sessile** or free-floating while others can move using flagella (e.g. *Euglena*) or move using false feet called **pseudopodia** (e.g. *Amoeba*)
- they can reproduce both **sexually and asexually**

Three groups of Protista are recognized:

Plant-like Protista:

- mainly **unicellular** organisms found in aquatic (water) environments
- most are **autotrophic**
- free floating aquatic plant-like protists are called **phytoplankton** (Figure 6)

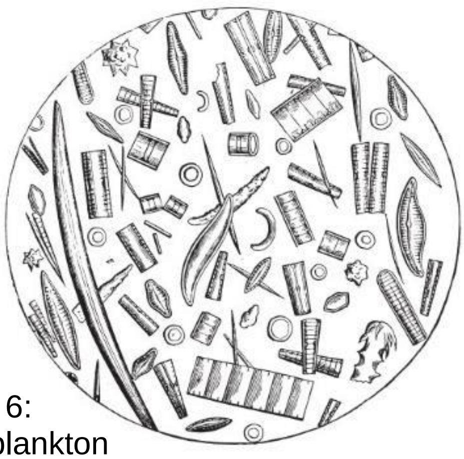

Figure 6: Phytoplankton

Animal-like Protista: • mainly heterotrophic free-living unicellular animals living in an aquatic environment e.g. *Amoeba* • some are parasitic and cause diseases such as malaria • free-floating aquatic animal-like protists are called **zooplankton** (Figure 7)	 Figure 7: Zooplankton
Algae • multicellular, macroscopic organisms commonly called seaweeds (Figure 8) • seaweeds contain various photosynthetic pigments which give them a green, red or brown colour • seaweeds may be free-floating or sessile (attached to a substrate)	 Figure 8: A species of red seaweed (*Gelidium pristoides*) harvested along the South African coast to produce agar

Fungi

The Kingdom Fungi includes moulds, yeasts, mildews, rusts, toadstools and mushrooms (Figure 9 – 12).

Key terminology

chitin	a fibrous substance consisting of polysaccharides, which is the major constituent in the exoskeleton of arthropods and the cell walls of fungi
hyphae	a network of multi-celled threadlike filaments forming the mycelium of a fungus
mycelium	a vegetative mass or network of fungal hyphae found in and on soil or organic substrates

multinucleate	cells that have more than one nucleus per cell, i.e., multiple nuclei shared in one common cytoplasm
rhizoids	threadlike structures that anchor lower plants and fungi to a surface
budding	a form of asexual reproduction which involves the pinching off of offspring from the parent cell; the offspring cell is genetically identical to the parent

Figure 9: Toadstools

Figure 10: Mushrooms

Figure 11: Bracket fungi

Figure 12: Breadmould

Characteristics

Fungi have the following characteristic in common:

- Some are **unicellular** (yeasts) while others are **multicellular** (mushrooms).
- **Eukaryotic** (i.e. have a nuclear membrane).
- **Heterotrophic** since they lack chlorophyll. Fungi that live off dead organic matter are said to be **saprotrophic**. **Parasitic** fungi live off living organisms. Fungi cause diseases such as thrush, ringworm and athlete's foot.

- Cell walls which contain **chitin**. Plants have cellulose in their cell walls.
- The bodies of multicellular fungi are made up of threads called **hyphae**. All the hyphae together form a **mycelium**.
- The hyphae are often **multinucleate** (have many nuclei).
- Fungi reproduce both sexually and asexually.
- Asexual reproduction in unicellular fungi such as yeasts is by budding.
- In multicellular fungi asexual reproduction is by means of spores.

Activity 1: Kingdoms

1. Name the five kingdoms which represent all living organisms (5)
2. Make a labelled diagram to show the internal structure of a bacterium. (6)
3. Name one important characteristic which distinguishes fungi from algae. (2)
4. Explain why viruses are not placed into one of the five kingdoms. (2)
5. Complete the following table: (12)

Organism	Unicellular/ Multicellular	Prokaryotic / Eukaryotic	Mode of nutrition
Viruses	acellular	neither	
Bacteria			
Phytoplankton			autotrophic
Zooplankton			
Fungi			

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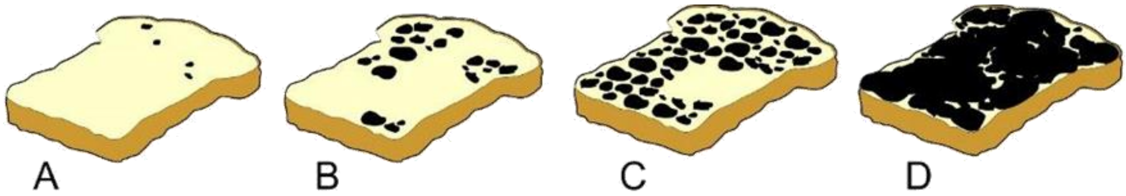
Activity 2: Practical investigation

Aim: Investigating the growth of bread mould under different temperature conditions

A Grade 11 learner investigated the optimum (ideal) temperature for growth of bread mould. The learner used the following method:

- The learner selected four black plastic containers with lids.
- A slice of bread was placed in each container.
- Before closing the containers, 30 ml of water was sprinkled over each slice.
- Container **A** was placed in a fridge (cold), container **B** was placed in a cupboard (cool), container **C** was kept at room temperature (mild) and container **D** was placed on a window sill (warm).
- After a week the slices of bread were removed from the containers and placed next to each other.

The results of the investigation are depicted below.



1. Formulate a hypothesis for the investigation. (2)
2. Name:
   (a) the dependent and
   (b) the independent variable in this investigation. (2)
3. State the relationship between the growth of bread mould and temperature. (2)
4. State three ways in which the learner made sure the results were valid. (3)
5. How could the learner have ensured that the results were reliable? (2)
6. Use the following scale to determine the percentage of bread mould growing on the slices of bread. Record the estimations in a table. (5)

0%	5%	25%	50%	75%	95%

7. Plot a bar graph to show the relationship between temperature (cold, cool, mild and warm) and the growth of breadmould using the table. (6)

(22)

The role that micro-organisms play in maintaining a balance in the environment

Micro-organisms play an essential **role** in the natural recycling of living materials.

Key terminology

decomposers	organisms that break down dead plant and animal (organic) material e.g. bacteria and fungi
saprophytes	organisms that live off dead organic matter

Micro-organisms as producers in food chains

Autotrophic bacteria, phytoplankton and algae can manufacture their own food by photosynthesis. The carbohydrates they produce are available to consumers. These organisms form the first link in a food chain. Oxygen, the waste product of photosynthesis, is made available to other organisms for respiration.

The role of micro-organisms as decomposers

- Bacteria and fungi are the main **decomposers**.
- They break down dead plant and animal remains and return the nutrients to the soil.
- Organisms which break down dead organic matter to obtain nutrients are called **saprophytes**.

The role of bacteria in the nitrogen cycle

Bacteria play an important role in the nitrogen cycle.

- Free living bacteria can convert atmospheric nitrogen to ammonia and nitrates.
- Higher plants can only use nitrogen when it is in the form of nitrates, so they rely on bacteria for the conversion.
- Some plants form special relationships with **nitrogen fixing bacteria**.
- When plants and animals die, de-nitrifying bacteria return nitrogen to the atmosphere by a process called **denitrification**.

Symbiotic relationships

Symbiosis refers to the living together of two or more species of organism. A symbiotic relationship may benefit one or both members or it can be beneficial to one but harmful to the other one.

Key terminology

mutualism	a symbiotic relationship where both organisms benefit
commensalism	a symbiotic relationship where one organism benefits without harming or affecting the other organism

parasitism	a symbiotic relationship where parasitic organisms benefit while causing harm to their hosts
lichens	composite organisms made up of fungi that grow symbiotically with algae or cyanobacteria
ruminant	an even-toed mammal that chews the cud regurgitated from its rumen e.g. cattle, sheep, antelopes, deer, giraffes, and their relatives.
mycorrhiza	The symbiotic association of fungi with the roots of trees.

Three types of symbiosis occur:

- **mutualism** – both organisms benefit e.g. lichens
- **commensalism** – one species benefits whilst the other does not benefit, nor is it harmed
- **parasitism** – one species benefits whilst the other is harmed

Lichens

Algae need a moist environment to survive and cannot live on dry land. They can, however, form a mutualistic relationship with a fungus and this called a **lichen (**Figure 13). The fungus provides the alga protection from the environment. Fungi however cannot produce food for themselves. They in turn obtain nutrients from the algae which can produce food by photosynthesis. In this way, both the alga and the fungus benefit.

Figure 13: Lichens are often the first organisms to occupy a habitat

The relationship between nitrogen fixing bacteria and plants

- Higher plants require nitrogen to manufacture proteins.
- Plants cannot use nitrogen directly from the atmosphere.
- Plants require nitrogen in the form of nitrates.
- Some soil bacteria can convert free nitrogen to nitrates that can be used by plants.

Some nitrogen-fixing bacteria live in special nodules in the roots of leguminous plants (i.e. pod producing plants such as beans and peas). They produce nitrates for the plant while the plant provides the bacterium with a place to live, carbohydrates and water. Both the plant and the bacteria benefit in this relationship.

The relationship between *E. coli* and the human intestine

- Not all the bacteria found in our intestines are harmful.
- Mutualistic bacteria such as *Escherichia coli (E. coli)* (Figure 14) live on the undigested remains of food in the gut and in turn make vitamin K which can be used by humans.
- Vitamin K plays an important role in blood clotting. Both humans and the bacteria benefit from the relationship.

Figure 14: *E. coli* bacteria

Mutualistic bacteria are also found in the digestive tracts of ruminants and termites where they are responsible for the digestion of cellulose into simple sugars.

Mycorrhizal fungi and the roots of higher plants

Filamentous fungi known as **mycorrhizas** can penetrate and become associated with the roots of higher plants. The fungi increase the absorption surface area of the roots. The fungus in turn, gets sugars from the plant.

Symbiosis in general: https://www.youtube.com/watch?v=zTGcS7vJqbs

Activity 3: Nitrogen use

1. Name the form of nitrogen which higher plants use. (1)
2. Describe three ways in which nitrogen becomes available to higher plants. (3)
3. What is a lichen? (3)
4. Describe the role bacteria play in maintaining the nitrogen balance in an ecosystem. (6)
5. The photograph below (Figure 15) shows a seedling without mycorrhizal fungi (left-hand side) and one with mycorrhizal fungi (right-hand side). The seedlings are the same age. Study the photograph and answer the questions that follow.

Figure 15: Seedlings with and without mycorrhizal fungi.

5.1 What is a **mycorrhiza**? (2)

5.2 Explain why the seedling on the right-hand side is bigger than the seedling on the left-hand side. (3)

(18)

Diseases caused by micro-organisms

Organisms that cause diseases are called **pathogens**. You are required to study only **one** disease from each of the four groups of micro-organisms discussed below.

Key terminology

pathogen	Infectious biological agent or organism that causes disease
vector	An agent who carries and transmits an infectious pathogen into another living organism.
host	Living cell in which a virus (or foreign molecule or microorganism) multiplies or hides.
epidemic	Refers to a sudden increase in the number of cases of a disease above what is normally expected.
pandemic	Refers to an epidemic that has spread over several countries or continents, usually affecting a large number of people

Diseases caused by viruses

Rabies

Rabies affects both domestic and wild animals such as dogs (Figure 16), jackal and mongooses. The rabies virus is passed from one animal to another in saliva. Humans usually get infected when they are bitten by a rabid animal.

Figure 16: Dogs infected by rabies often foam at the mouth.

After a person has been bitten by a rabid animal, there is an incubation period of up to 60 days during which time the victim shows no symptoms. After this period the victim may show one or more of the following symptoms:

- headaches and fever
- sore throat

- nausea
- fatigue or tiredness

These symptoms are followed by an agitated phase where the victim has convulsive seizures, salivates and fears water (**hydrophobia**). They also have difficulty in swallowing and breathing. Once the symptoms of the disease appear, there is no cure and the patient dies within 10 days from heart failure or breathing difficulties.

Rabies can be managed as follows:

- vaccination of dogs and livestock in areas where the disease is found
- immunization of people with high-risk occupations such as veterinarians
- immunization of travellers going to areas where the disease is found
- training of health workers and veterinarians
- destroying of animals infected with the disease

Treatment of rabies

- It is difficult to treat the disease, so it is important to avoid being bitten by animals infected by rabies.
- Wild animals which suddenly appear to be tame should not be touched.
- If there is contact with an animal which is behaving suspiciously, the person should seek medical attention immediately.

HIV / AIDS

Acquired Immune Deficiency Syndrome (AIDS) is a sexually transmitted disease caused by the Human Immunodeficiency Virus (HIV) (Figure 17). The virus weakens the immune system by infecting and destroying the immune cells which are known as the CD_4 – cells.

Figure 17: HIV virus in the blood stream

The HI virus is spread mainly through the transfer of body fluids such as semen and blood from an infected person to another person by one of the following ways:

- sexual intercourse
- blood transfusions of untested blood
- sharing contaminated syringes (e.g. drug users)
- from an infected mother to the foetus

The virus in not transferred in the air, in saliva or by shaking hands with an infected person.

The effects of HIV/AIDS on an individual include:

- A lack of symptoms during the first phase of infection which can last years.
- Flu like symptoms which include headaches, fever, tiredness, and the swelling of lymph glands in the armpits, throat or groin can occur.
- As the immune system weakens symptoms such as repeated cold-sore infections, prolonged fevers, night sweats, chronic diarrhoea (runny tummy), etc. occur. Extreme weight loss can also occur.
- A weakened immune system allows secondary or opportunistic infections to occur. These include respiratory infections, pneumonia, epilepsy, dementia, skin cancers, lymph cancer and tuberculosis.
- In the final phase of HIV infection, the disease is known as AIDS. Death can occur in this phase due to secondary infections.

HIV/AIDS affects families in the following ways:

- If the breadwinner becomes ill there is no income and a family may become poverty stricken.
- The virus is transmitted to an unborn child during pregnancy.
- If both parents are infected and die, their children become orphans.
- Brothers and sisters may be separated from each other if the parents die.

The economy of a country is also affected by HIV/AIDS:

- The disease is more common in young working people and reduces the labour force especially in the mining industry.
- The costs of treatment and care are high.

Management of HIV/AIDS requires:

- Testing for the virus in people who are at high risk (e.g. health workers, prostitutes, drug users).
- Counselling and treatment for infected people with antiviral drugs.
- Strengthening the immune system of infected persons.
- Treatment of secondary infections.
- Education and the prevention of infection by not having sexual intercourse (casual sex) or using protection such as a condom.

Influenza

Influenza is commonly called “flu” and is caused by the influenza virus. The virus spreads through the air when a patient coughs or sneezes (Figure 18). It can also spread through contact with bird droppings or contaminated surfaces.

Symptoms include:

- a sore throat
- muscular pain
- headaches
- coughing.

Symptoms usually only last a few days, but some strains of the virus can be deadly.

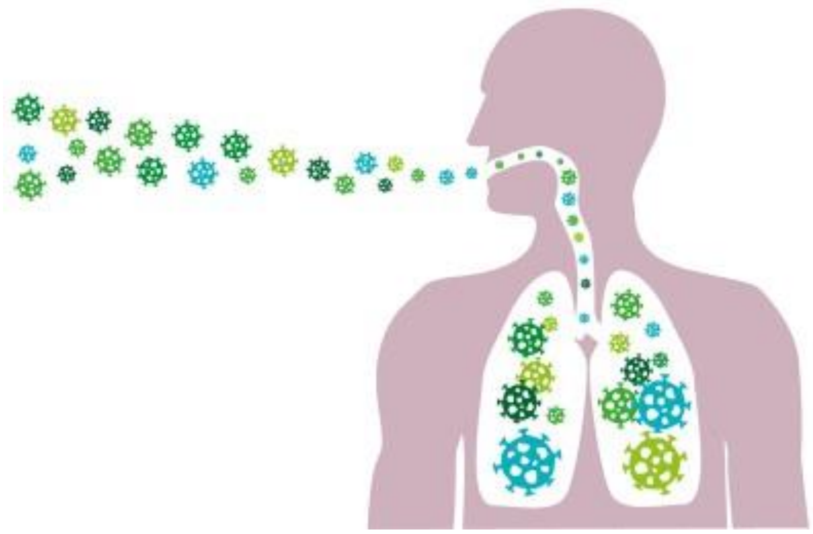


Figure 18: Flu viruses can be spread by coughing

Viruses do not respond to antibiotics. Flu is best managed with the use of vaccines. Flu viruses mutate rapidly to form new strains which means that a new flu vaccine must be developed each year.

To avoid catching flu, people must wash their hands regularly. People who are already infected should not cough or sneeze without covering their mouths.

Diseases caused by bacteria

Blight

Blight is the term given to plants which suddenly wilt (droop) and die. It is caused by several different bacteria. Blight is a significant problem for commercial farming as it affects crops such as apples, grapes and tomatoes (Figure 19).

Figure 19: Tomatoes affected by blight

Symptoms of blight include:

- drooping or dried up shoots and stalks
- lesions ('sores') on the leaves
- flowers that turn black and die
- death of the whole plant if not treated

Blight must be managed as follows:

- only disease-free stock should be planted
- pruning tools must be disinfected
- cutting back should only be done on dry windless days
- affected plant material should be burnt to avoid spores from spreading

Cholera

Cholera is commonly found in areas where there is overcrowding, unsafe drinking water and a lack of proper sanitation (Figure 20). Cholera is caused by the bacterium *Vibrio cholerae*.

Figure 20: Cholera breeds in unhygienic places

Symptoms of cholera include:

- watery diarrhoea (runny tummy) which leads to dehydration
- vomiting

Note that some people do not show any symptoms of cholera but can become carriers of the disease.

Management of the disease should include:

- access to clean drinking water or water purification tablets
- preventing the spreading of the disease by proper sanitation and disposal of sewerage
- infected people must be given fluids with added electrolytes to drink
- severely infected people will have to be put on a drip
- the bed linen and clothes of infected people must be disposed of
- anything which cholera patients have touched must be washed in hot water and sterilized using chlorine bleach
- people living in cholera areas should be educated about the importance of hygiene and be encouraged to boil water before drinking.

Treatment of cholera involves:

- rehydration
- antibiotic treatment

Tuberculosis

The bacterium, *Mycobacterium tuberculosis* causes the lung disease tuberculosis (TB) (Figure 21). The bacterium can also attack other parts of the body such as the kidneys, brain and spinal cord.

TB is spread through the air when infected people cough or sneeze. The bacterium spreads quickly in confined, overcrowded spaces where there is poverty and poor sanitation.

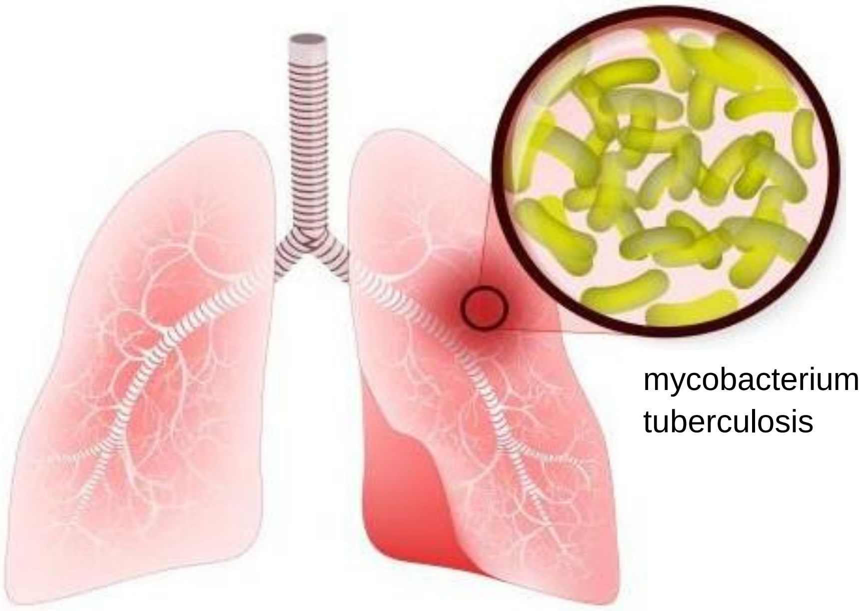


Figure 21: TB commonly infects the lungs

TB can infect anyone who breathes in the bacterium but usually only develops in people with weak immune systems such as babies, young children, HIV positive people, drug users, diabetics and poverty-stricken people.

The effect of TB on infected persons includes:

- extreme tiredness and weakness
- loss of appetite and weight
- chills, fever and sweating at night
- excessive coughing

- chest pains
- coughing up blood

Management of TB requires:

- identification of infections through X-rays, skin tests or tissue cultures.
- educating the patient regarding the completion of treatment.

Treatment of TB involves:

- Treatment with a number of drugs over a period of about 6 months. When patients do not complete their treatment, they can develop a drug-resistant form of TB which is very difficult to treat. Patients are often kept in a TB hospital for treatment and to make sure they take their medication.
- DOTS (Directly Observed Treatment Short Course) was developed so that someone makes sure that the patient completes their treatment.

Anthrax

Anthrax is caused by the bacterium *Bacillus anthracis*. It affects goats, cattle, sheep and horses. The spores are either inhaled by the animal or they enter through wounds. Once inside the body, the bacterium enters the bloodstream and multiplies very rapidly. It releases very strong toxins and causes tissues to breakdown, bleeding and eventually death.

Humans become infected when they are exposed to infected animals or their products. The following symptoms appear in humans:

- severe breathing problems and shock,
- inflammation of the gastro-intestinal tract,
- a painless skin ulcer with a black necrotic area in the middle (Figure 22).

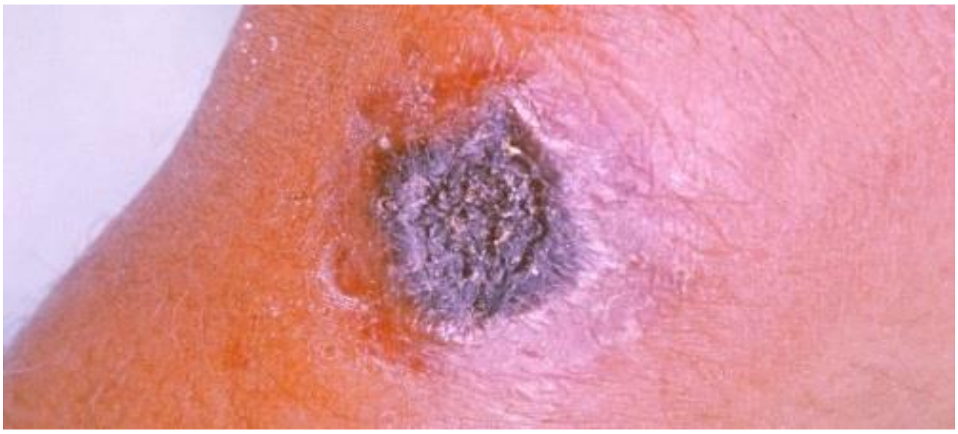


Figure 22: A typical symptom of an anthrax infection

Anthrax can be managed by:

- Vaccination of stock animals.
- If there is an outbreak of anthrax, animals showing signs of infection must be isolated and treated with antibiotics. All the other animals that have been in contact with the infected animals must be vaccinated.
- The bodies of dead animals must be burned to destroy spores which could survive for up to 90 years.
- Humans that have come into contact with anthrax must wash with antimicrobial soap and their clothes must be burned.
- The bodies of humans that have died from anthrax should be cremated to avoid the disease spreading further.

Diseases caused by Protista

Malaria

Introduction to Malaria: https://www.youtube.com/watch?v=f5XKob0lc2A

- Malaria is a life-threatening disease found mainly in tropical and sub-tropical areas of the world.
- Malaria is caused by the protozoan *Plasmodium vivax* and is spread by the female *Anopheles* mosquito.
- The female *Anopheles* mosquito is called the **vector**.
- A vector carries a disease-causing organism from an infected host to a new host.
- The malaria parasite requires two hosts (mosquitoes and humans) to complete its life cycle.

Symptoms of malaria include:

- early symptoms that can be mistaken for flu
- fever and shivering
- headache
- joint pain
- vomiting
- convulsions
- anaemia

If left untreated, malaria may lead to the infected person falling into a coma, followed by death.

The effects of malaria on the economy include:

- Loss of income if the breadwinner cannot work or dies, resulting in poverty.
- Malaria treatment is expensive. Poor people in undeveloped countries cannot afford treatment.

The best way to manage malaria is to avoid being bitten by mosquitoes in areas where malaria occurs. This can be done by:

- staying indoors between sunset and sunrise.
- covering doors and windows with gauze to stop mosquitoes from entering rooms.
- sleeping under mosquito nets.
- applying insect repellents to exposed skin.
- wearing long sleeves and pants if you need to be outdoors at night.
- drain places where there is standing water e.g. drains, ponds, gutters, old tyres etc., as mosquitoes breed in standing water.

Anti-malarial drugs can be taken before entering a malaria area. Drugs are available to treat people infected with malaria.

Governments in malaria areas need to provide health-care facilities like clinics. They also control the breeding of mosquitoes by spraying with DDT, an insecticide.

Diseases caused by fungi

Rusts

- Rusts are a group of fungi that infect crop plants (tomatoes, beans etc.), grasses and flowering plants such as roses, hollyhocks, and snapdragons.
- The hyphae of the fungus burrow into the plant tissue and destroy it.
- Bright orange raised areas can be seen on the surface of the plant leaves which resemble rusted metal when infected (Figure 23).

Figure 23: Rust is commonly seen on the underside of leaves

Management and treatment of rust include:

- planting of rust-resistant crops or plants
- keeping plants healthy by adding nutrients to the soil or their water
- sterilizing of equipment, especially pruning (cutting) tools
- spaying with fungicides (chemicals which kill fungi)
- burning of affected plant material to prevent the spores from spreading

Thrush

- Thrush is caused by a yeast (fungus) called *Candia albicans.*
- Thrush can grow on any part of the body but favours moist areas such as the mouth, vagina and upper parts of the digestive tract.

Oral thrush (in the mouth) is characterised by white sores on the tongue and in the mouth (Figure 24). Symptoms include difficulty with eating and an uncomfortable burning in the mouth. Thrush is common in bottle- and breast-fed babies and in people with false teeth.

Figure 24: Oral thrush

Vaginal thrush commonly occurs in pregnant women and women using oral contraceptives (birth control tablets). Tight-fitting pants and underwear can encourage thrush to develop. Vaginal thrush is characterised by severe itching, a burning sensation when urinating and a greyish-white vaginal discharge.

Other factors that contribute to the development of thrush include:

- a weakened immune system caused by HIV / AIDS or chemotherapy
- diabetes – *candida* thrives on high blood sugar
- moist skin folds in overweight people
- babies with wet nappies for a prolonged period
- poor health as a result of stress, lack of sleep, poor diet rich in sugars
- excessive use of antibiotics

Thrush can be managed by reducing the factors that the fungus favours for example:

- wear loose-fitting clothes and cotton underwear especially when it is hot
- do not use perfumed soaps and bubble baths
- eat a well-balanced diet that is low in refined sugars
- probiotics should be taken if antibiotics are taken over a long period of time
- treat oral thrush with an antifungal mouthwash. Antifungal creams can be applied to the affected areas. In extreme cases, systemic treatment in the form of tablets may be necessary
- dentures (false teeth) must fit well and be sterilized often

Ringworm

Ringworm is caused by a fungus and not a worm. Fungal spores can live and spread on the skin of both humans and animals (Figure 25). Ringworm is often spread by contact with affected pets in a home.

Figure 25: Ringworm affects both humans and animals.

Symptoms include itchy sores (often circular-shaped) on the skin.

Management and treatment include:

- treatment of the skin with antifungal ointments
- treatment of pet animals in the home
- avoid sharing clothes with an infected person

Athlete's foot

Athlete's foot is a fungal infection found mainly between the toes and on the arches of feet (Figure 26). It is caused by the fungus *Tinea pedis*. The fungus feeds on the keratin (protein) in the skin and results in flaky and cracked skin. The cracks allow bacteria to enter.

This fungus thrives in warm, moist places. It may be contracted by walking barefoot in public places such as showers, public swimming pool areas and changing rooms

Figure 26: Athlete's foot

Athlete's foot can be treated and managed as follows:

- keep the affected areas dry
- wear open sandals when it is hot
- wear clean, cotton socks if you need to wear closed shoes. avoid nylon socks
- wash feet well and dry well between the toes
- apply fungal ointments or powders to feet if they are infected
- avoid infections by wearing slip-slops in public showers

The following videos give a short introduction to these diseases:

Tuberculosis https://www.youtube.com/watch?v=202hkf43HXQ

HIV/AIDS https://www.youtube.com/watch?v=FDVNdn0CvKI

Ringworm https://www.youtube.com/watch?v=ryzwWnsBmXg

Cholera https://www.youtube.com/watch?v=jG1VNSCsP5Q

Rabies https://www.youtube.com/watch?v=kxBIJvNHZg4

Influenza https://www.youtube.com/watch?v=yhhJfT86Bgg

Thrush https://www.youtube.com/watch?v=UiTLpa_LoFw

Activity 4: Diseases

Complete the following table:

Disease	Organism responsible	Symptoms	Management and cure
rabies			
AIDS			
influenza			
cholera			
tuberculosis			
anthrax			
malaria			
thrush			
ringworm			
athletes foot			
rusts			
blight			

(36)

Immunity

Immunity refers to the way in which a plant or animal is able to fight an infection.

Key terminology

lymphocyte	white blood cell type which fight infection
antigen	a complex molecule that induces an immune response (or disease reaction) in the body
antibody	a protein made by the immune system to target and combine with a specific antigen (invader) and make it useless
phagocytosis	the process by which a cell engulfs a solid particle to form an internal compartment known as a phagosome (phago – eat, cyto – cell)
lysosome	an organelle containing digestive enzymes to break down bacterial or viral cell walls

vaccine	a biological preparation made from damaged virus or bacteria particles used to stimulate an immune response by the body's immune system against viral and bacterial infectious diseases
antibiotic	medicine e.g. penicillin which is developed from living organisms e.g. bacteria or fungi and used to fight infections caused by either bacteria or fungi
insulin	hormone made in the pancreas and released into the blood to help convert glucose to glycogen

The response of plants against an infecting micro-organism

The first line of defence in plants includes the waxy cuticle, bark and the closely packed epidermal cells which protects them from invading micro-organisms. If a plant is injured, it can produce sticky gums and resins in an attempt to seal the wound and prevent infection.

The second line of defence occurs when a plant becomes infected by a pathogen and its **natural immune response** is activated. It releases chemical compounds such as **salicylic acid** which are transported in the phloem to cells which are not affected. The unaffected cells respond by producing various chemical defences to protect themselves.

The response of animals against an infecting micro-organism

Animals have two types of immunity:

- **Natural immunity** which is present at birth, and
- **Acquired immunity** which develops after exposure to pathogens.

The body has many ways to prevent pathogens from entering. This is called the first line of defence. It includes:

- a multi-layered skin
- antiseptic tears
- mucus lined air passages which trap pathogens
- enzymes (lysozyme) in the saliva
- ear wax in the ear canal
- hydrochloric acid and enzymes in the stomach

The second line of defence involves two responses should pathogens gain entry:

(i) **Primary response** – this response tries to destroy the pathogen and prevent it from spreading. This is brought about by inflammation (swelling and redness) of local areas and fever which raises the body temperature.

(ii) **Secondary response** – this activates the immune system which:

- destroys the invading pathogens
- holds a memory of pathogens that have been destroyed, to reduce or prevent re-infection.

The immune system involves two groups of white blood cells *viz.* lymphocytes and phagocytes. These are discussed in the following sections.

Lymphocytes

Lymphocytes are found in the tonsils, lymph glands, spleen and in the blood. Two types of lymphocytes occur: **B-lymphocytes** and **T-lymphocytes**.

B-lymphocytes

Special proteins called **antigens** are found on the surface of pathogens (Figure 27). B-lymphocytes recognise the antigens and make special proteins called **antibodies**. Antibodies destroy germs and when they encounter the same germs again, they respond quickly. This is known as **natural immunity**.

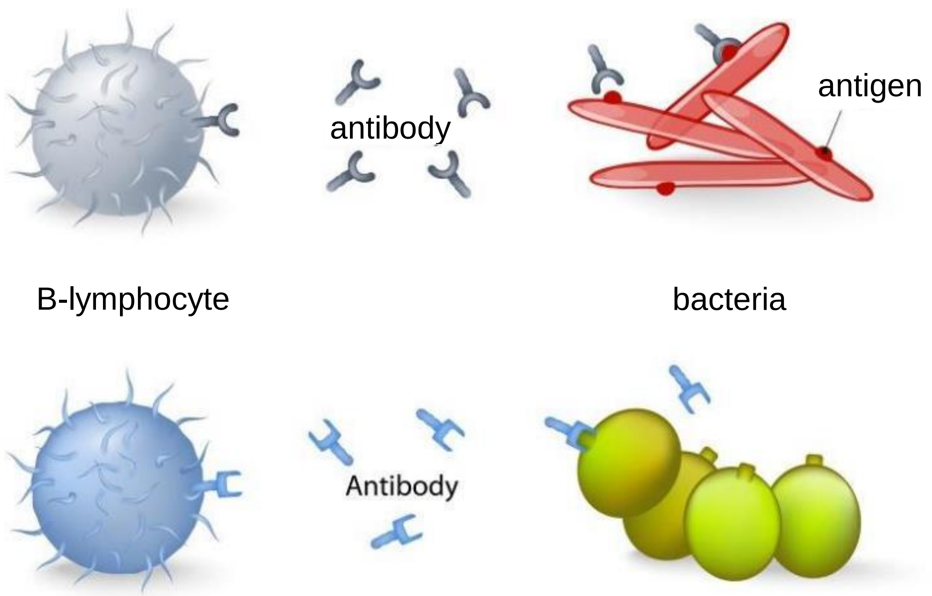


Figure 27: Antibody – antigen relationship

Antibodies destroy germs by:

- causing bacterial cells to burst.
- labelling the germs so that phagocytes can ingest them (Figure 27).
- making germs clump together so that they are easy to recognize.
- neutralising bacterial toxins.

T-lymphocytes

T-lymphocytes are found mainly in the lymph glands. Two types occur:

1. **CD4 cells** – helper cells which start the response.
2. **Killer T-cells** which destroy body cells infected with viruses or parasites.

Phagocytes

Macrophages, which are a type of phagocytic cells, are able to identify bacteria. They produce pseudopodia (false feet) which flow around the bacteria and engulf them. This process is known as **phagocytosis**. Vacuoles filled with enzymes called **lysosomes** fuse with the vacuole containing the bacteria and destroy them.

The process of phagocytosis: https://www.youtube.com/watch?v=7VQU28itVVw

Vaccinations

A **vaccine** is a suspension of dead, weakened or fragmented micro-organisms or their toxins, that will stimulate the production of antibodies by the lymphocytes.

Vaccinations or immunisation is the process of giving a vaccine either by injection or orally (by mouth) to prevent disease. The antibodies stay in the blood and give long-lasting protection against disease. This type of immunity is called **artificially acquired active immunity**.

Children are usually vaccinated against measles, mumps and rubella.

How do vaccines work: https://www.youtube.com/watch?v=rb7TVW77ZCs

The use of drugs to fight infecting micro-organisms

Antibiotics

Antibiotics are drugs that fight infections caused by bacteria. Antibiotics cannot fight infections caused by viruses because viruses do not feed and therefore do not ingest the antibiotics.

The best-known antibiotic is penicillin which is produced by the fungus *Penicillium* (Figure 28). Penicillin was discovered by Alexander Fleming in 1929 (Figure 29).

Figure 28: *Penicillium* fungus growing on an agar plate

Figure 29: Alexander Fleming

Antibiotics usually target a specific part of a bacterium. For example, they:

- prevent cell walls from forming.
- damage cell membranes.
- stop protein synthesis.

Bacteria are able to build up a resistance to antibiotics which is why it is important to always complete a course of antibiotics. The first dose of antibiotics usually kills all the weak bacteria. If the course is not completed, the stronger bacteria that are left behind multiply and become drug resistant.

Biotechnology

Biotechnology refers to the use of micro-organisms to make substances which are useful to humans. These include medicines such as antibiotics and insulin as well as foods such as maas (fermented milk), bread, wine and cheese.

The making of antibiotics

Natural antibiotics are made by fungi such as *Penicillium,* a mould (Figure 28), which is found on the skins of fruits. When the mould is collected and put in a vat at about 25°C with sugar and amino acids, it grows and multiplies rapidly. After about five days the penicillin produced by the mould can be removed and purified.

The making of insulin

The pancreas in the human body produces insulin to regulate the blood glucose content of the blood. If the pancreas does not function properly the person is said to have **diabetes mellitus**. People with diabetes need to control their intake of sugars and must inject themselves daily with insulin. Bacteria can be used to make insulin (Figure 30).

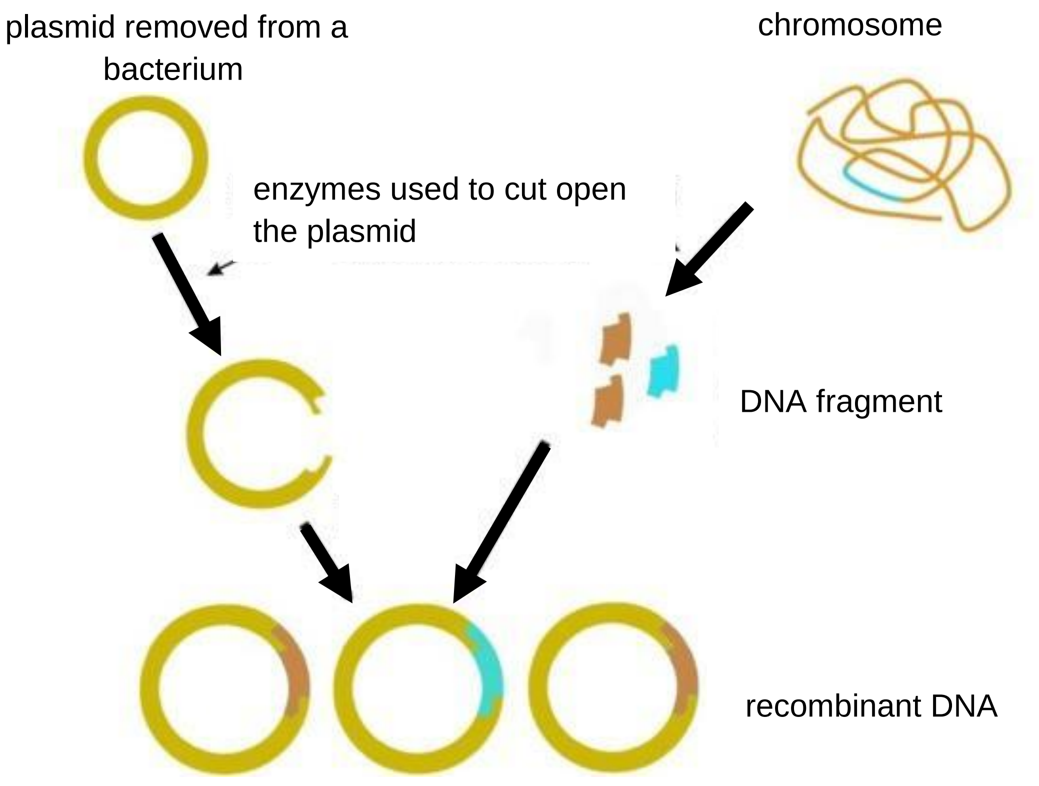


Figure 30: The modification of bacteria to make insulin

- a plasmid is removed from a bacterium
- the plasmid is cut open using an enzyme
- a piece of DNA containing the gene for making insulin is extracted from a chromosome taken from a human pancreas cell
- the DNA is joined to the plasmid from the bacterium to form recombinant DNA
- the recombinant DNA is inserted into a bacterium
- the genetically engineered bacteria are grown in large vats containing nutrients
- the DNA in the bacteria instructs the bacteria to make insulin
- the insulin is then extracted and purified.

The most commonly used bacterium is *E.coli*.

Traditional technology

Micro-organisms such as yeast can undergo alcoholic fermentation (see respiration chapter later) in the absence of oxygen. During this process glucose is changed into ethyl alcohol, carbon dioxide and energy.

Humans use this process to manufacture:

- Beer – beer is made from maize, sorghum, millet, barley or rice and hops.
- Wine – wine is traditionally made from grapes. Yeasts found on the skins of fruit ferment the grape sugar after the grapes are crushed.
- Bread – yeasts are used to make bread dough rise. The carbon dioxide given off during alcoholic fermentation expands when heated in the oven creating air pockets. The alcohol produced evaporates when the bread is baked.
- Cheese – *Lactobacillus* bacteria can be used to convert milk sugar called lactose into lactic acid. Lactic acid curdles the milk and forms a solid mass known as curds. Curds are pressed and separated from the watery whey to make cheese.
- Maas – maas is similar to yoghurt and is made by bacterial fermentation of milk. Lactic acid thickens the milk and acts as a preservative.

Biodiversity and classification of micro-organisms: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Antibodies are proteins that

A break down pathogens.
B catalyse biochemical reactions.
C are produced by T-cells that kill disease carrying viruses.
D bind with specific antigens.

1.1.2 Which organism does not belong to a kingdom?

A virus
B fungus
C bacterium
D protozoan

1.1.3 The following is a list that describes viruses:

i) They play an important role as decomposers.
ii) They are major pathogens of humans.
iii) They are parasites.
iv) They reproduce within a host cell.

Which of the following are of biological importance in viruses?

A (i), (ii) and (iii)
B (ii), (iii) and (iv)
C (i), (iii) and (iv)
D (ii) and (iv)

1.1.4 The cell walls of most fungi are mainly composed of:

A chitin
B cellulose
C protein
D lignin

1.1.5 The use of antibiotics is an effective treatment for…

A bacterial and viral infections
B bacterial infections only
C viral infections only
D neither viral nor bacterial infections (5 × 2) = (10)

1.2 Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number.

1.2.1 Microbes which cause disease.
1.2.2 Viruses that attack bacteria.
1.2.3 A relationship between two organisms which live together for the benefit of one or both of the organisms.
1.2.4 The ability to produce antibodies.
1.2.5 The use of micro-organisms to make useful substances.
1.2.6 An organism that transfers a pathogenic organism from one host to another.
1.2.7 Plant-like Protista.
1.2.8 The mutualistic relationship between a fungus and an alga.
1.2.9 Organisms that have a definite nucleus.
1.2.10 The process used by lymphocytes to engulf bacteria.

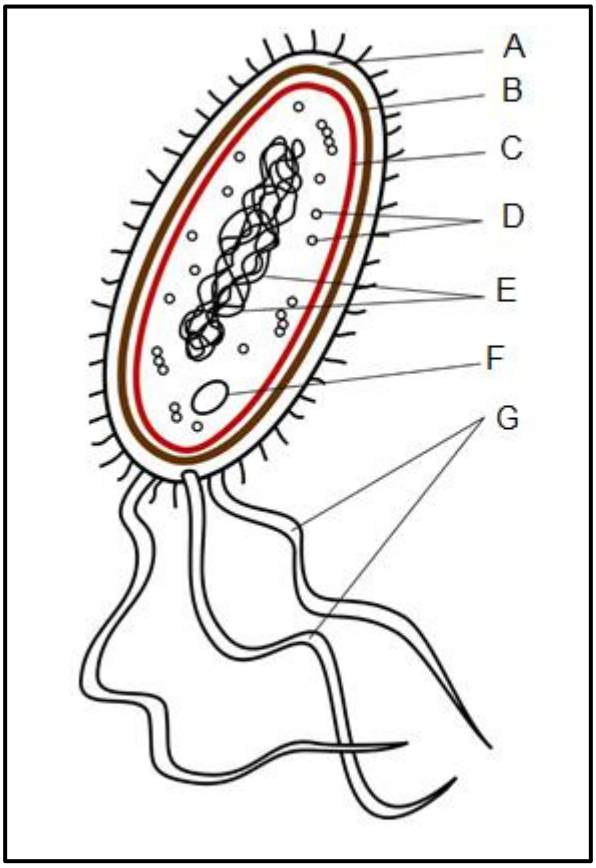
(10 × 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	**Column II**
1.3.1 Organisms that feed on dead organic matter.	A: saprophytes B: parasites
1.3.2 Genetic material found in viruses.	A: DNA B: RNA
1.3.3 Malaria is caused by a…	A: bacterium B: virus
1.3.4 Whip-like structures used for locomotion in bacteria.	A: flagella B: cilia

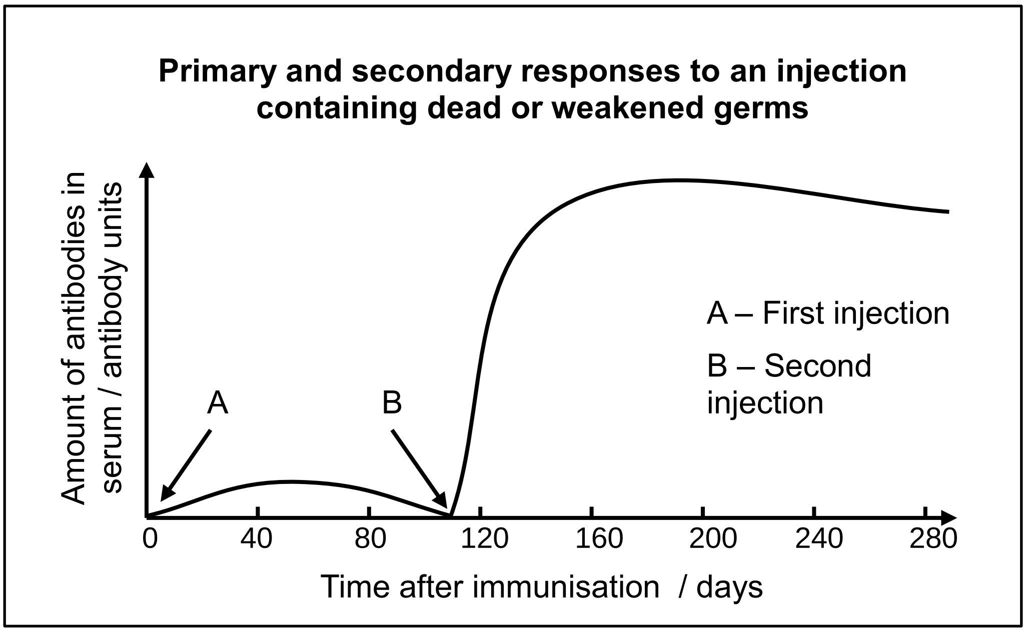
(4 x 2) = (8)

1.4 The diagram below is that of a bacterial cell. Study it carefully and then answer the questions that follow.



1.4.1	Provide labels for the parts labelled A to D.	(4)
1.4.2	State the function of the part labelled E.	(1)
1.4.3	Describe how the structure labelled F can be used in the manufacturing of insulin for diabetics.	(5)
1.4.4	Briefly explain how bacteria develop resistance to antibiotics and how humans can contribute to this phenomenon.	(3)
1.4.5	Identify the structure labelled G and state its function.	(2)
		(15)

1.5 Study the graph below, which gives the body's response to a vaccination given by an injection and a booster injection. Answer the questions that follow.

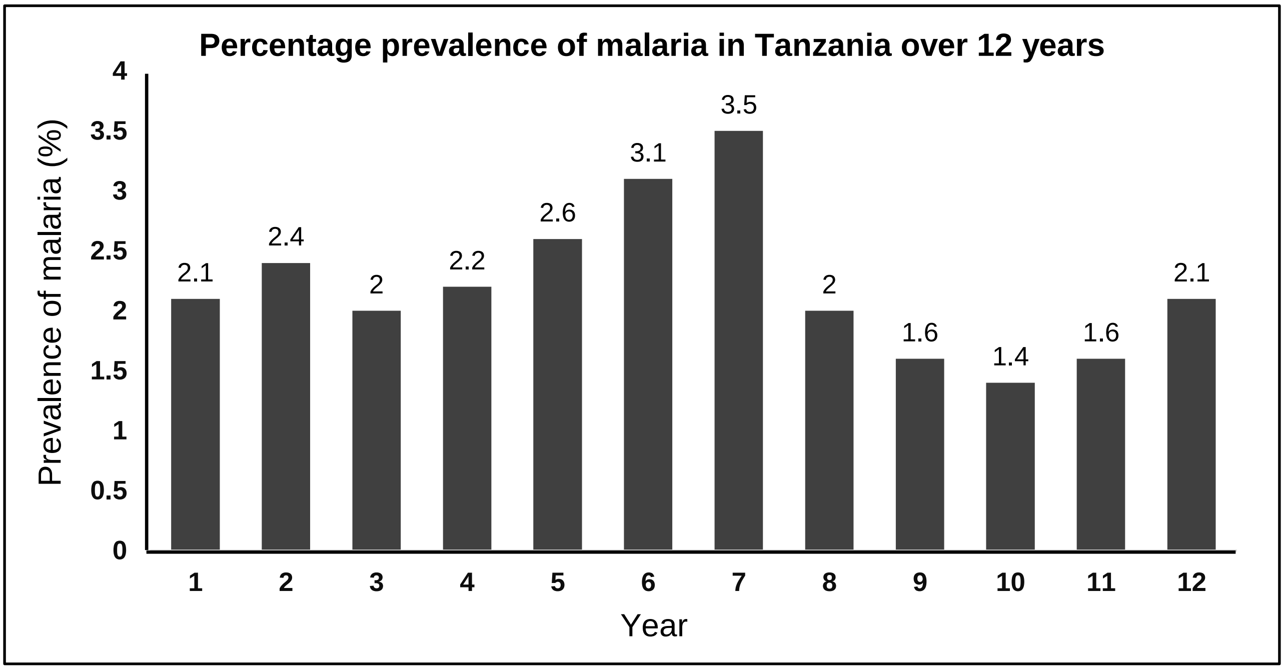


1.5.1	What happened to the antibody level after the first injection?	(2)
1.5.2	What would happen to the person if they encountered the disease organism after the second injection?	(1)
1.5.3	Mention two common ways of receiving vaccines.	(2)
1.5.4	From what is a vaccine made?	(1)
1.5.5	Which cells in the immune system produce the antibodies?	(1)
		(7)

Section A: [50]

Section B: Question 2

Use the graph below to answer the following questions:



2.1 In which year was the percentage of malaria the highest? (1)

2.2 Calculate the percentage increase in malaria infections from year 3 to year 6. Show all working. (3)

2.3 Name two precautionary methods that can be implemented to prevent contracting malaria when travelling in a malaria infested area. (2)

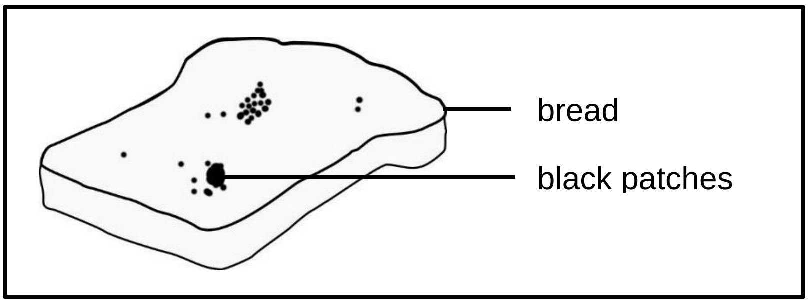
2.4 Give two symptoms of malaria. (2)

2.5 Give two possible reasons for the decline in the number of malaria cases after year 7. (2)

[10]

Question 3

3.1 During the holidays a learner forgot to take his lunch box out of his school bag. Inside were some uneaten sandwiches. At the beginning of the following term his mother found black, furry patches growing on the left-over bread.



3.1.1 Identify the organism most likely to be responsible for the growth on the bread. (1)

3.1.2 Name three conditions which made the lunch box a suitable environment for the organism mentioned in 3.3.1 to grow. (3)

3.1.3 Name three ways in which this type of growth on bread and other foods can be prevented. (3)

(7)

3.2 A student investigated the number of bacteria on the skin of people's hands after they washed and dried it. The same washing method was employed, but hands were dried either by using hot air from a hot air blower or by using paper towels. Swabs were used to take samples from the dried skin and bacteria were cultured from the swabs. The table below shows the number of bacteria that was cultured.

Study the table below and answer the questions that follow.

Samples	**Number of bacteria (×10^8) per square centimetre (cm^2) on hand skin following washing and drying**	
	Air-dried skin	Towel-dried skin
1	8,91	1,11
2	9,75	0,98
3	6,14	0,42
4	8,72	1,02

3.2.1 Write down the aim for this investigation. (1)

3.2.2 Suggest three factors that must be kept constant in this investigation to make this a valid test. (3)

3.2.3 Write down the conclusion the student could make based on the results of this investigation. (3)

(7)

3.3 A type of bacterium called *Escherichia coli* (*E.coli*) normally lives in the large intestine of humans. To determine whether *E.coli* is present in water, a chemical indicator is used. If the chemical indicator changes from a clear red colour to a cloudy yellow colour, this indicates that *E.coli* is present.

In an investigation conducted by a group of Grade 11 learners, samples taken from three rivers (X, Y and Z) were investigated for the presence of *E.coli.* Samples were taken from each river and put into glass bottles, which contained the clear red indicator solution. The bottles were then incubated at 37°C for two days. Only river Y showed presence of *E.coli.*

3.3.1 Explain two safety precautions that the learners should take when conducting this investigation. (2 × 2) = (4)

3.3.2 Suggest one reason for incubating the sample at 37°C. (1)

3.3.3 State how *E.coli* could have entered river Y. (1)

(6)

[20]

Section B: [30]

Total marks: [80]

2: Biodiversity of plants

CHAPTER 2: BIODIVERSITY OF PLANTS

Introduction

All plants are thought to have evolved from simple unicellular algae. Four major plant groups exist namely:

- Division Bryophyta.
- Division Pteridophyta.
- Division Gymnospermae (Gymnosperms)
- Division Angiospermae (Angiosperms)

A cladogram illustrating the relationship between these divisions is illustrated in Figure 1.

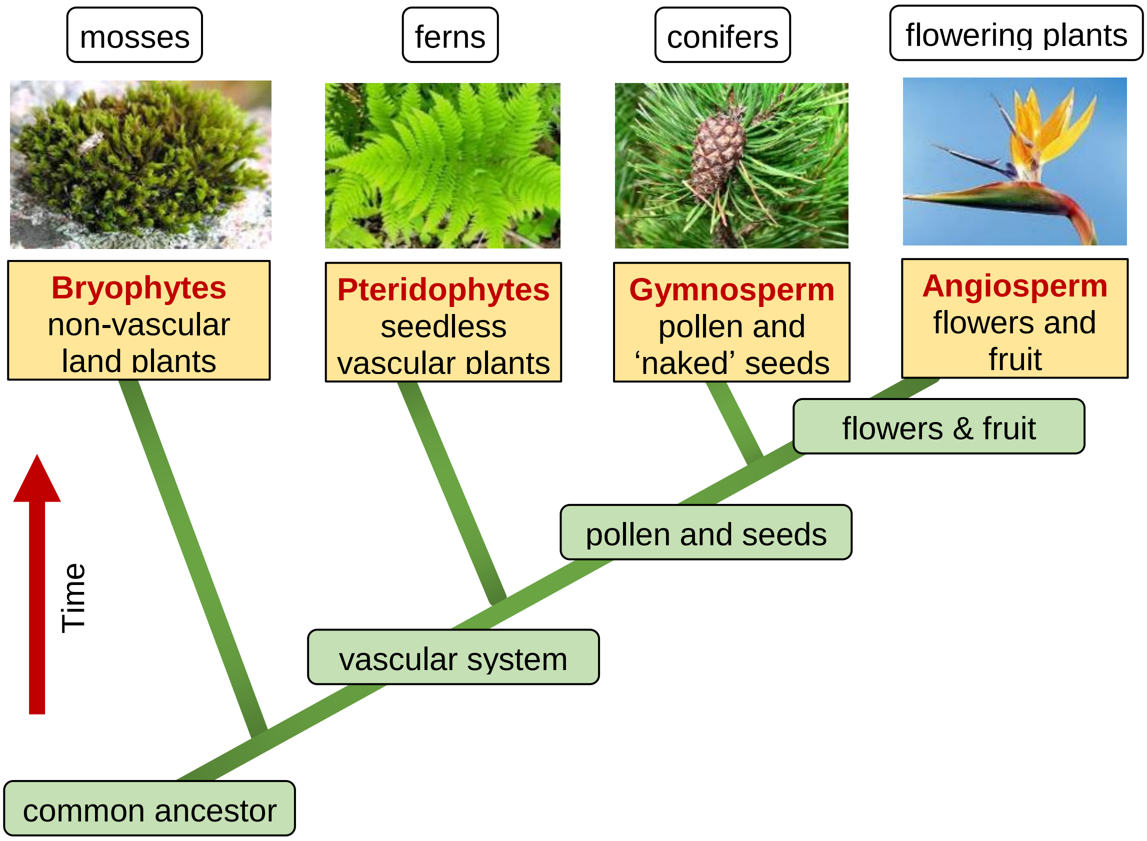


Figure 1: Cladogram showing the evolutionary relationship between the major plant divisions

The four major plant divisions

Key terminology

multicellular	an organism made up of many cells.
eukaryotic	any single or multicellular group of organisms that have a **membrane-bound nucleus** containing genetic material
autotrophic	organisms which can synthesize their own food e.g. green plants, algae and some bacteria.
phylogenetic diagram/ cladogram	a diagram which shows the evolutionary relationship between organisms
thallus	a plant body that is not differentiated into stem and leaves and lacks true roots and a vascular system; thalli are typical of algae, fungi, lichens, and some liverworts
rhizoids	a filamentous outgrowth or root hair on the underside of the thallus in some lower plants, especially mosses and liverworts, serving both to anchor the plant and (in terrestrial forms) to conduct water
gametophyte	the gamete-producing generation
sporophyte	the spore-producing generation
sporangium	spore producing structure
zygote	formed by the union of the sperm cell and the egg cell
haploid	haploid is the term used when a cell has half the usual number of chromosomes
diploid	having two sets of chromosomes or double the haploid number of chromosomes in the germ cell

The four groups (divisions) of plants belong to the Kingdom Plantae. They have the following in common:

- multicellular
- eukaryotic (cells have a membrane bound nucleus)
- cell walls are made of cellulose
- most are autotrophic and have chloroplasts for photosynthesis
- a life cycle involving two generations: a **diploid**, spore producing generation called a **sporophyte** and a **haploid**, gamete producing generation called a **gametophyte** – referred to as an **alternation of generation**

The characteristics used to place a plant into one of the four groups depends on:

- the presence or absence of true conducting tissues such as xylem and phloem
- the presence or absence of true, roots, stems and leaves
- the type of reproduction and reproductive structures formed
- the degree of dependence on water for reproduction

Characteristics of the Kingdom Plantae:
https://www.youtube.com/watch?v=gJrOATCtV-k

The biodiversity of plants specifically for grade 11:
https://www.youtube.com/watch?v=jINRLEYp3ck

Division Bryophyta

Bryophytes are the most primitive terrestrial plants. The division Bryophyta includes mosses, liverworts and hornworts. Mosses are commonly found in damp shady areas (Figure 2).

Figure 2: Mosses growing in a shady area

Characteristics of Bryophytes

- Mosses are generally small (< 20 cm).
- They do not have true roots, stems or leaves. For this reason, the plant body is referred to as a **thallus**.

- Water can be absorbed directly through the leaves because there is not a waxy cuticle covering the leaves.
- The leaves are not true leaves and are often referred to as 'leaflets'.
- The size of mosses is limited because they do not have any conducting tissues i.e. no xylem or phloem (vascular tissue) is present.
- Rhizoids at the base of the plant are responsible for anchoring the plant to a substrate.
- Bryophytes can reproduce either asexually or sexually.
- The gametophyte generation is the dominant generation and consists of a green leafy plant, capable of photosynthesis.
- No fruits or seeds produced.

Division Pteridophytes

The division Pteridophyta includes all ferns. There are approximately 12 000 different species of ferns. They range in size from tiny plants of only 1 cm in height to tree ferns which can grow to 25 m in height. Most ferns require a warm, damp, shady habitat (see Figure 3).

Figure 3: Ferns growing on a forest floor

Key terminology

frond	the leaf of a fern usually with many divisions
rhizome	a stem which grows horizontally
adventitious roots	roots which arise at the nodes of stems
sori	a cluster of sporangia found on the underside of fern leaves

Characteristics of Pteridiophytes

- Ferns have true leaves, roots and stems.
- Fern leaves are covered by a waxy cuticle to prevent excessive loss of water.
- The leaves are often divided into smaller leaflets. A leaf which is divided into smaller leaflets is called a **compound leaf**. Fern leaves are referred to as a **frond**.
- The presence of vascular tissues allows ferns to grow taller than mosses. They have both xylem and phloem which transport water and photosynthetic products respectively.
- The stems of most ferns grow horizontally and are called **rhizomes**. The rhizomes are usually protected by brown scale-like leaves.
- **Adventitious roots** grow from the nodes of the horizontal stem. These are true roots because they have xylem and phloem and absorb water for the plant. The roots also anchor the plant in the soil.
- Ferns reproduce both sexually and asexually. The dominant generation in ferns is the **sporophyte generation**. Spores are produced in **sporangia** arranged in **sori** under the leaf (Figure 4).
- No fruit or seeds are produce.

Figure 4: Sori on the under-surface of a fern frond

Division Gymnosperms

The division Gymnosperms includes cycads, *Gingko biloba*, *Welwitschia* and pine trees (Figures 5A to 5D). Gymnosperms all produce seeds which develop into cones.

Figure 5A: Cycad

Figure 5B: *Gingko biloba*

Figure 5C: *Welwitschia*

Figure 5D: Pine

Characteristics of Gymnosperms

In gymnosperms the sporophyte generation is dominant and the most visible e.g. the pine tree.

- Gymnosperms have true roots, stems and leaves.
- Vascular tissues, namely xylem and phloem are present. Unlike higher plants, the xylem in pine trees does not have vessel elements. Only xylem tracheids are present to transport water. This is the reason why the wood of pine trees is softer than the wood of higher plants.
- The leaves of pine trees are needle-like (Figure 6) and have a cuticle to reduce the loss of water through evaporation.
- The natural habitat of a pine tree is very cold in winter. The reduced volume of the leaves, prevents ice crystals from forming which would damage the leaves internally. The shape of the tree also stops snow from collecting on the branches.

Figure 6: The needle-like leaves of a pine tree

- Pine trees have well developed root systems.
- Gymnosperms do not produce flowers. They form both male and female cones. It is important to note that fertilization is not dependent on water. Pollen is carried by the wind from a male cone to the female cone.
- The seeds of the pine are said to be “naked” because they are not protected by a fruit. The seeds are carried on the exposed scales of the female cone. When the seeds are ripe, they fall out of the cone and are carried by wind to another location. Each seed has a wing to help with wind dispersal (Figure 7).

  It is important for the survival of the species that the seed does not fall under the tree. If it germinates under the mother tree it will be in the shade and in competition with the mother tree for water and nutrients.
- Pine trees are not indigenous to South Africa and are able to make better use of available water than the natural vegetation because of their extensive root system.

Figure 7: Pine seeds

Did you know? Pine trees are commercially very important. Pine trees are cultivated in South Africa in huge plantations. The wood is used to make paper and furniture. Pine nuts are the seeds of pine trees. They are used to flavour drinks and make pesto.

Division Angiosperms

Angiosperms are commonly referred to as “flowering plants” and are the most varied and successful group of plants. Most angiosperms are autotrophic, but some are parasitic, while others are saprophytes. Angiosperms typically produce seeds which are found inside fruits.

Key terminology

fibrous/ adventitious root system	formed by many thin, moderately branching roots growing from the stem – common in monocotyledons
tap root system	characterized by a main root or primary root system, growing vertically downward – common in dicotyledonous plants

Characteristics of Angiosperms

- The sporophyte generation is the dominant generation in angiosperms. It consists of true roots, stems and leaves.
- Xylem and phloem are responsible for transporting water and photosynthetic products, respectively. The structure of a typical angiosperm sporophyte is illustrated in Figure 8.

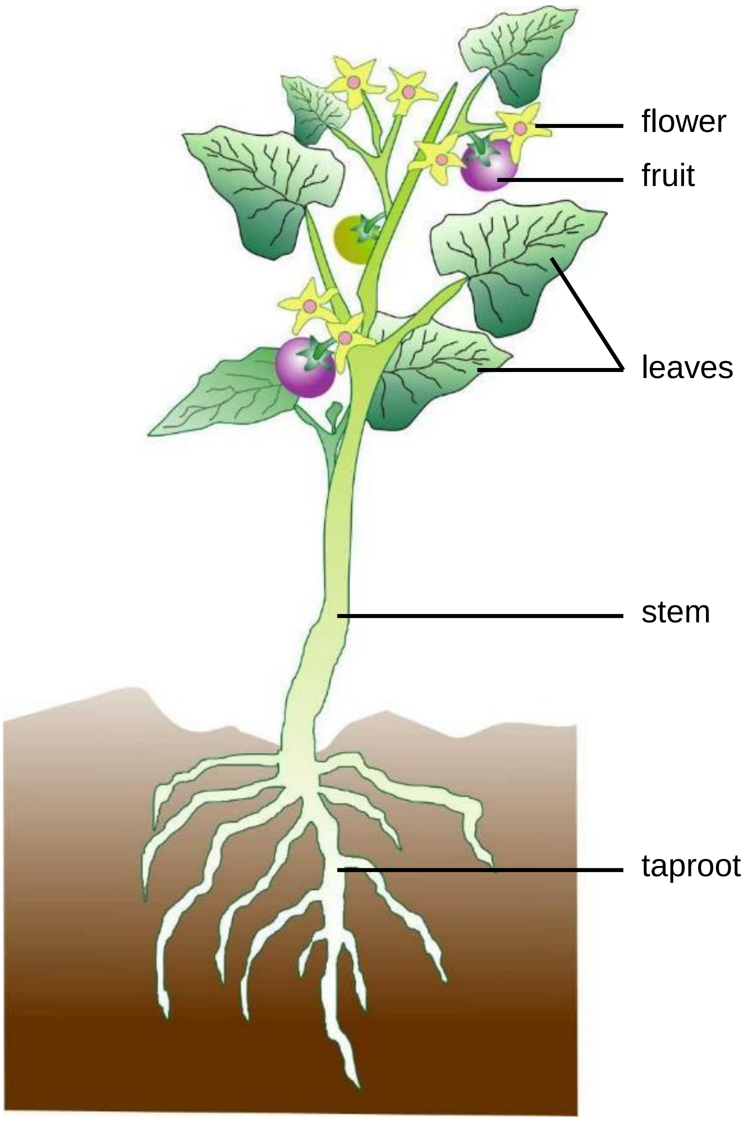


Figure 8: The structure of a typical angiosperm

- Angiosperms have either fibrous (adventitious) root systems or tap root systems. The roots are capable of absorbing water and dissolved mineral salts.
- The stems of angiosperms are divided into nodes and internodes. Leaves form at the nodes on the stem. The leaves are covered in a waxy cuticle to prevent excessive loss of water by evaporation.
- Angiosperms produce seeds protected by fruit.

The life cycle of angiosperms is similar to that of gymnosperms except that the seeds in angiosperms are protected by a fruit. Angiosperms produce flowers instead of cones.

Decreasing dependence on water for reproduction

As plants have increased in size over millions of years, they have become progressively less dependent on water for their survival and for the completion of their life cycles.

Of the four groups studied, the bryophytes are the least adapted to surviving dry conditions for the following reasons:

- they have no cuticle, no supporting tissues and no vascular tissues
- plant body is a thallus because there are no true roots, stems or leaves
- the gametophyte is the dominant generation
- the sporophyte is totally dependent on the gametophyte for both food and water
- the male gametes are motile (capable of motion) and require water to swim to the female gamete

The pteridophytes are more evolved than the bryophytes but are still dependent on water for fertilization. They have the following adaptations which enable them to grow larger than bryophytes:

- leaves with a cuticle to prevent desiccation (drying out)
- vascular tissue to transport food and water
- the sporophyte is the dominant generation and is not dependent on the gametophyte for water and food once mature

Both the gymnosperms and angiosperms are well adapted to life on land. Adaptations include:

- leaves with a cuticle
- true roots, stems and leaves
- an embryo enclosed in a seed to prevent drying out
- pollen grains to protect and transfer the sperm cells i.e. water is not needed for fertilization

Asexual and sexual reproduction

Both animals and plants are capable of asexual and sexual reproduction. In asexual reproduction only one parent is required, and the new organism is produced by mitosis. In sexual reproduction a haploid sperm cell fuses with a haploid egg cell to produce a diploid zygote. The zygote divides by mitosis to form an embryo and later, a new organism.

The advantages of asexual reproduction

- Only one parent is required.
- Asexual reproduction is quicker because the parent does not need to find a mate.
- All the offspring are identical and if conditions are favourable, they can crowd out any competition.
- Asexual reproduction does not rely on pollinators or dispersion agents.

The disadvantages of asexual reproduction

- All the offspring are genetically identical. If conditions become unfavourable, they will all die.
- Poor characteristics in the parents will be passed on to the offspring.
- Rapid multiplication by asexual reproduction may lead to overcrowding.

The advantages of sexual reproduction

- The offspring are genetically different and are able to withstand a variety of conditions.
- Farmers can select organisms with desirable characteristics and cross-breed with them.

The disadvantages of sexual reproduction

- Two parents are required.
- Plants that reproduce sexually rely on pollinating agents and dispersal agents to spread their seeds.

Flowers as reproductive structures

Flowers have the following functions:

- contain and protect the reproductive organs
- attract pollinators

Key terminology

calyx	formed by the green structures around the petals (the sepals) together; serves to protect the flower and its reproductive organs
corolla	all the petals of a flower together form the corolla
receptacle	the thickened part of a stem from which the flower organs grow
perianth	the non-reproductive part of the flower; the calyx and corolla that form a protective envelope surrounding the sexual organs
stamen	male part of the flower consisting of a filament and pollen producing anthers
pistil	female part of the flower consisting of a stigma, style and an ovary where ovules are produced
fruit	a fleshy, often sweet layer, formed around the seeds in angiosperms following fertilization

All the parts of a flower are actually modified leaves arranged in whorls (circles around a central point). Each whorl is specialized to perform a specific function. The four whorls are the:

- calyx
- corolla
- androecium
- gynoecium

In a typical plant, the outermost whorl is called the **calyx** and consists of a number of green **sepals**. All the floral parts are attached to a **receptacle**. The **corolla** is made up of coloured **petals** to attract pollinators (Figure 9). The calyx and corolla are known collectively as the **perianth**.

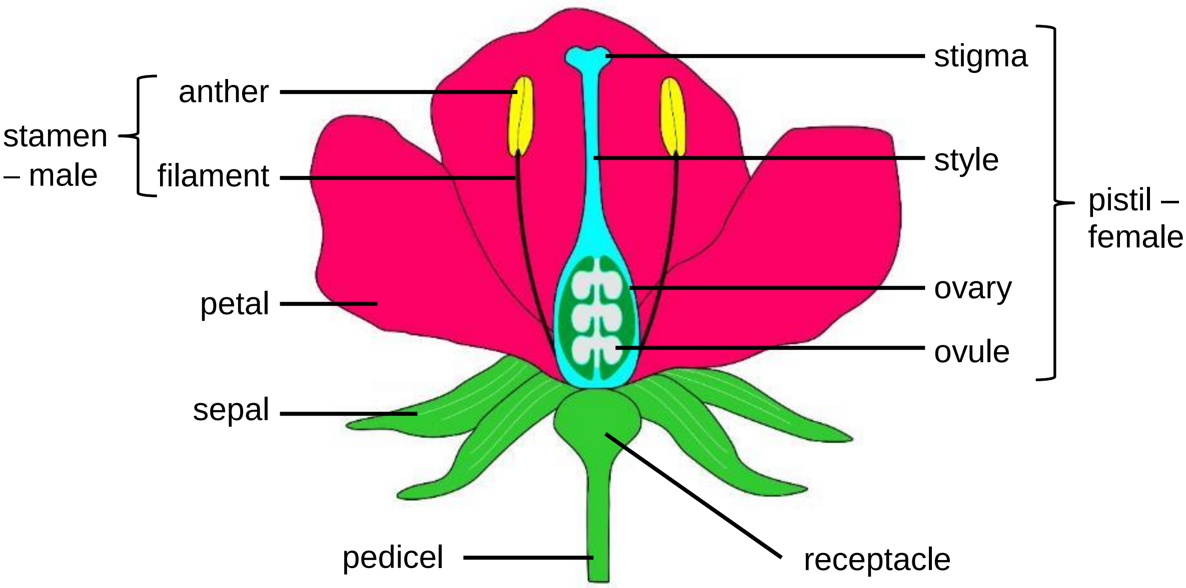


Figure 9: A longitudinal section through a typical dicotyledonous flower

The stamens are the male part of the flower. Each stamen consists of a **filament** and a bi-lobed **anther** with four pollen sacs or microsporangia. Pollen grains (microspores) are haploid and produced by **meiosis.**

The female part of the flower usually consists of **carpels** fused together to form one or more **pistils**. Each pistil consists of a **stigma**, **style** and **ovary**. Ovules are formed inside the ovary by meiosis.

When a pollen grain lands on the stigma, it germinates by growing down the style towards the ovule carrying the male gametes to fertilize the ovule.

The fertilized ovule forms a seed and the ovary wall thickens to become a fruit. In general, fruit do not develop without fertilization.

Pollination

An introduction to pollination:
https://www.youtube.com/watch?v=LiczM-w3V-U

Pollination can be defined as the transfer of pollen from an anther to the stigma of the same or the stigma of a different flower of the same species.

Self-pollination occurs when pollen is transferred between flowers of the same plant or the anther and the stigma of the same flower (Figure 10). Most plants are adapted to prevent self-pollination. For example, the pollen may ripen before the stigma. The pollen will then be dispersed before the stigma is mature. In other flowers, the stigma is mature before the anthers mature and receives pollen from other plants of the same species. Some flowers are adapted to be incompatible with their own pollen.

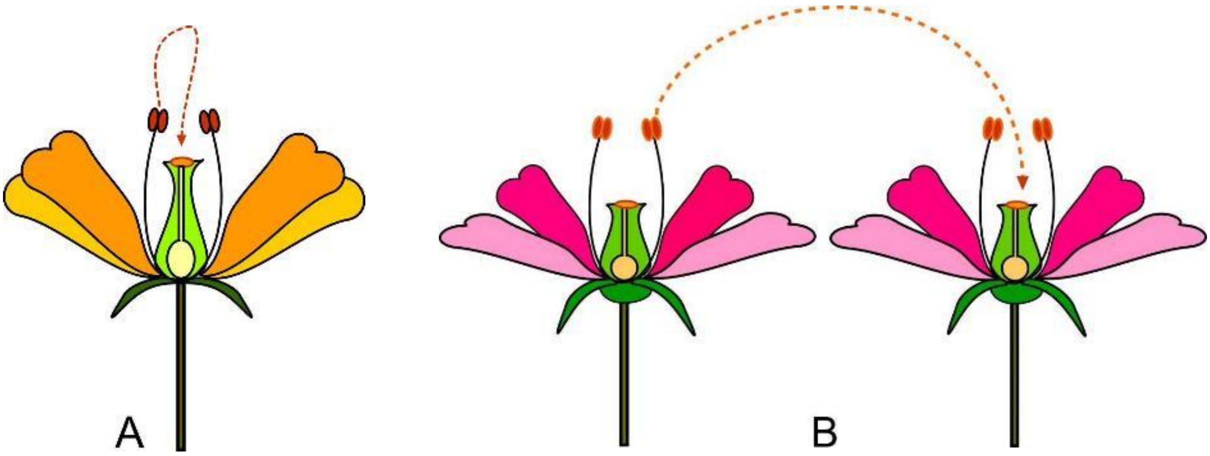


Figure 10: Types of pollination — (A) self-pollination, (B) cross pollination

Cross-pollination occurs when pollen is transfer from the flower of one plant to the flower of another plant of the same species (Figure 10). Cross-pollination is important because it creates genetic diversity. This means that the offspring are genetically different to the parent. Genetic diversity ensures that a species has a better chance of surviving unfavourable conditions.

Pollination is vital for the production of fruit crops (e.g. apples and pears) and seed crops (e.g. maize, legumes, wheat).

Plants rely on wind, water or pollinators such as insects and birds, to transfer pollen from one flower to another.

Adaptations of flowers for pollination

Flowers show a variety of adaptations to ensure that pollination takes place.

Key terminology

nectar	a sugar-rich liquid produced by plants in glands called nectaries to attract pollinators

Adaptations for pollination through insects

In South Africa the indigenous salvia flowers are insect pollinated (Figure 11).

Figure 11: Salvia flower species provide a landing platform for insect pollinators

Flowers that are pollinated by insects often have the following **characteristics:**

- Large, conspicuous petals in bright colours except red. Some insects cannot tell the difference between red and black.
- Sweet scent to attract moths and butterflies.

- A reward for the pollinator such as nectar and/or pollen.
- Anthers and stigmas are inside the flower so that the insect must brush past them to get to the nectar thus transferring the pollen
- Sticky or spiky pollen grains which stick to the insect's body.
- Large quantities of pollen are produced because some will be eaten by the visiting insect.
- Flowers either open during the day for insects that are active during the day such as bees or at night for insects active at night e.g. moths.
- Flowers have UV markings visible only to insects.

Adaptations for pollination through birds

Examples of indigenous flowers pollinated by birds in South Africa include our national flower, *Strelizia regina* (Figure 12).

Figure 12: Bird pollinated *Strelitzia regina*

Flowers pollinated by birds usually have the following **characteristics:**

- Produce large quantities of dilute nectar.
- Flowers are bigger than most insect pollinated flowers.
- Stamens and stigmas protrude beyond the petals.
- Open during the day.
- Often red because red can be seen by birds in contrast to insects.
- Generally sturdy.
- Little or no scent because birds have a poor sense of smell.

- Ovules are protected from probing beaks.
- Pollen grains stick together in clumps so that the bird picks up enough pollen. to fertilize a large number of ovules with just one visit.
- The flowers are borne above the leaves so that hovering birds can reach them.

Adaptations for pollination through wind

Wind pollination is not an efficient method of pollination because vast quantities of pollen must be produced in order for some of it to land on a receptive stigma of the right species.

Some trees and grasses, restios (Figure 13) and sedges are wind pollinated. Most of our agricultural crops are wind pollinated e.g. maize, oats and rice.

Figure 13: Indigenous restios are wind pollinated

Wind pollinated flowers have the following **characteristics:**

- They do not have a scent or nectar.
- Flowers are often small and either green or brown in colour because they do not need to attract pollinators.

- The male flowers have large anthers
- The flowers are borne on flexible stalks that move in the wind.
- usually very small
- lack a calyx and a corolla
- enormous amounts of pollen are produced
- stigmas are long and feathery

Activity 1: Pollination and parts of flowers

1. Study the pictures below and indicate if they are pollinated by insects, birds or by wind. Give a reason that is visible in the picture for your answer. (10)

A

B

C

D

E

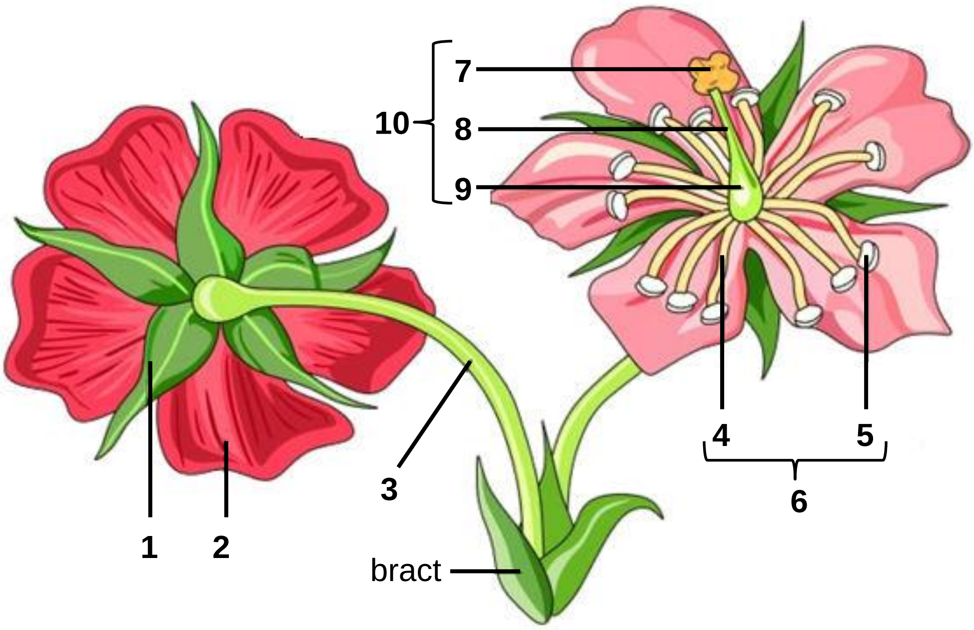
2. The following table compares flowers which are pollinated by pollinators with flowers which are wind pollinated. Copy the table into your book and complete it.

Table: The difference between pollinator and wind pollinated flowers.

Feature	Pollination by a pollinator	Wind pollinated
flower		small and inconspicuous
stigma		
stamens		
pollen		
scent		
energy spent		

(11)

3. Supply labels 1 – 10 for the following diagram. (10)



(31)

The significance of seeds

A seed is formed from a fertilised ovule.

Key terminology

radicle	embryonic root
plumule	embryonic shoot
monocotyledons	plants that have only one cotyledon; other possible characteristics: flower parts in multiples of threes (three, six or nine petals), sepals that make up their flowers
dicotyledons / or dicots	having two embryonic leaves or cotyledons

Seeds either have one cotyledon (**mono**cotyledons) or two cotyledons (**di**cotyledons) which store food for the developing embryo. Seeds are surrounded by a tough, protective seed coat called a **testa** (Figure 14A and 14B).

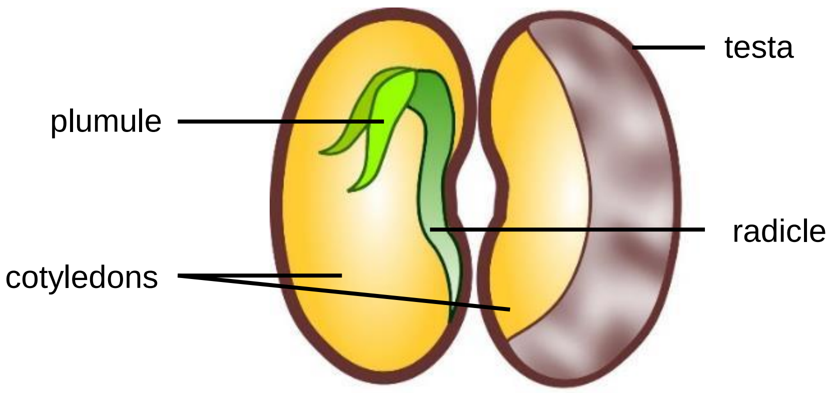


Figure 14A: Dicotyledon

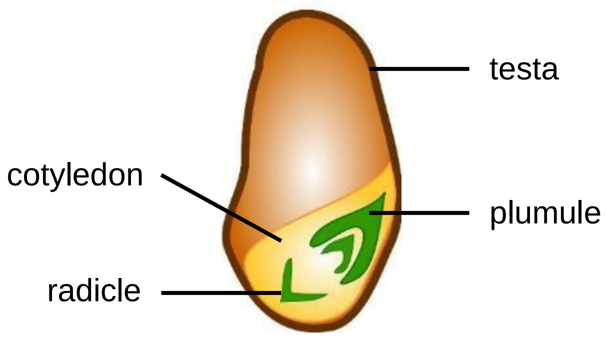


Figure 14B: Monocotyledon

Seeds are produced by sexual reproduction, so every seed is genetically different. This increases the chance of survival for the species. Seeds have various adaptations to ensure that they are dispersed. Some seeds remain dormant until favourable conditions return.

Seed banks

A seed bank is a facility established to store seeds of both crop plants and wild crops to ensure that they do not become extinct and to make sure that biodiversity is maintained. Seeds are also an important food source for birds, animals and humans.

Seed banks often store the seeds of rare or unusual plants. The seeds of the original plants used to hybridise and produce new, hardier varieties are also stored. Stored seeds are often used for research purposes.

Seeds are stored at a temperature below freezing point. Before the seeds are frozen, they are dried to prevent bacteria and fungi from causing them to rot.

Inside the Svalbard Seed bank: https://www.youtube.com/watch?v=2_OEsf-1qgY

Activity 2: Seed banks

1. Give two reasons why seed banks are important. (2)
2. Before seeds are frozen in a seed bank, they are dried. Explain why. (2)

(4)

Seeds as a food source

Examples of seeds that humans cultivate, and harvest include coffee, maize, wheat, peas, soya beans and rice. Seeds such as beans, peas and soya beans are called pulses. Pulses are a good source of protein whilst the grains such as wheat, rice and maize are a good source of carbohydrates. Many of these crops form the staple diet of poorer countries.

Endemic seeds as a food source

- Endemic seeds occur naturally, only in certain areas. Sorghum is endemic to Africa but is now grown all over the world. Sorghum is traditionally eaten as a porridge or used to make a traditional African beer.
- The dried, crushed kernels of maize are used to make samp. Samp is often cooked with red beans.
- Millet (Figure 15) does not contain gluten and is often used by people who are allergic to gluten.

Figure 15: Pearl millet in cultivation

Biodiversity of plants: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Bryophytes are terrestrial plants that have no…

A cellulose
B rhizoids
C vascular tissue
D sporophyte phase

1.1.2 The sporangia on the under surface of fern leaves are called…

A sporophylls
B sori
C cones
D sporogonia

1.1.3 Conserving endemic seeds in South Africa will enable the following:

A The protection of plants against disease
B A lot of money to be made for South Africa
C The restoration of over-exploited medicinal plants
D Food crops to be grown in dry conditions

1.1.4 Alternation of generations is exhibited by…

A Bryophytes
B Pteridophytes
C Spermatophytes
D All plants (4 × 2) = (8)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 Reproduction which uses non-reproductive parts of a plant to produce new plants.

1.2.2 Plants without true roots, stems and leaves.

1.2.3 Places where seeds are stored to help preserve biodiversity.

1.2.4 A reproductive structure found in gymnosperms and angiosperms only, consists of a plant embryo with a protective coat.

1.2.5 A group of plants that have seeds enclosed in an ovary.

1.2.6 The part of the plant embryo that develops into the root.

1.2.7 The tough outer coat of a seed.

1.2.8 The part of the flower that the fruit is derived from.

1.2.9 The collective name for a filament and an anther.

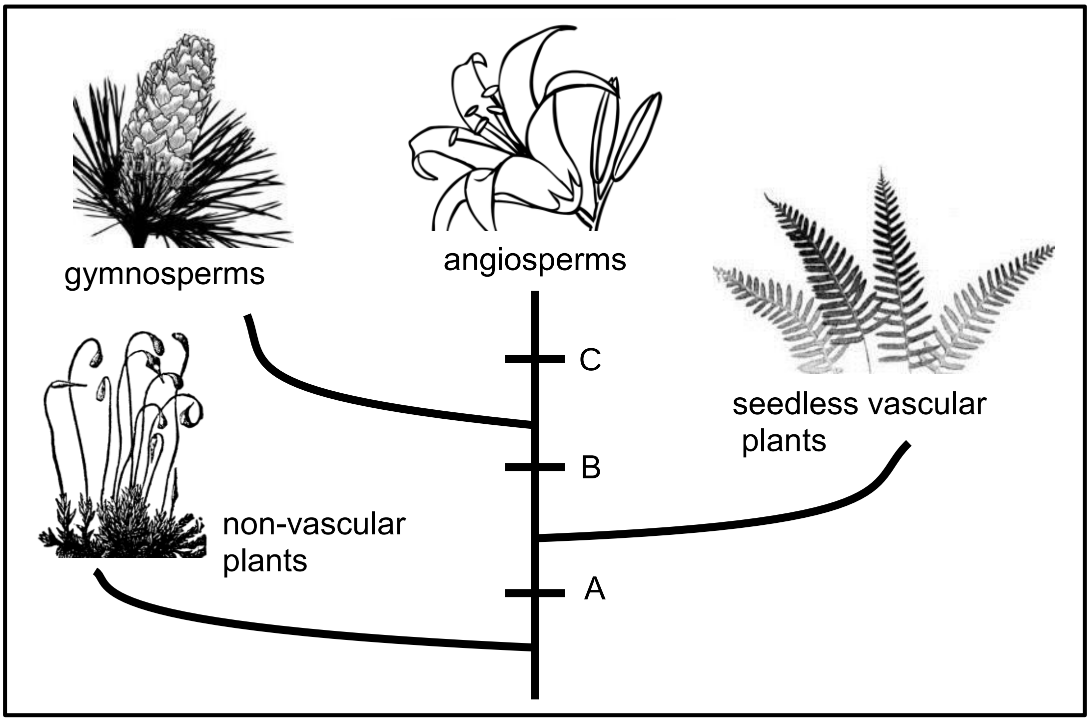
(9 × 1) = (9)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	**Column II**
1.3.1 A division of plants with a vascular system, seeds, and no flowers.	A: gymnosperm B: angiosperm
1.3.2 The purpose of flowers.	A: attract pollinators B: form fruit
1.3.3 Gametophyte is dominant	A: ferns B. mosses
1.3.4 Thallus plant	A: bryophytes B: pteridophytes
1.3.5 The part that is formed from a fertilized ovule	A: seed B: fruit

(5 × 2) = (10)

1.4 The diagram below is a cladogram of plants and their algal ancestors. A, B and C indicate key structural features in the evolution of higher plants. Study the diagram and answer the questions which follow.



1.4.1 Name the most important adaptation(s) that evolved at each of the positions labels A, B and C. (3)

1.4.2 Which division of plants is represented as non-vascular plants in the diagram? (1)

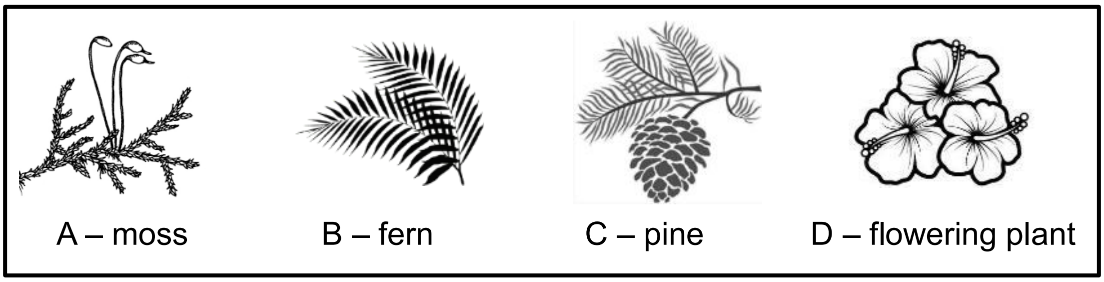
1.4.3 Explain why seedless vascular plants are able to grow taller than the nonvascular plants. (2)

1.4.4 In what way are the seeds of gymnosperms different to seeds of angiosperms? (2)

1.4.5 What is the collective name for all seed-bearing plants? (1)

(9)

1.5 Study the different plant diagrams shown, and answer the questions below.



1.5.1 Identify the divisions to which each of the above plants belongs. (4)

1.5.2 Name one of the divisions identified in question 1.5.1 that is …

A dependent on water for fertilization? (1)

B produces seeds for fertilization? (1)

1.5.3 Mention three similar structural adaptations of the prothallus in ferns and the gametophyte in mosses, which make them to be poorly adapted to a terrestrial life. (3)

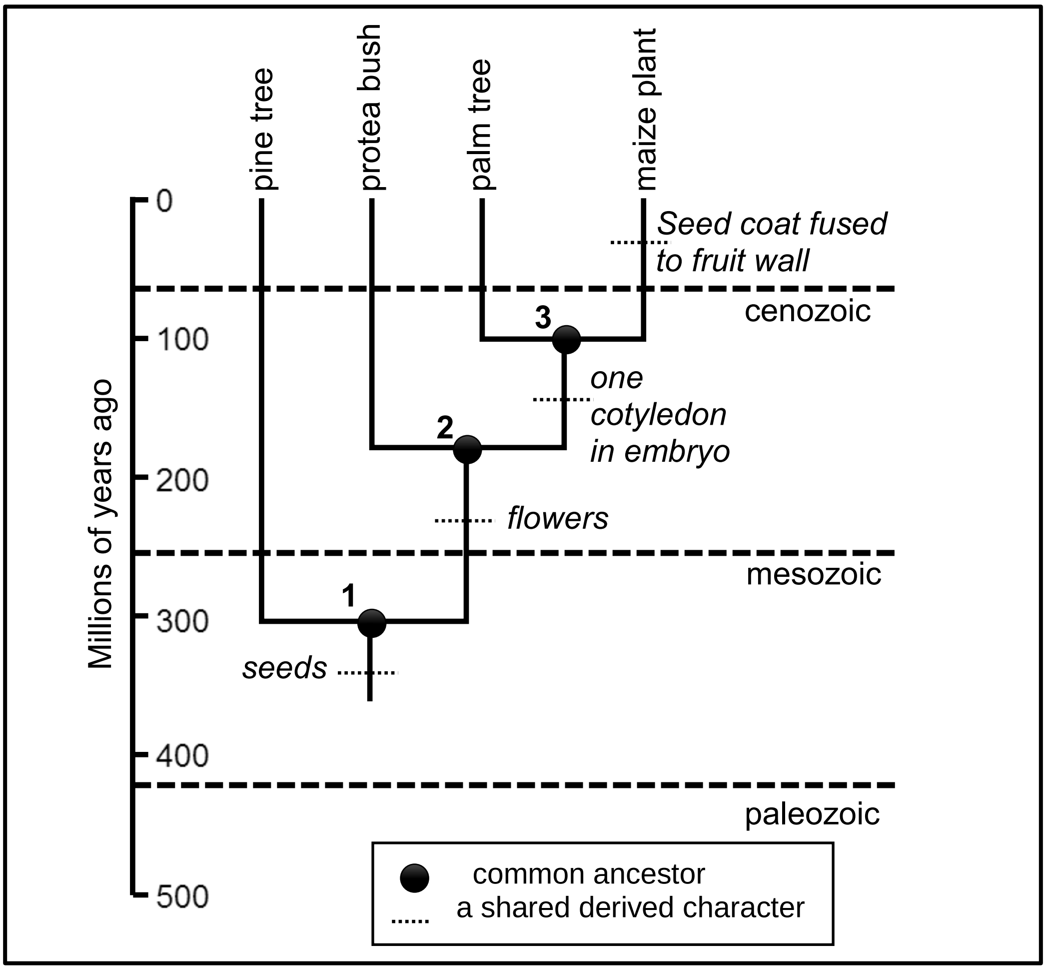
(9)

Section A: [45]

Section B

Question 2

2.1 Study the diagram which shows the phylogenetic tree of four plant species and answer the questions that follow.



2.1.1 Provide a definition of a *phylogenetic tree.* (1)

2.1.2 State whether the following statements are true or false. In each case give a reason for your answer.

a) The solid circle numbered **3** represents the common ancestor of the protea bush, palm tree and maize plant. (2)

b) The protea bush is more closely related to the pine tree than it is to the maize plant because they are located next to each other on the phylogenetic tree, (2)

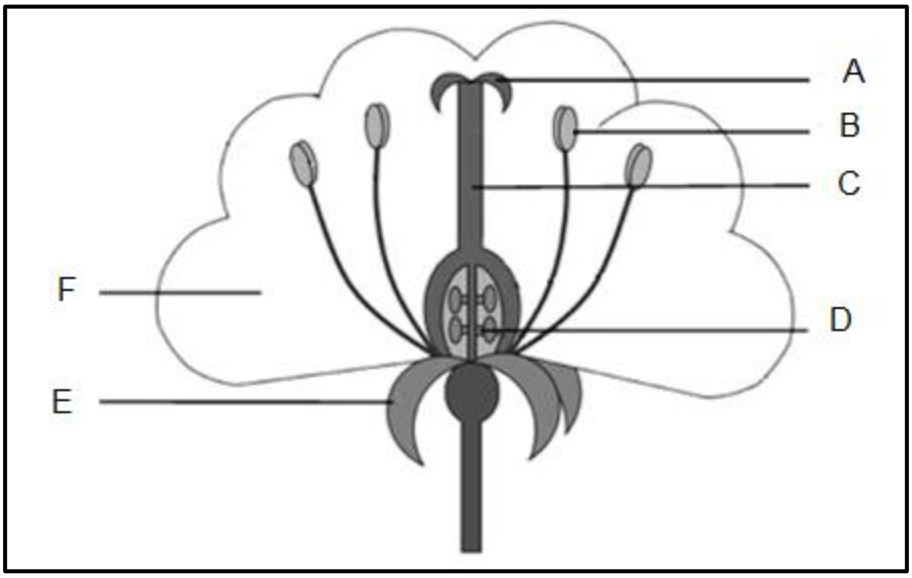
c) Palm trees evolved from pine trees. (2)

d) Protea bushes, palm trees and maize plants are all flowering plants. (2)

2.1.3 How many millions of years ago did the ancestor of the palm tree and maize diverge? (1)

(10)

2.2 Study the diagram below showing the structure of a flower.



2.2.1 What type of pollination can be linked to this flower? (1)

2.2.2 Identify the parts labelled A and B. (2)

2.2.3 What do we call F and E together? (1)

2.2.4 Using the number only, identify the following:

a) Part which receives pollen. (1)

b) Structure where a seed can form. (1)

c) Part where pollen is produced. (1)

2.2.5 A seed bank in Norway has been storing seeds of a rare and endangered plant. To keep the seeds fresh, 120 of the seeds of this plant were selected to be grown. Of the 120 seeds, only 90 germinated. What percentage of the seeds was not fertile? Show all your workings. (2)

2.2.6 Plants have to spend a lot of energy to produce flowers. Explain why it is still an evolutionary advantage to produce flowers in plants. (5)

(14)

2.3 Tabulate five structural differences between wind-pollinated and insect-pollinated flowers. (11)

Section B: [35]

Total marks: [80]

3: Biodiversity of animals

CHAPTER 3: BIODIVERSITY OF ANIMALS

Introduction

Key terminology

phylogenetic tree	a diagram showing the evolutionary relationships between ancestral groups or organisms and their descendants
phylum	a taxonomic rank below **kingdom** and above **class**
taxonomist	biologists that identify and group organisms according to their characteristics

Biodiversity refers to the variety of life on Earth. There are approximately 1,5 million recorded animal species on Earth. Animals are sorted according to their similarities and differences (Figure 1). All animals belong to the Kingdom Animalia. This kingdom is further divided into phyla (singular: phylum) which are based on differences in their basic body plan.

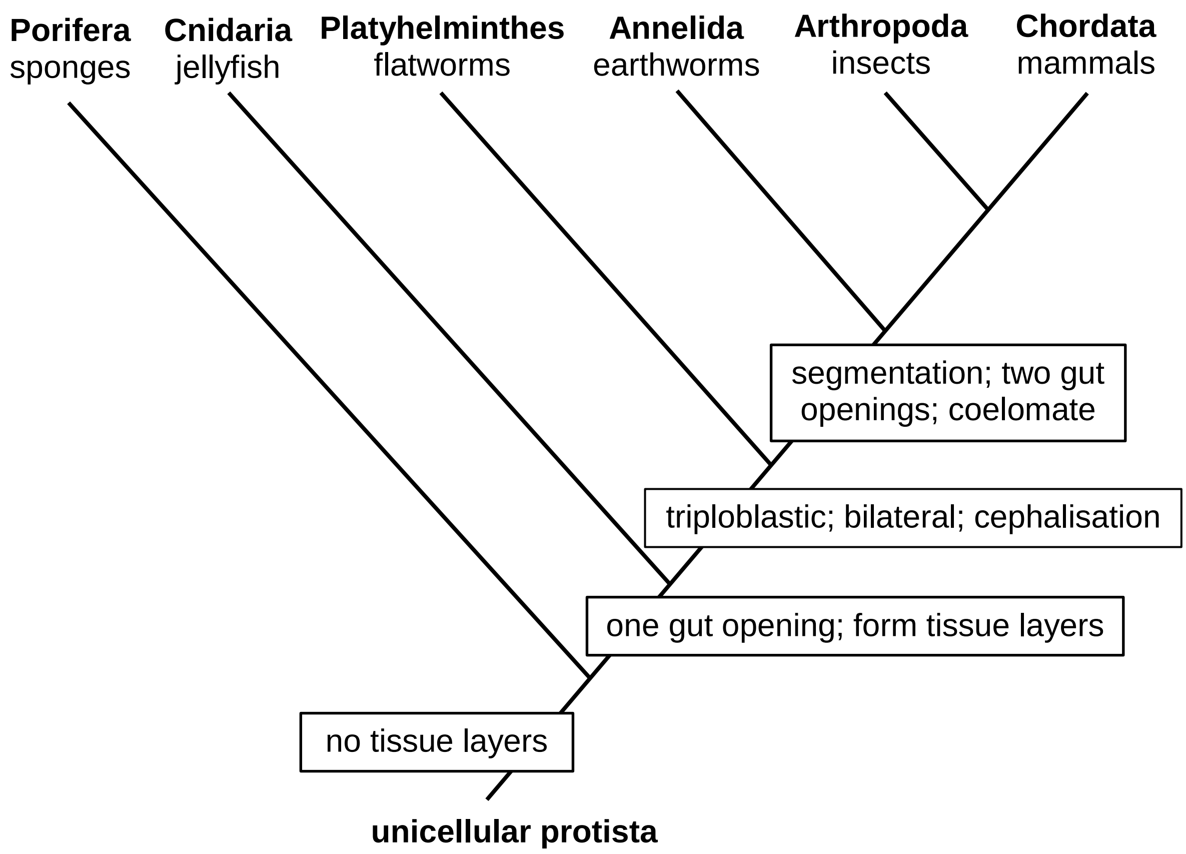


Figure 1: Phylogenetic tree of Kingdom Animalia, showing divisions into phyla

Introduction to animal biodiversity: https://www.youtube.com/watch?v=Tvrs9jA3SP0

Key features of body plans

A body plan is structural characteristics of an organism that separates it from other organisms or groups of organisms. Important features of body plans include:

- body symmetry and cephalisation
- tissue layers
- number of gut openings
- the presence of a body cavity

Key terminology

cephalisation	the presence of a definite head that contains sense organs in animals; first seen in the phylum Platyhelminthes
sessile	organisms that are immobile and attached to one place for life, e.g. sponges and barnacles
gut	portions of the alimentary canal

Body plans & associated phyla: https://www.youtube.com/watch?v=FMBpaV2dScM

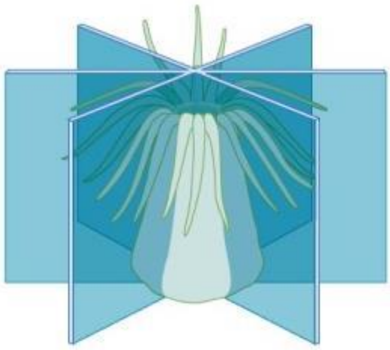
Body symmetry and cephalisation

An organism is symmetrical when it can be cut into two equal and identical halves through one or more plane. Multicellular organisms can be **asymmetrical**, **radially symmetrical** or **bilaterally symmetrical**.

Animals that have bilateral symmetry are usually more advanced and have **cephalisation**. Cephalisation is when most of the sense organs, feeding appendages and the brain are near the anterior part of the body, as shown in Figure 4.

Animals with bilateral symmetry are usually active and are constantly moving around in search of food, mates and interacting with their environments.

The table below provides illustrations of the three types of symmetry.

Type of symmetry	Description	Example
asymmetry e.g.: amoeba, sponges	• no symmetry, i.e. they cannot be divided into two equal halves (Figure 2)	 Figure 2: asymmetrical – sponge
radial symmetry e.g.: Cnidaria	• body plan can be cut through more than one plane to obtain two equal halves (Figure 3) • usually **sessile** or are able to move around only a little	 Figure 3: a radially symmetrical animal – sea anemone
bilateral symmetry e.g. all other phyla except Porifera and Cnidaria	• body plan can be divided into two equal halves in only one plane. i.e. they have a left side and a right side that are identical • cannot be divided into an equal anterior (front) and posterior (back) end, as shown in Figure 4.	 Figure 4: a bilaterally symmetrical animal – goat

Tissue layers

The first tissue layers formed in the embryo are called germ layers. The germ layers differentiate into different organs.

Key terminology

diploblastic	having a body wall that is composed of two layers: the endoderm and ectoderm
triploblastic	any organism that develops from a three-layered embryo; ectoderm, mesoderm and endoderm
coelom	a fluid-filled cavity that lies between the ectoderm and endoderm and is found in triploblastic organisms
hydrostatic force	a force exerted by a liquid, usually water, increased with constriction and gravity
peristalsis	an automatic wave of muscle contraction and relaxation that moves food in one direction through the digestive tract

Primary germ layers

The primary germ layer consists of the **ectoderm** (outer layer) and the **endoderm** (inner layer).

- The ectoderm will develop into the skin or epithelium and the nervous system of the animal.
- The endoderm will form the digestive system.
- Animals that only have two germ layers (ecto- and endoderm) are called **diploblastic animals** (Figure 5).
- Diploblastic animals do not form complex organs and are more primitive animals.

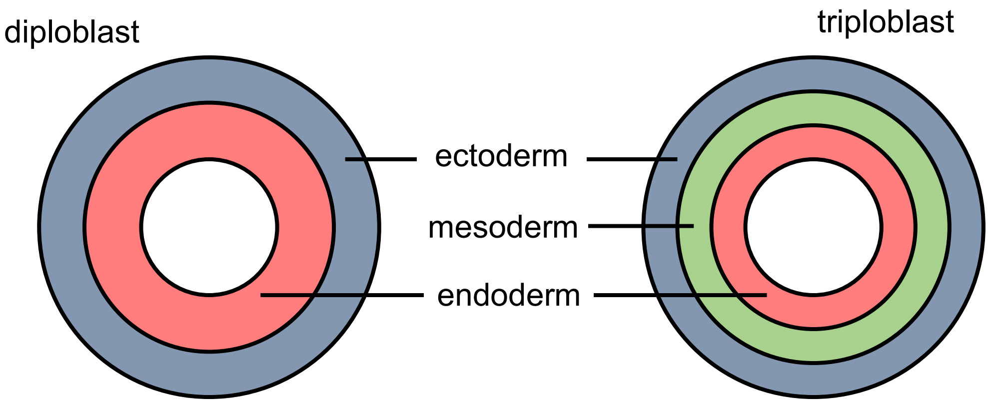


Figure 5: Tissue layers in embryonic development; ecto (outside), endo (inside), meso (middle)

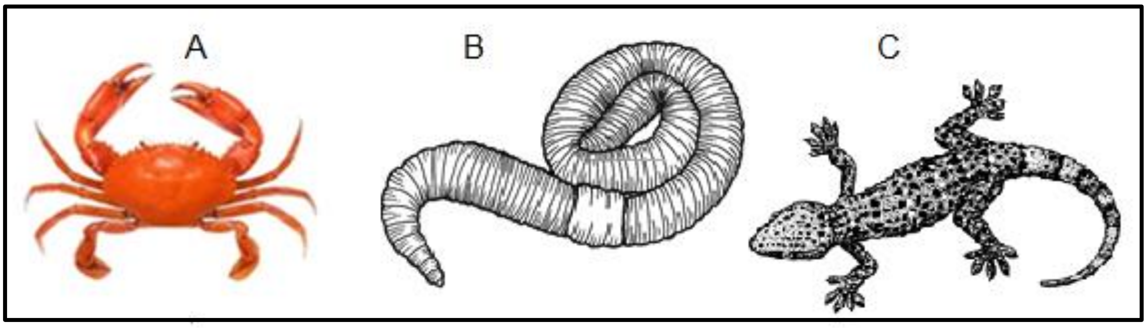
Secondary germ layers

The mesoderm is a secondary germ layer which develops between the endoderm and the ectoderm.

- Animals that have three tissue layers (i.e. ecto-, endo- and mesoderm) are called **triploblastic animals**. Figure 5 illustrates these three tissue layers.
- The mesoderm develops into connective tissue, bone, blood, reproductive organs, cartilage, blood and the lymphatic systems.

Activity 1: Body symmetry and tissue layers

1. Study the diagrams below and answer the questions that follow.

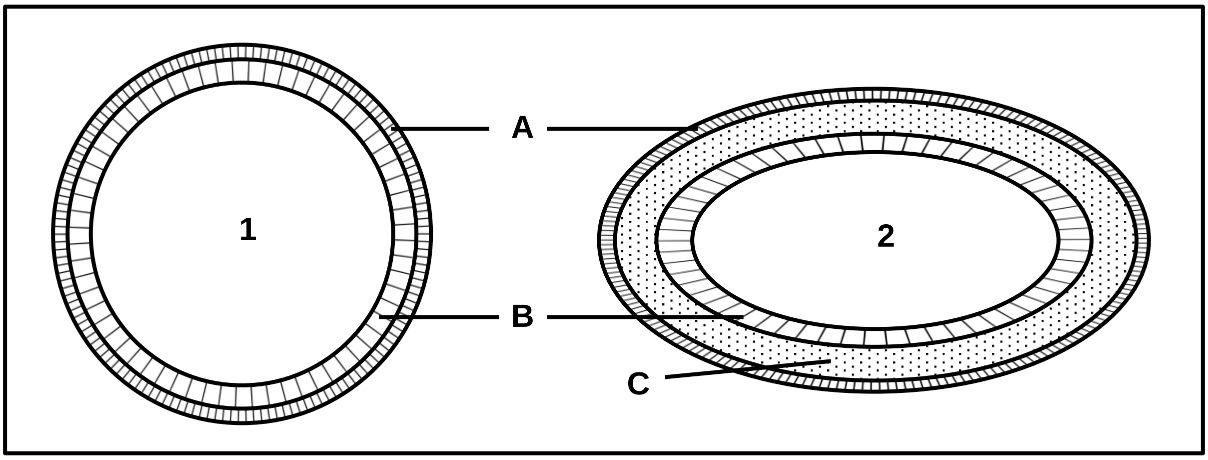


1.1 Give the body symmetry of the organisms A to C respectively. (3)

1.2 What are the advantages of an organism that has bilateral symmetry? (2)

1.3 Give the letters of the organisms that show cephalisation. (3)

2. Study the diagram below and answer the questions that follow.



2.1 Provide labels for A, B and C. (3)

2.2 Which diagram, 1 or 2, is a diploblastic organism? (1)

2.3 Give a reason for your answer in question 2.2 (1)

2.4 What advantages does an organism with a mesoderm have? (2)

(15)

Opening to the gut

Animals have either one or two openings to the gut / digestive system.

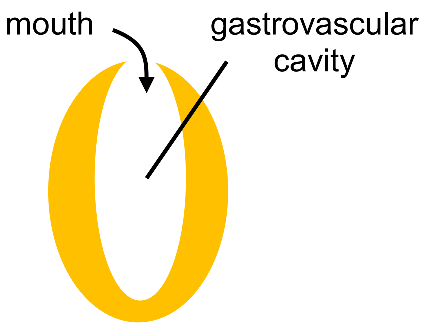
<table>
<tr><th>Openings</th><th>Description</th></tr>
<tr><td>One opening</td><td>Animals with only one opening to the gut will consume food through the opening (mouth) and excrete waste through the same opening. There is only one opening for both the mouth and the anus (Figure 6).
• A one-opening to the gut is also called a blind-ending gut.
• This limits the amount of food that these animals can consume – they must excrete the waste from their digestive system before they can consume more food.


Figure 6: Representation of one opening to the gut</td></tr>
<tr><td>Two openings</td><td>Animals with two openings to the gut can consume food through a mouth opening and excrete waste through another opening called the anus (Figure 7). This type of gut is also called a through-gut.
• A through-gut is an advantage because food can be consumed continuously because it moves through the digestive system.
• Sections of the digestive system can also specialize (e.g. stomach) to improve the efficiency of the digestive process.


Figure 7: Representation of two openings to the gut</td></tr>
</table>

Coelom (body cavity)

A coelom is a body cavity that develops inside the mesoderm tissue layer in more advanced animals. Animals without a coelom are said to be acoelomate.

Acoelomate

An acoelomate animal does not have a body cavity or coelom (Figure 8A).

Acoelomate animals may be either diploblastic or triploblastic. Acoelomate animals are usually smaller and are less mobile that coelomates.

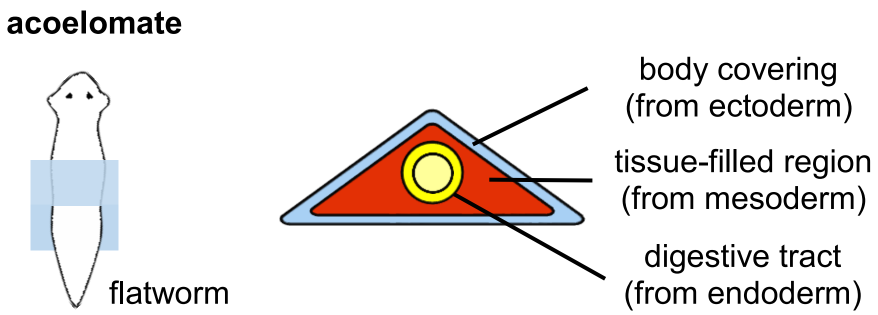


Figure 8A: Acoelomate body form

Coelomate

Coelomate animals have a body cavity or coelom in their mesodermal tissue layer (Figure 8B). However, some triploblastic organisms have a body cavity that is not surrounded by mesoderm. This cavity is called a **pseudocoel** (pseudo- means false or not real) (Figure 8C).

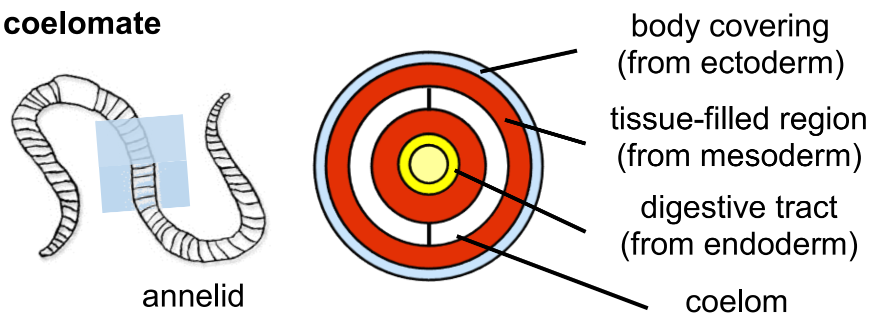


Figure 8B: Coelomate body form

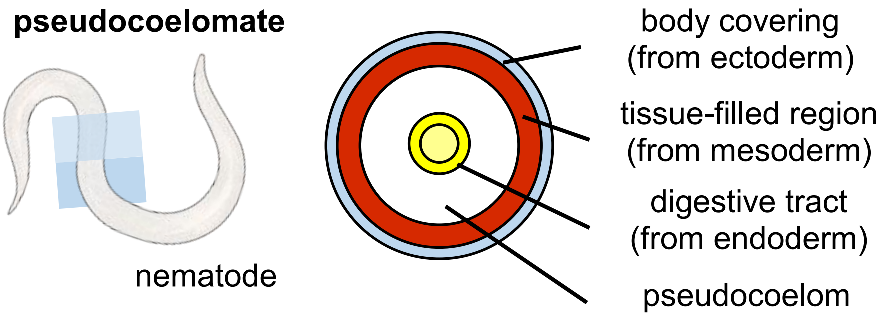


Figure 8C: Pseudocoelomate body form

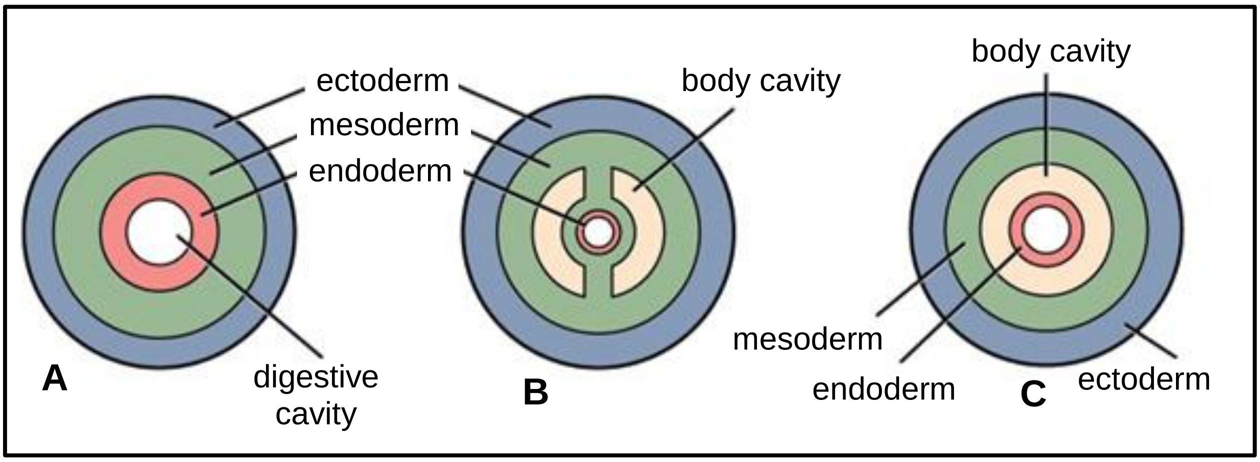
Advantages of a coelom

- Allows more complex organs to develop such as digestive organs, muscular system, blood system etc.
- Allows the creation of a hydrostatic force to be generated for movement in soft-bodied animals
- It separates the endoderm and ectoderm from each other with a cavity which allows the layers to move independently of each other. This allows **peristalsis** to occur
- In some organisms, the coelomic fluid (fluid found in the coelom) helps to transport nutrients and waste in the body

An animal must be triploblastic before it can be a coelomate because the coelom develops into the mesoderm.

Activity 2: Coeloms

Study the diagram below and answer the questions that follow.



1. Which diagram (A, B or C) represents a:
   1.1 pseudocoelomate
   1.2 acoelomate
   1.3 coelomate (3)
2. Which diagram represents the most advanced organism? (1)
3. What advantages does a coelom give to an animal? (4)

(8)

Animal phyla

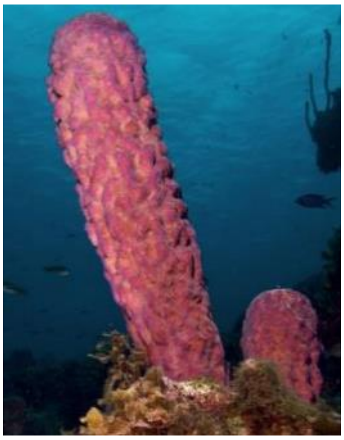
Only six of the approximately 33 animal phyla will be discussed in this chapter. We shall use the body plans discussed in the previous section to describe the different phyla. The phyla will be discussed in order from the simplest to the more advanced.

Key terminology

invertebrates	organisms without a backbone
vertebrates	animals that have a backbone or spinal column
spicule	a minute (very small) sharp-pointed object or structure that is typically present in large numbers, found in sponges
nematocyst	a specialized cell in the tentacles of a jellyfish or other coelenterate, containing a barbed or venomous coiled thread that can be projected in self-defense or to capture prey
mesoglea	the tissue in jellyfish that functions as a hydro-static skeleton
acellular	not consisting of, or not containing cells
haemocoel	the body cavity of most invertebrates containing circulatory fluid
exoskeleton	a thick, rigid outer covering that protects and supports bodies and provides places for muscles to attach in animals, e.g. arthropods
ecdysis (moulting)	the process of casting off the outer cuticle in arthropods

Six phyla are studied, including:

- Phylum Porifera e.g. sponges
- Phylum Cnidaria e.g. blue bottles, jelly fish, sea anemones
- Phylum Platyhelminthes e.g. flukes, tapeworms, free-living planarians
- Phylum Annelida e.g. leeches, earthworms and polychaetes
- Phylum Arthropoda e.g. crab, spider, locust, millipede, centipede, fly
- Phylum Chordata e.g. fish, mammals, birds, reptiles, amphibians

Phylum Porifera • aquatic (live in water) • asymmetrical with **no cephalisation** • function at a cellular level • acoelomate • no openings to the gut • sessile organisms that feed by filtering out floating particles from the water column (Figure 9) • the body is made up of millions of spicules which protect and support the sponge	 Figure 9: Filter-feeding sponge

Phylum Cnidaria
• aquatic, mostly marine but some live in freshwater habitats
• **radially symmetrical** with **no cephalisation**
• diploblastic which means they have a cellular ectoderm and a cellular endoderm.
• they also have an acellular jelly-like layer between these two layers called the **mesoglea.**
• acoelomate
• one opening to the gut that acts as both the mouth and the anus. the mouth often has tentacles that help catch prey.
• Cnidarians occur in two different body forms:
  ○ a sessile polyp phase (Figure 10)
  ○ a free-swimming medusa (Figure 11)
 	
Cnidarians have stinging organelles in their cells called **nematocysts** that they use for catching their prey and for protection.
Cells that contain nematocysts are called **cnidocytes** or **nematocytes**
	
	Figure 10: Polyp e.g. sea anemone
	
	Figure 11: Medusa e.g. jellyfish

Phylum Platyhelminthes

- most are internal parasites but some are aquatic and free-living
- **bilaterally symmetrical** with **cephalization** – a definite anterior, posterior, dorsal and ventral side because they are bilaterally symmetrical (Figure 12)
- **dorsoventrally flattened** which means they appear squashed from the dorsal to the ventral side
- have their sense organs and nerve tissue concentrated in the anterior region of their body (cephalisation) which allows them to detect what lies ahead of them – aids in feeding and avoiding danger
- **triploblastic** which allows them to develop tissues and organs e.g. nervous tissue and reproductive organs
- **acoelomate** and therefore no circulatory system
- one opening to the gut – the digestive cavity branches around the body to transfer nutrients around the body

Figure 12: Free-living *Planaria*

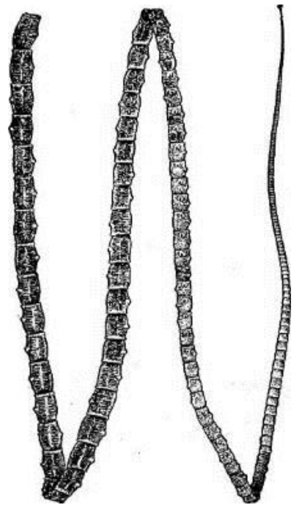


Figure 13: Tapeworm

Phylum Annelida

- aquatic (freshwater and marine) and terrestrial habitats
- bilaterally symmetrical with cephalisation
- triploblastic
- coelomate - coelom is a fluid-filled cavity that is used as a **hydrostatic skeleton** for movement
- **segmented** which means their bodies consist of repeating segments, called **metameres**

Figure 14: An earthworm

Phylum Arthropoda

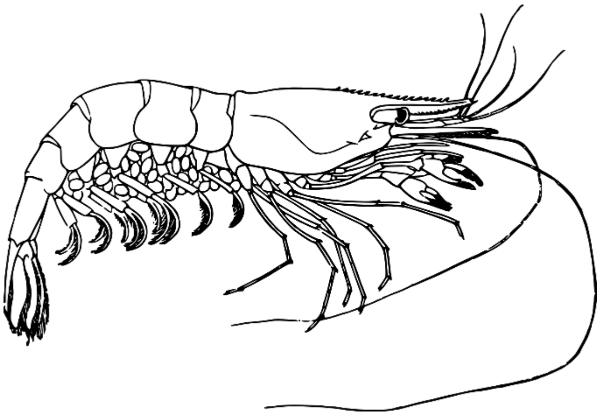


Figure 15: Diagram of a shrimp

- aquatic (freshwater and marine (Figure 15)) and terrestrial
- bilaterally symmetrical with cephalisation
- triploblastic
- coelomate – the coelom is filled with a fluid, which acts like blood, called a **haemocoel**. arthropods therefore have an **open circulatory system**
- more advanced segmentation of body parts so that each segment has a particular form and function i.e. abdomen, thorax and head
- all arthropods have **jointed appendages** that are used for movement and feeding
- two openings to the gut (a through-gut)
- a waterproof **exoskeleton** made of chitin

The exoskeleton:

- protects the arthropod from drying out
- prevents diffusion of gases across its waterproof surface; arthropods have therefore developed gaseous exchange organs such as gills and lungs
- does not grow as the arthropod grows and it must be shed regularly (**ecdysis**) and regrown; the arthropod is vulnerable during regrowth of the exoskeleton because it is weaker and requires a lot of energy

Phylum Chordata

- aquatic (freshwater and marine) and terrestrial
- bilaterally symmetrical with cephalisation
- triploblastic
- coelomate
- segmented body
- two openings to the gut (through-gut)
- all vertebrates have a rod-like support named a **notochord** which may develop into the **vertebral column** (Figure 16)

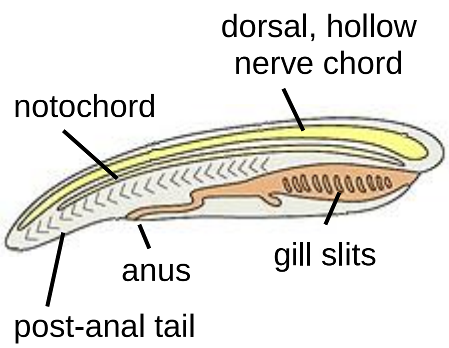


Figure 16: Anatomy of a lancelet

Vertebrates ….

- have a hollow dorsal tubular **nerve cord** (spinal column) which often forms the anterior brain (e.g. humans)
- initially develop **pharyngeal gill slits** that disappear in terrestrial chordates at adulthood
- have a **post-anal tail**
- Chordata can be **ectothermic** or **endothermic**. The body temperature of exothermic animals is regulated by the external environment whereas the body temperature of endothermic animals is regulated by internal metabolic reactions. Examples of endothermic animals are humans and birds.

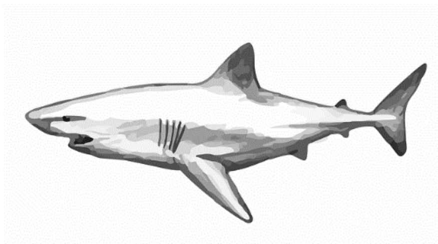


Figure 17: A shark - a typical chordate

Phylum Porifera and Cnidaria: https://www.youtube.com/watch?v=tlfsHPpkSPs

Circulatory systems

An open circulatory system pumps haemolymph (similar to blood) around the body but the haemolymph does not stay inside vessels as in a closed circulatory system. Instead it flows into the haemocoel (body cavity) and diffuses back into vessels that bring the haemolymph back to the heart (Figure 18).

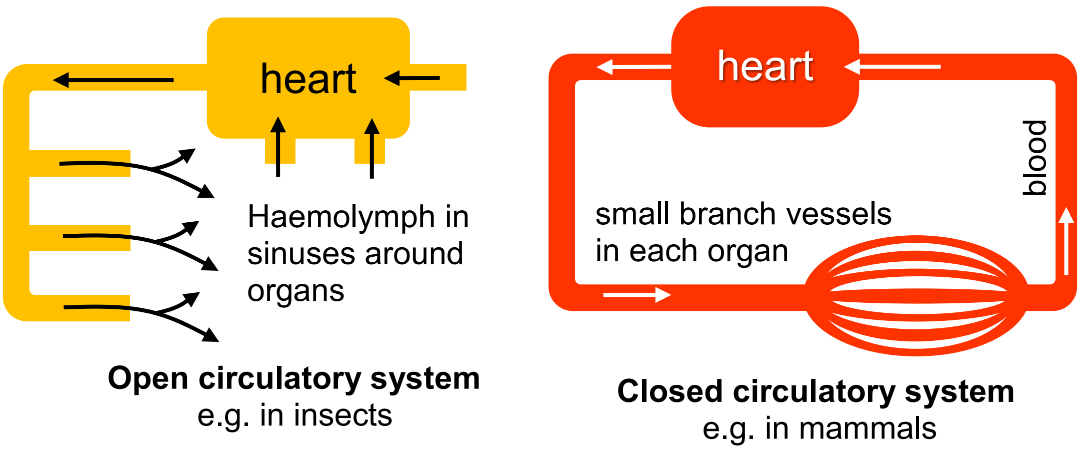


Figure 18: Comparison between an open and a closed circulatory system.

Phyla: Annelida and Arthropoda: https://www.youtube.com/watch?v=YQb7Xq0enTI

Summary of phylum Chordata:
https://www.youtube.com/watch?v=kgZRZmEc9j4&t=4s

Activity 3: Phyla characteristics

Study the diagrams below and answer the questions that follow.

a) 	b) 
c) 	d) 
e) 	f) 

1. Identify in which phyla each organism belongs. (6)
2. Tabulate the characteristics of Cnidaria and Platyhelminthes. (13)
3. Which organism is considered the most advanced? Explain your answer. (2)
4. Which phyla do not have tissue or organs? (1)
5. Describe what a notochord is. (2)

6. Name the phylum that has nematocysts and describe the purpose of these nematocysts. (2)

7. What is the function of the haemocoel in Arthropods? (2)

8. Explain why Arthropods cannot grow larger very large. (2)

(30)

Relationship between body plan and modes of living

An animal's body plan is important to understand its mode (way) of living. Table 1 on the next page provides a comparison of the various phyla body plans and modes of living.

Table 1: Comparison of the characteristics of the six animal phyla. Phyla are the simplest on the left side and more advanced on the right side of the table.

	Phylum					
	simplest ⟶					more advanced
Characteristics	**Porifera**	**Cnidaria**	**Platyhelminthes**	**Annelida**	**Arthropoda**	**Chordata**
Example	sponges	jellyfish, bluebottle, sea anemone	flatworm, planarian, tapeworm	polychaete worm, earthworm, leeches	spider, millipede, crab, insect	shark, fish, frog, snake, bird, mammal
Body symmetry	asymmet-rical	radial	bilateral, dorso-ventrally flattened	bilateral	bilateral	bilateral
Cephalisation	none	none	yes	yes	yes	yes
Gut openings	no gut	one	one	two	two	two
Tissue layers	no true tissue	diploblastic	triploblastic	triploblastic	triploblastic	triploblastic
coelom	acoelomate	acoelomate	acoelomate	coelomate	coelomate	coelomate
Mode of living	aquatic, sessile	aquatic, sessile, free-floating, dimorphic lifecycle	most are internal parasites, some aquatic, free-living	aquatic or terrestrial, moist environments, highly mobile	aquatic or terrestrial, can survive in dry habitats	aquatic or terrestrial, can survive in dry and extreme habitats

Surface area to volume

The surface area to volume ratio refers to the surface area of an organism in relation to its volume.

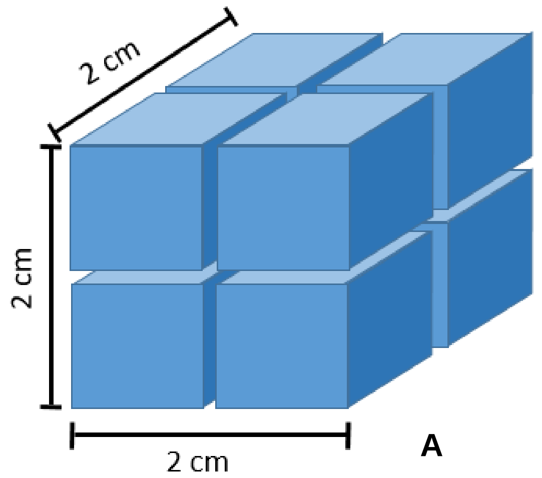
- Larger organisms have less surface area per volume than smaller organisms. This is important to understand when comparing the size of an organism (volume) and their gaseous exchange surfaces (surface area).
- The surface area to volume ratio will also affect the rate of heat gain or loss from the environment.
- Larger animals usually require specialised breathing structures (e.g. lungs) to increase their gaseous exchange surface area.
- Smaller organisms are able to use their body's surface area to bring gases into the body (e.g. Platyhelminthes, Annelida).

Table 2: Equations to calculate surface area and volume of cube or rectangle

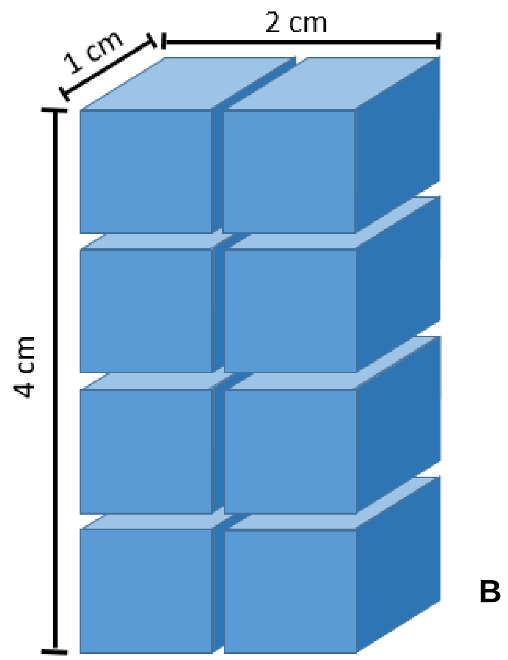
Surface area	Volume
(Length x width) of all surfaces	Length x width x height

Activity 4: Surface to volume

1. Calculate: (a) the surface area, (b) volume and (c) the surface area to volume ratio of the two models representing organisms that are shown below: (12)



A



B

2. By referring to the surface area to volume ratios calculated, explain the advantage that the phylum Platyhelminthes (flat worms) have over the phylum Annelida (segmented worms). (3)

(15)

The role of invertebrates in agriculture and eco-systems

Invertebrates perform numerous functions in the ecosystem that provide us with food, clean water and air, and even clothes. Below are three of the main roles that invertebrates play.

Key terminology

detritus	organic matter produced by the decomposition of dead organisms
humus	organic component of soil, formed by the decomposition of leaves and other plant material by soil microorganisms
aeration	the process of turning or puncturing compacted soil to allow air and water penetration

Pollination

Pollination is the transfer of pollen from the male parts of a flower to the female parts of a flower of the same species by a **pollinator** (Figure 19).

- Pollination results in fertilisation for the production of fruits and seeds.
- Bees are the most important pollinators because they spend their entire life collecting pollen and nectar for their developing young.
- There are many other invertebrates that pollinate flowers (examples include: ants, moths, butterflies).

Figure 19: A bee covered in pollen, feeding from a flower

Decomposition

Decomposition is the process that decays or breaks down organic molecules from dead organisms into simpler organic molecules that are released into the environment and reused in nutrient cycles.

- Invertebrates (worms, beetles etc.) break down complex organic molecules (**detritus**), such as leaf litter, into simpler molecules.
- Microscopic decomposers (i.e. bacteria and fungi) can further break down the organic matter into **humus**.
- Humus is the organic part of soils which greatly improves the quality of soils for plants.

Soil aeration

Invertebrates like earthworms, burrow in the soil and make tunnels through the soil (Figure 20). These tunnels allow gases to move through and aerate the soil. The activities of earthworms are important because:

- Their tunnels accelerate the decomposition of nutrients to be reused for plant growth
- The community structure of the habitat is dependent on soil nutrients and plant growth
- Their tunnels improve drainage of the soil
- The earthworms act as pumps when they move through the tunnels by pushing and pulling air around their tunnels
- Their tunnels loosen the soil and allow plant roots to penetrate deeper into the soil

Figure 20: An earthworm in its underground tunnel

Activity 5: The role of invertebrates

1. Name three ways in which invertebrates play an important role in agriculture and ecosystems. (3)
2. Describe the earthworm's contribution to decomposition and soil aeration and how it contributes to soil fertility. (3)
3. Explain how decomposition contributes to nutrient cycling in the soils. (3)
4. How can decreasing bee populations affect the sustainability of natural ecosystems? (3)

(12)

Biodiversity of animals: End of topic exercises

Section A: Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer. Write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.11 D

1.1.1 A characteristic of the Chordata is that they

A have no coelom.
B have mammary glands.
C are diploblastic.
D have bilateral symmetry.

1.1.2 Name the phylum to which the organism below belongs:

A Cnidaria
B Arthropoda
C Annelida
D Chordata

1.1.3 Triploblastic animals that lack a through-gut and coelom.

A Cnidaria
B Flatworms
C Arthropods
D Annelids

1.1.4 *Dicrocoelium dendriticum* is a flatworm parasite of grazing vertebrates such as sheep and cattle. Which combination correctly shows the phyla to which the parasite and host species belong?

	Dicrocoelium	**Cattle / Sheep**
A	Annelida	Chordata
B	Platyhelminthes	Arthropoda
C	Annelida	Arthropoda
D	Platyhelminthes	Chordata

1.1.5 Which one of the following is NOT a characteristic of Porifera?

A asymmetrical
B lack nerve tissue
C diploblastic
D aquatic

(5 × 2) = (10)

1.2 Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number.

1.2.1 The concentration of sense organs at the anterior end of an animal leading to the formation of a head.
1.2.2 Blood filled cavity found in Arthropoda.
1.2.3 An animal phylum that lacks true tissues and organs.
1.2.4 The germ layer that gives rise to muscles and other internal organs, other than the gut.
1.2.5 Animals that are attached to a substrate.
1.2.6 A rod-like structure in Chordata usually replaced with a vertebral column.
1.2.7 Body cavity filled with fluid and lined with mesoderm.
1.2.8 An organism in which the body wall is made up of two layers of cells.
1.2.9 Organisms that use stinging cells and tentacles to catch their prey.
1.2.10 Arrangement of the body such that cutting through the centre of the structure in any direction produces two identical halves.

(10 × 1) = (10)

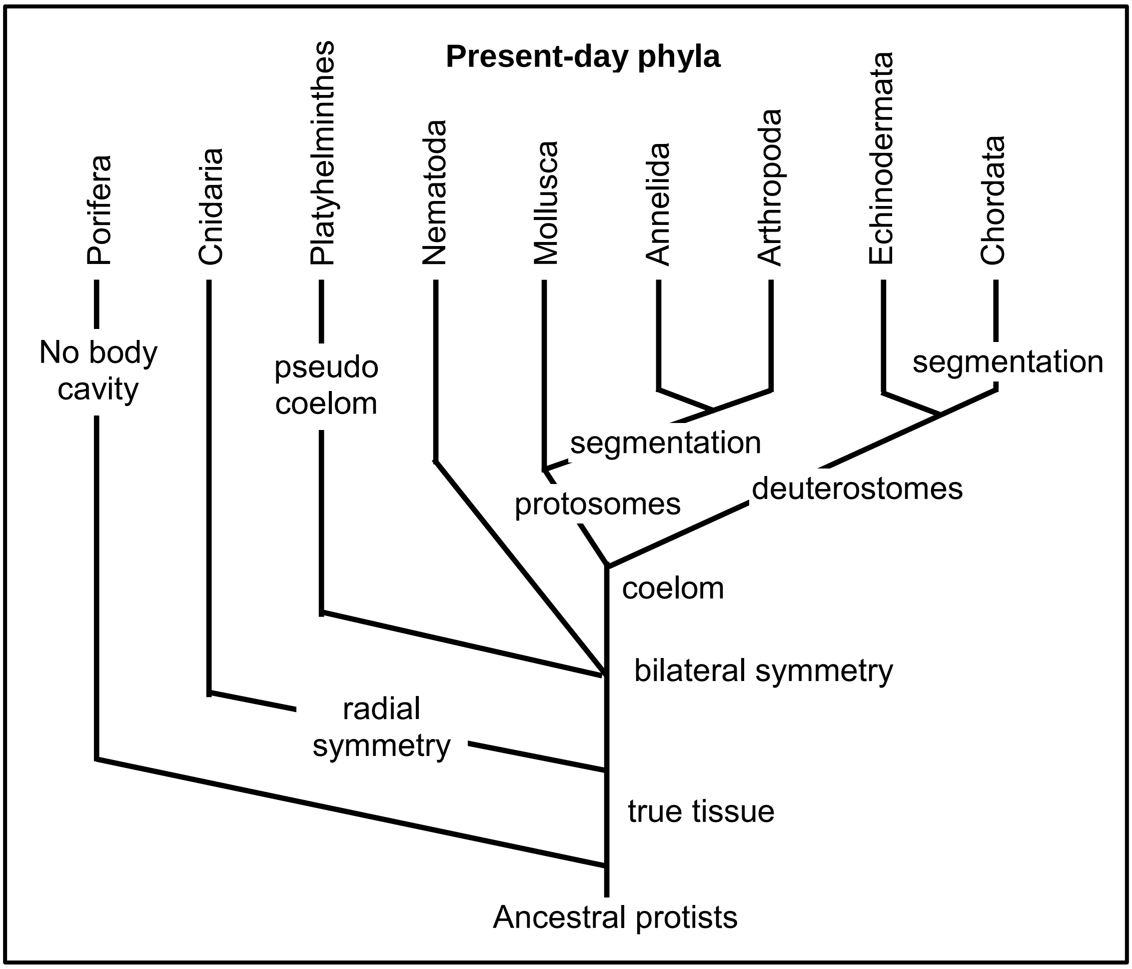
1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **None** next to the question number.

Column I	Column II
1.3.1 The body has jointed appendages and an exoskeleton.	A: Arthropoda B: Chordata
1.3.2 Gel-like, non-cellular layer in Cnidaria	A: mesoderm B: mesoglea
1.3.3 The division of the body into a series of similar units.	A. segmentation B. cephalisation

1.3.4 A fluid-filled body cavity found in some animals.	A: gut B: coelom
1.3.5 Many are parasitic and therefore have a negative impact on agriculture.	A: Platyhelminthes B: Annelida

(5 × 2) = (10)

1.4 The diagram below shows a phylogenetic tree of different animals. Study the diagram and answer the questions that follow.



1.4.1 According to this phylogenetic tree, which group was the ancestor of the animal kingdom? (1)

1.4.2 How many phyla are depicted in the phylogenetic tree? (1)

1.4.3 The first major split in the animal kingdom was into radial- and bilateral symmetry:

a) Which phylum does not form part of the split? (1)

b) Which phylum has radial symmetry? (1)

1.4.4 The second split is animals which have a coelom and animals which lack a body cavity:

a) Which phylum has no body cavity? (1)

b) Which phylum has a pseudo-coelom? (1)

1.4.5 From the phylogenetic tree, identify three phyla which have a true body cavity as well as bilateral symmetry. (3)

1.4.6 Name one of the phyla that underwent segmentation. (1)

(10)

Section A: [40]

Section B

Question 2

2.1 Figures A, B and C represent different phyla of animals.

2.1.1 Identify the phylum represented in figures A, B and C. Write the letter with the correct phylum. (3)

2.1.2 What type of symmetry does figure A have? (1)

2.1.3 Give one benefit of the type of symmetry mentioned in 2.1.2. (1)

2.1.4 Which figure(s) has / have the following characteristics? Write only the letter A, B or C: For example 2.1.4 (e) D

a) triploblastic

b) dorso-ventrally flattened

c) cephalisation

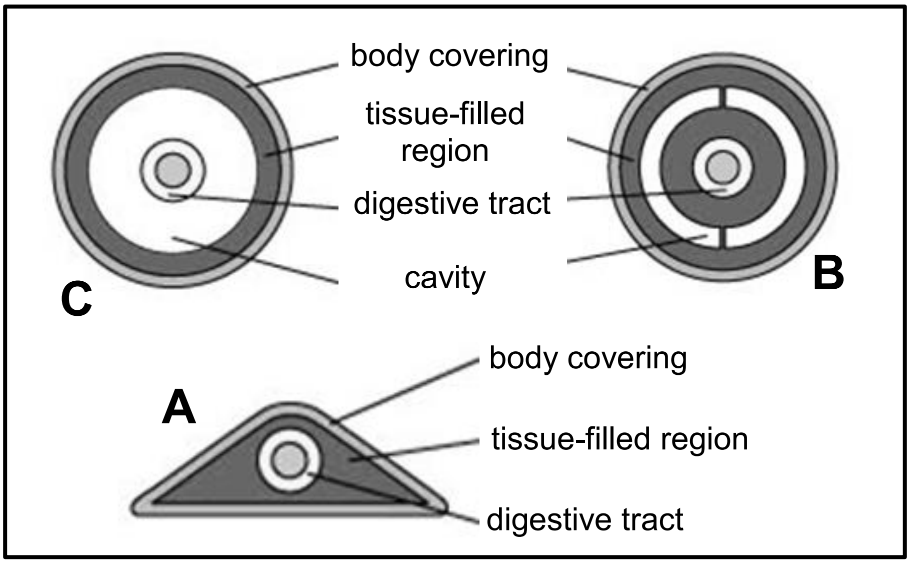
d) coelomate (6)

2.1.5 Give one advantage of having a high surface area to volume ratio for animals. (1)

2.1.6 Draw a diagram of a cross section of a triploblastic body plan labelling each tissue layer. Indicate what each tissue layer gives rise to. (6)

(18)

2.2 Study the diagrams below and answer the questions that follow.



2.2.1 Write only the letter(s) of the diagram(s) that represent the following:

a) pseudo-coelomate

b) acoelomate

c) triploblastic

d) chordate (6)

2.1.7 Name one advantage of a through-gut in annelida. (2)

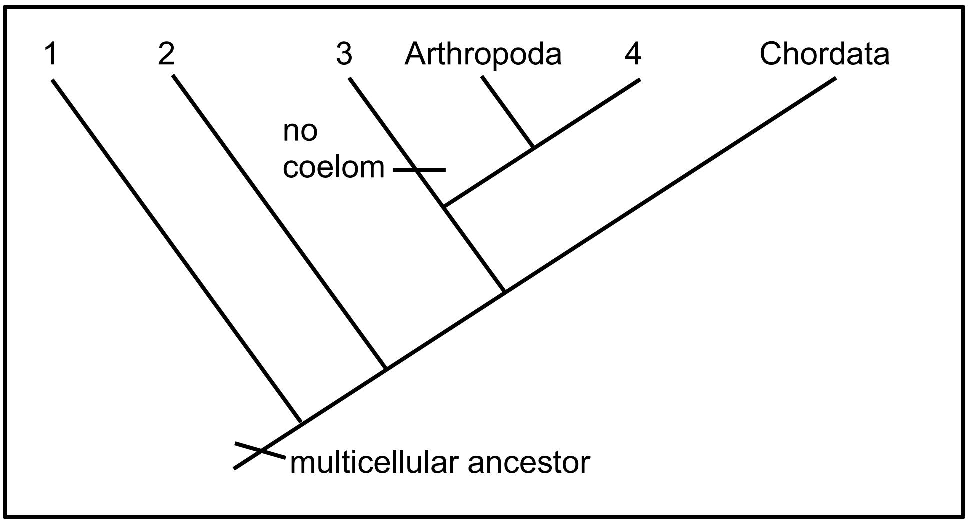
2.1.8 From which embryonic layer does the tissue-filled layer develop? (1)

(9)

[27]

Question 3

3.1 The diagram below is a cladogram of animal phyla.



3.1.1 Name the feature common to all the phyla illustrated in the cladogram. (1)

3.1.2 What is a cladogram? (1)

3.1.3 Name the feature common to animal phyla labelled 3 and 4 as well as arthropoda and chordata. (1)

3.1.4 Provide labels for animal phyla labelled 1, 2 and 3. (3)

(6)

3.2 Invertebrates play an important role in agriculture and ecosystems.

3.2.1 Distinguish between a vertebrate and an invertebrate. (2)

3.2.2 Name one phylum which contains invertebrates. (1)

3.2.3 To which phylum do each of the following organisms belong?

a) Bees

b) Earthworms

c) Butterflies (3)

3.2.4 Invertebrates play a vital role in pollination of plants.

a) Define the term pollination. (2)

b) What class of arthropods is mainly involved in the pollination process? (1)

c) What role does this group play in the pollination process? (2)

d) What effect will the elimination of this class of pollinators have in an ecosystem? (3)

3.2.5 Discuss the role of invertebrates, such as earthworms, in the decomposition process. (3)

(17)

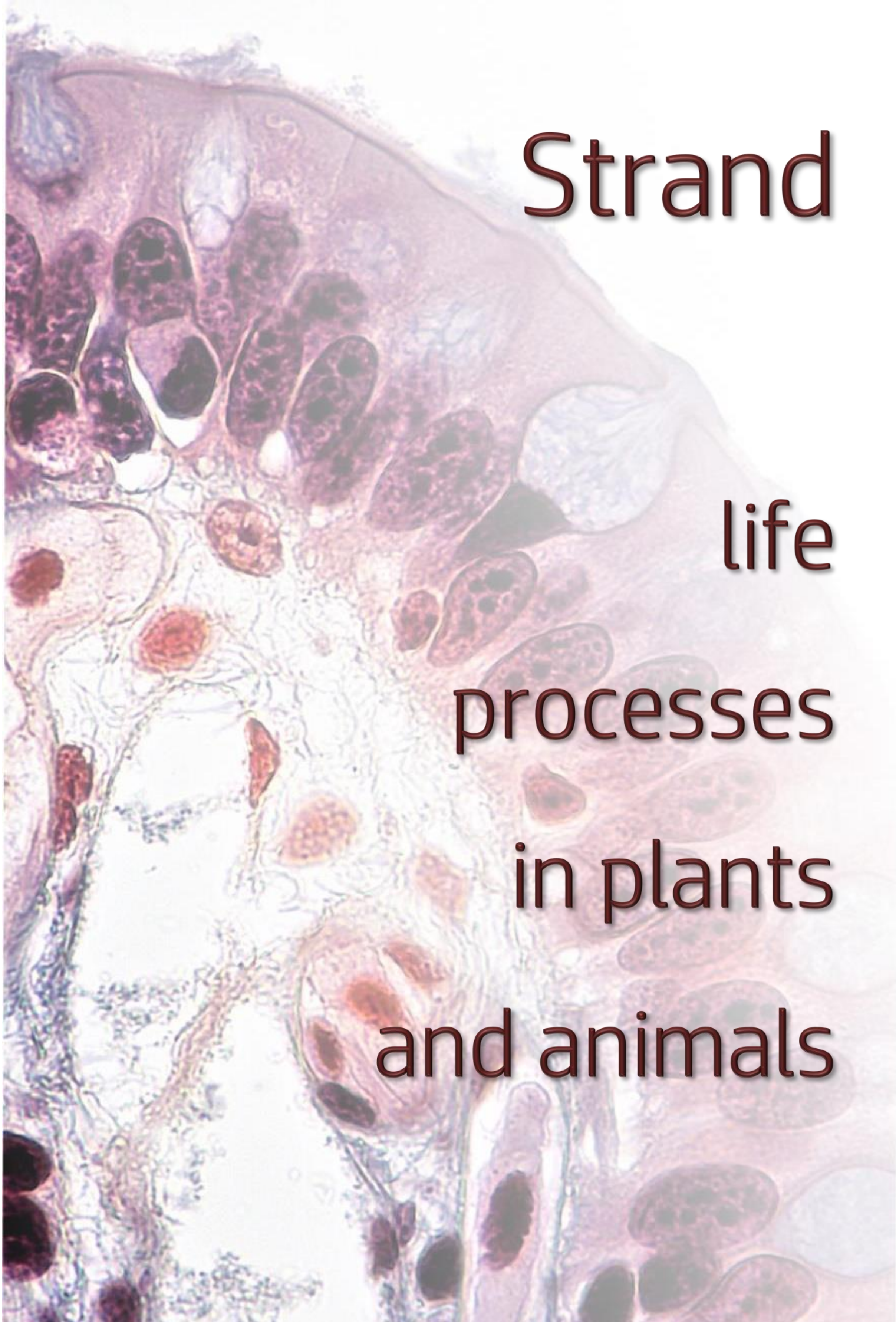
[23]

Section B: [50]

Total marks: [90]

Strand

life processes in plants and animals



4: Photosynthesis

CHAPTER 4: PHOTOSYNTHESIS

Introduction

All living organisms require energy to survive. This energy can either be obtained directly from the sun (plants) or from the food that is eaten (animals). In this chapter, we will look at how plants convert radiant energy into chemical potential energy using the raw materials available to them. The term **photosynthesis** means light is used (photo) to manufacture (synthesis) energy.

Key terminology

metabolism	chemical processes in organisms controlled by enzymes
anabolism	building up chemical reactions
catabolism	breaking down chemical reactions
iodine solution	chemical used to test for starch – a positive test results in the colour changing from brown to blue-black
autotrophic	green plants that produce their own food through photosynthesis
heterotrophic	organisms that cannot photosynthesize and obtain food from other organisms

The definition of photosynthesis

Photosynthesis is a **chemical process** by which **carbohydrates (glucose)** is produced using **radiant energy**.

Key terminology

radiant energy	energy from the sun, needed by plants for photosynthesis
chloroplast	organelle in plants, site for photosynthesis
chlorophyll	green pigment needed for photosynthesis
thylakoids	part of the chloroplast that contains chlorophyll
grana	stacks of thylakoids, light dependent phase of photosynthesis takes place here
stroma	liquid part of the chloroplast, light independent phase of photosynthesis takes place here

Photosynthesis occurs in **green plants** and takes place in the chloroplast of a cell. This can be seen in Figure 1 below:

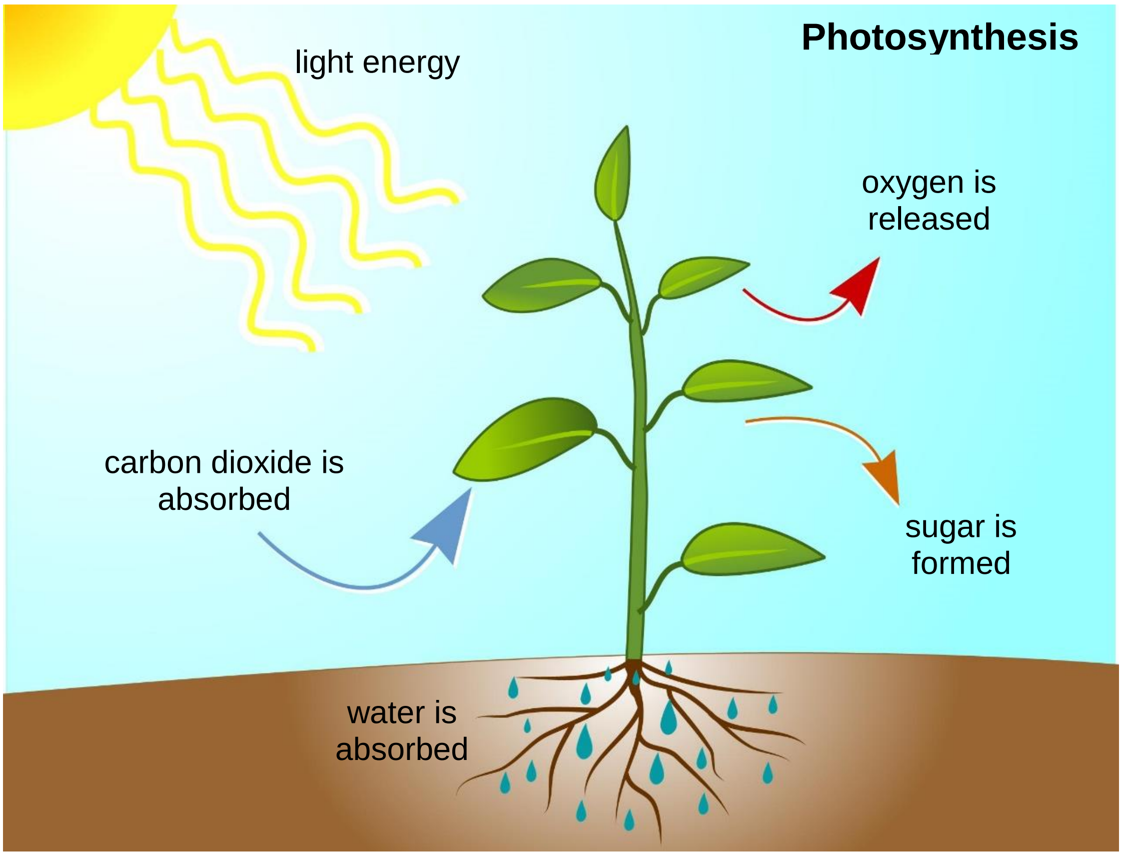


Figure 1: A diagram to show the requirements and products of photosynthesis

Requirements and products of photosynthesis

Plants are adapted to obtain what is required for photosynthesis as well as to release the products. The requirements for and products of photosynthesis can be represented in the equations given below:

Word Equation

$$\text{Carbon dioxide} + \text{Water} + \text{Radiant energy} \xrightarrow[\text{Enzymes}]{\text{Chlorophyll}} \text{Glucose} + \text{Oxygen}$$

Chemical Equation:

$$CO_2 + H_2O + \text{radiant energy} \xrightarrow[\text{Enzymes}]{\text{Chlorophyll}} C_6H_{12}O_6 + O_2$$

The requirements and products for the process of photosynthesis are tabulated below (Table 1).

Table 1: The requirements for and products of photosynthesis

Requirements	Products
Carbon dioxide: Diffuses into the leaves of plants	**Glucose:** Carbohydrate formed. It is converted and stored as starch in plants or glycogen in animals
Water: Inorganic substance absorbed from soil by the roots of plants	**Oxygen:** Gas that is released back into the atmosphere from the leaves
Radiant energy/ light energy: Absorbed from the sun by leaves of plants	
Chlorophyll: Green pigment found inside the **chloroplasts**	
Enzymes: Found inside the chloroplasts	

The structure of a chloroplast

The process of photosynthesis occurs inside of the chloroplast, an organelle found only in plant cells (Figure 2).

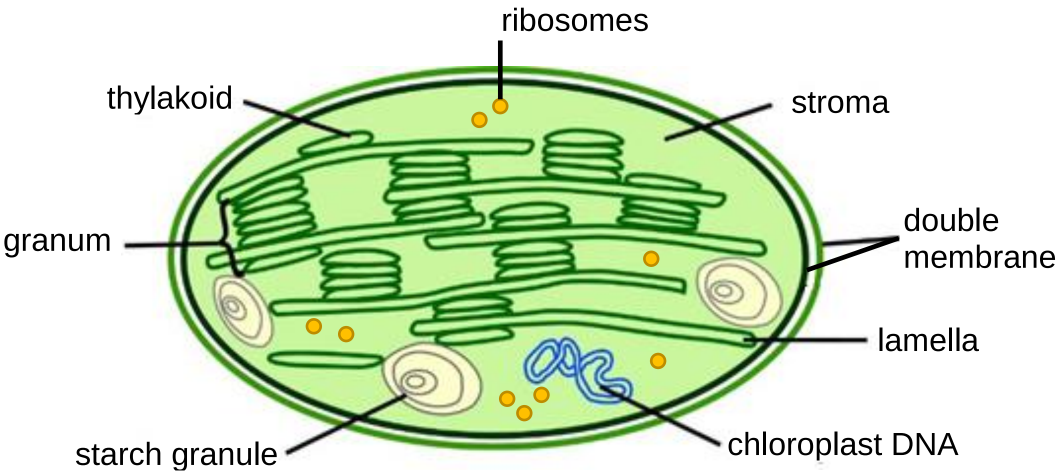


Figure 2: The chloroplast

Table 2: The parts of the chloroplast and their functions.

Part of the chloroplast	Function
thylakoid	disc shaped membranes that that contain chlorophyll
granum	a stack of thylakoids
lamella	membranes that make up the thylakoids
stroma	liquid part of the chloroplast
starch granule	glucose produced is stored as starch in this structure
chloroplast DNA	contains genetic information
double membrane	protects the chloroplast and allows substances to move in and out

The process of photosynthesis

The process of photosynthesis occurs in two phases:

- Light dependent phase: light is required
- Light independent phase: no light is required

Key terminology

photolysis	splitting of water molecules into oxygen atoms and hydrogen atoms. photo = light, lysis = split
phosphorylation	formation of energy transporting molecules called ATP
ATP	adenosine triphosphate, energy carriers in cells
Calvin cycle	cyclical process during light independent phase of photosynthesis
glucose	carbohydrate formed during photosynthesis
starch	stored form of glucose in plants
glycogen	stored form of glucose in animals

Light dependent phase

The light dependent phase of photosynthesis (Figure 3) takes place in the **grana** of chloroplasts as follows:

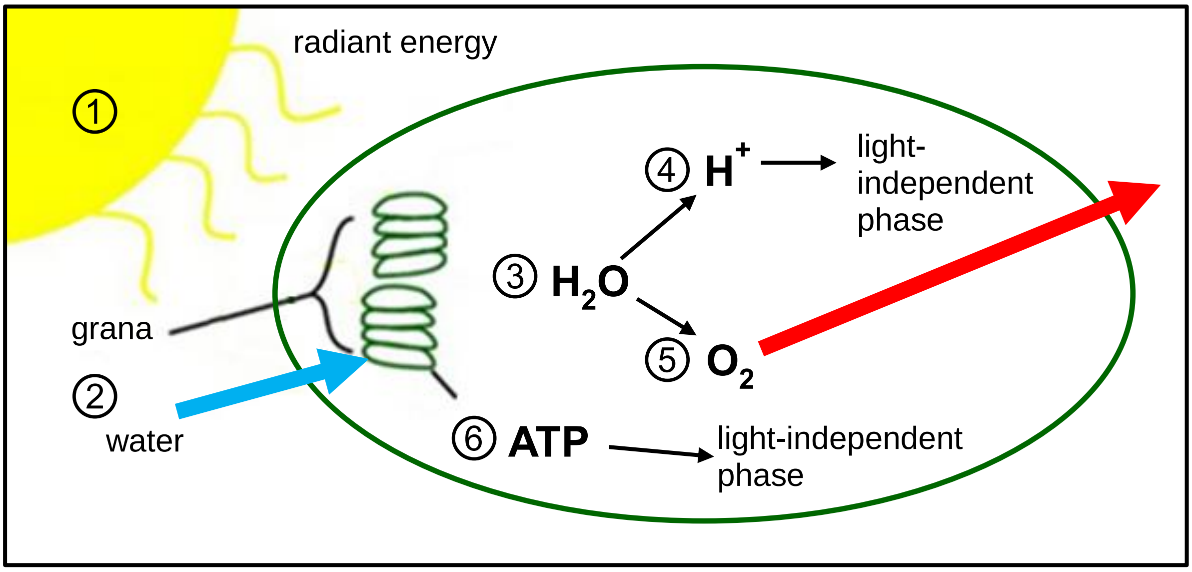


Figure 3: The light dependent phase of photosynthesis

The numbers in the diagram represent the sequence of events:

1. The required radiant energy is absorbed by chlorophyll in the grana.
2. Water is absorbed into the grana of the chloroplast
3. Radiant energy causes the water molecule to split (**photolysis**), releasing:
   4. Energy rich hydrogen (H^+) ions which are taken into the light-independent phase, and
   5. Oxygen which is released back into the atmosphere
6. Radiant energy also causes the energy carrier ATP to be formed (**phosphorylation**) which will be used in the light-independent phase.

Light independent phase

The light independent phase of photosynthesis (Figure 4) takes place in the **stroma** of chloroplasts as follows:

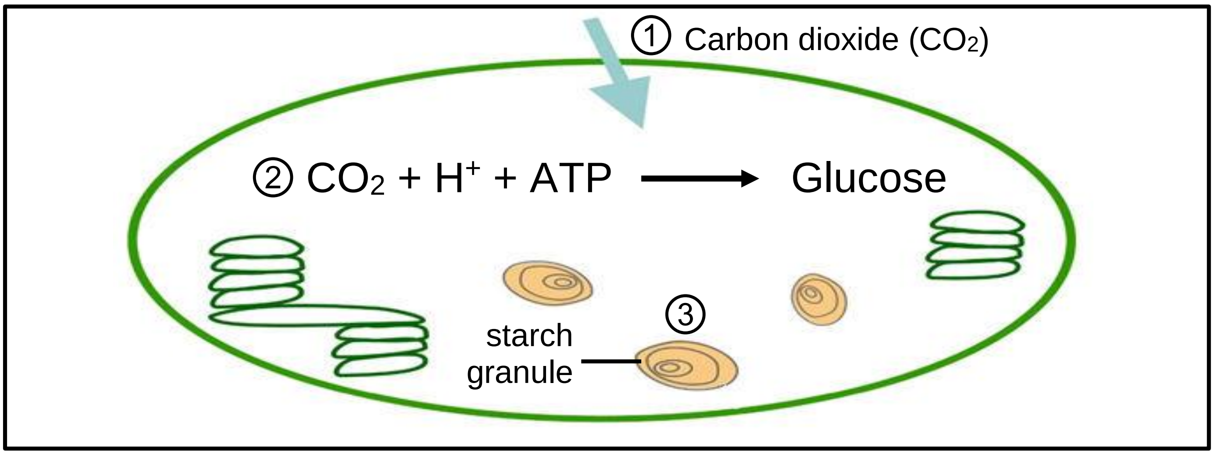


Figure 4: The light independent phase of photosynthesis

The numbers in the diagram represent the sequence of events:

1. Carbon dioxide is absorbed from the atmosphere
2. Carbon dioxide and energy rich Hydrogen (H^+) atoms, from the light dependent phase, are combined by using ATP, from the light dependent phase to from carbohydrates (glucose)
3. Excess glucose is stored as starch in starch granules.

This phase can take place in the presence of light or during the absence of light because light is not required during this phase.

A comparison between the phases of photosynthesis

The following table (Table 3) provides a short overview of the different phases of photosynthesis.

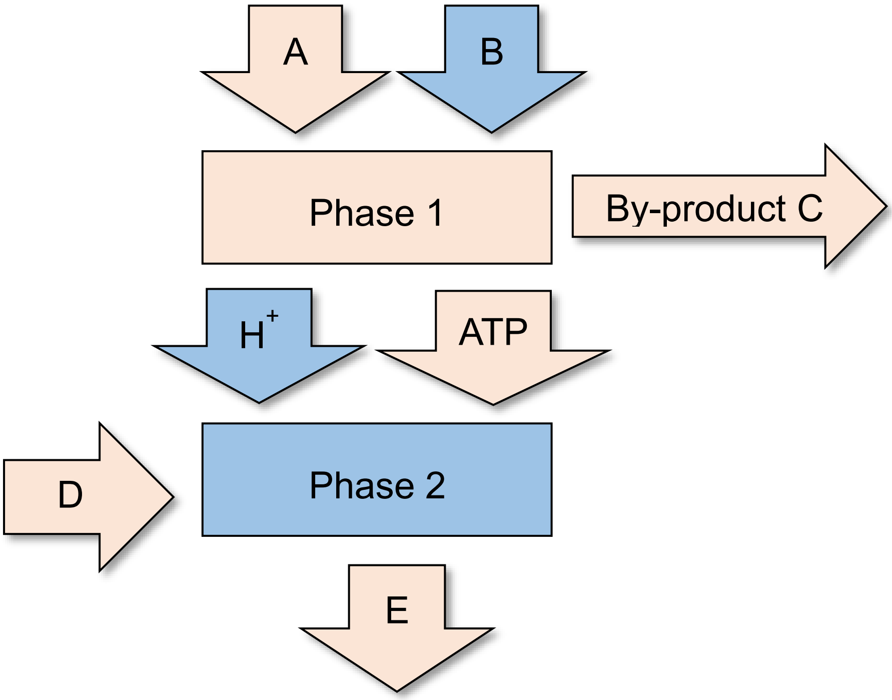
Table 3: Overview of the phases of photosynthesis

Light dependent phase	Light independent phase
Occurs in the grana	Occurs in the stroma
Light is required	Light is not required
Radiant energy is absorbed and used for the reactions of photolysis & phosphorylation	Carbon dioxide is absorbed from the atmosphere
Photolysis occurs: hydrogen is released and oxygen is returned to the atmosphere	Hydrogen and carbon dioxide combine by using atp to form glucose
Phosphorylation occurs: ATP is produced	Excess glucose is stored as starch

Activity 1: Photosynthesis

1. Provide a definition for photosynthesis. (2)
2. Name the organelle in which this process occurs. (1)
3. Name the two phases of photosynthesis and provide the names of the specific structures in the organelle mentioned above, where each phase of photosynthesis takes place. (4)

4. The diagram below represents the process of photosynthesis



a) Identify the phases labelled as Phase 1 and Phase 2 (2)

b) Provide the two raw materials labelled as A and B. (2)

c) Name the by-product labelled as C. (1)

d) Which substance labelled as D is essential for Phase 2? (1)

e) Name the product E that is produced during Phase 2. (1)

f) In what form is E stored in plants? (1)

(15)

The importance of photosynthesis

Photosynthesis is important for the following reasons:

- It balances the levels of carbon dioxide and oxygen in the atmosphere.
- The process uses carbon dioxide and releases oxygen.
- It uses radiant energy to produce chemical potential energy in the form of glucose which serves as food for other organisms.
- Proteins and lipids are made by using the stored starch.

Environmental factors affecting the rate of photosynthesis

Photosynthesis can take place at different rates (speeds). Depending on the concentration of the raw materials, photosynthesis will take place more slowly or more quickly. The factors that affect the rate of photosynthesis (how slowly or quickly it takes place) are:

- The intensity of light
- The concentration of carbon dioxide
- The temperature

The intensity of light

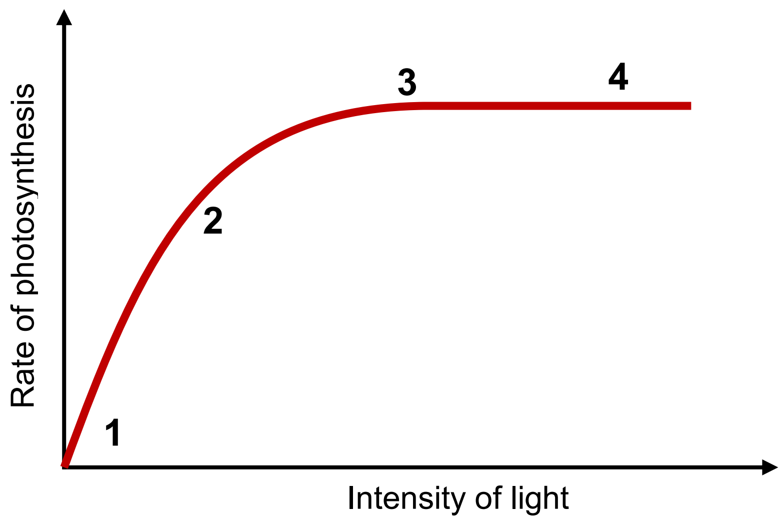


Figure 5: Line graph showing the effect of light intensity on the rate of photosynthesis

Light intensity influences the rate of photosynthesis (Figure 5) as follows:

1. At low light intensity, the rate of photosynthesis is low.
2. As light intensity increases, the rate of photosynthesis also increases. This will happen up to a certain point.
3. When light intensity is at the optimum amount, photosynthesis will occur most rapidly.

4. If light intensity increases past the optimum, the rate of photosynthesis will remain constant. The other factors such as carbon dioxide become limiting factors which reduces the rate of photosynthesis.

The concentration of carbon dioxide

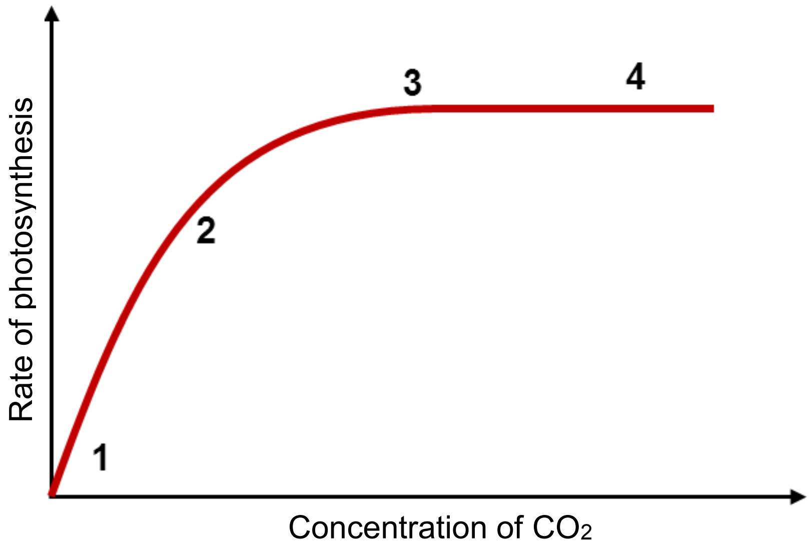


Figure 6: Line graph showing the effect of the concentration of carbon dioxide on the rate of photosynthesis.

The concentration of carbon dioxide (CO_2) influences the rate of photosynthesis (Figure 6) as follows:

1. At a low carbon dioxide concentration, the rate of photosynthesis is low.
2. As the carbon dioxide concentration level increases, the rate of photosynthesis also increases. This will happen up to a certain point.
3. When the optimum amount of carbon dioxide is present, photosynthesis will occur most rapidly.
4. If the carbon dioxide concentration is higher than the optimum amount, then photosynthesis will remain constant. This is because the light independent phase cannot take place more quickly than what it does at the optimum level of carbon dioxide concentration.

Temperature

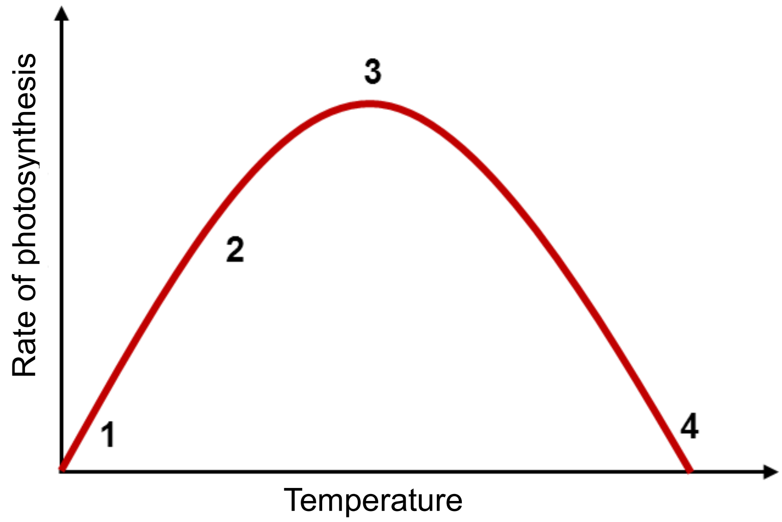


Figure 7: Line graph showing the effect of temperature on the rate of photosynthesis

A rise or fall in temperature influences the rate of photosynthesis that takes place. Temperature influences the rate of photosynthesis (Figure 7) as follows:

1. When temperature is low, the rate of photosynthesis is low.
2. As temperature increases, the rate of photosynthesis also increases.
3. When temperature is at the optimum amount, the rate of photosynthesis will reach a maximum.
4. If the temperature is higher than the optimum amount, then photosynthesis will decrease in rate. This is because the enzymes used in the process will denature at high temperatures and will no longer function.

Greenhouses

A greenhouse (as shown in Figure 8) is a structure with a transparent roof and walls, and is used to grow plants.

Key terminology

greenhouse	a glass or plastic structure that traps heat and allows light to enter, used to grow plants
greenhouse effect	phenomenon where heat from the sun is trapped on Earth by CO_2 in the atmosphere

Figure 8: A greenhouse

Light enters the greenhouse through the roof and heat is trapped inside the structure. Greenhouses can be used to maintain the optimal levels of the factors affecting the rate of photosynthesis. This is done in the following ways:

- Light passes through the transparent structure. Artificial lights can be used to allow the plants to photosynthesis for longer periods of time.
- Carbon dioxide is present in the atmosphere but more can be pumped into the greenhouse or be produced by burning gas lamps.
- The temperature can be kept at the optimum level by using heating and cooling devices.

The greenhouse effect is a natural phenomenon where heat is trapped in the atmosphere of the Earth by carbon dioxide. This is very important to keep Earth at a temperature which allows for life to occur. Without the greenhouse effect, the Earth would be too cold to support life.

Due to carbon dioxide in the atmosphere increasing, the greenhouse effect is becoming enhanced and this is leading to global warming.

Investigations

There are investigations which can be performed to determine if a factor is required for photosynthesis or to determine the rate at which photosynthesis is occurring. In the investigations, one plant (**the experiment**) is given all of the requirements except for the factor being tested. Another plant is given all of the requirements in the same investigation and is referred to as the **control.** In most of the investigations, a test for starch is performed at the end to prove that photosynthesis took place.

Destarching a plant

Before starting the investigations, starch must be removed from the plant. To do this:

- the plant is placed in a dark cupboard for 48 hours
- the plant uses the stored starch during the 48 hour period
- it can be proved that the starch present at the end of the investigation is due to photosynthesis occurring.

The starch test can be used to prove that starch is a product of photosynthesis

Investigation 1: The Starch Test

The Starch Test: https://www.youtube.com/watch?v=0s_xZqvwm_s

During photosynthesis glucose is produced which is converted into starch. To determine whether photosynthesis occurred, a test for starch can be performed.

If starch is present, then it can be concluded that photosynthesis occurred. If starch is not present, then it can be concluded that photosynthesis did not occur.

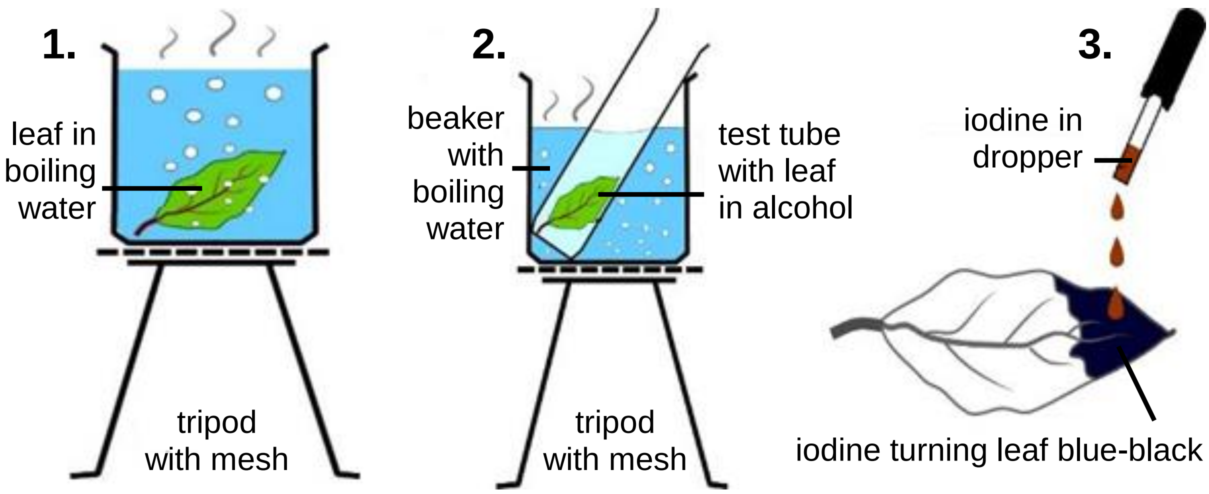


Figure 9: Experimental set-up to show starch is produced during photosynthesis

Method:

1. Place a leaf in a beaker of boiling water (see Figure 9). This softens the leaf and kills the cells to stop metabolism
2. Place the leaf into a test tube containing ethanol (alcohol).

3. Allow the test tube to stand in a beaker of boiling water (water bath) for approximately 10 minutes

   Ethanol cannot be exposed to direct heat because it is highly flammable and has a boiling temperature lower than water, this is why it is placed into the water bath.

   Chlorophyll is soluble in alcohol and will be extracted from the leaf.

   The leaf will turn white in colour and become brittle.

4. Carefully remove the brittle leaf from the alcohol and rinse it in water to soften it.

5. Spread the leaf on a tile and pour a few drops of iodine solution onto it.

Results:

The leaf turns blue black which proves that starch has been produced by photosynthesis.

The following investigations can be used to show the requirements and products of photosynthesis.

Investigation 2: Light is required for photosynthesis

Light is one of the requirements for photosynthesis. An investigation can be performed to show that without light, starch will not be produced and therefore no photosynthesis took place.

Aim: To prove that light is required for photosynthesis

Method:

- Destarch a potted plant by placing it in a dark cupboard for 48 hours
- Cover a portion of the leaf, still attached to the plant, with aluminium foil (Figure 10)

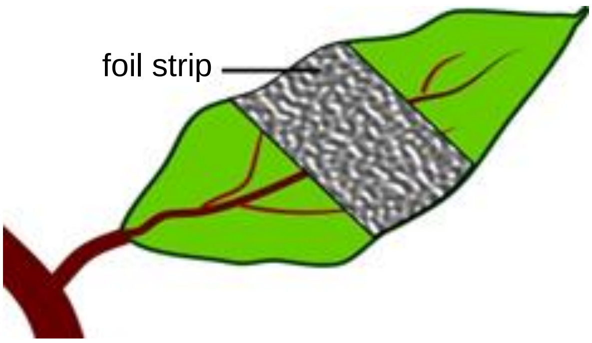


Figure 10: Aluminium foil covering part of a leaf

- Place the plant in a sunny area for 48 hours
- Pick the leaf and remove the foil
- Test for the presence of starch using the starch test.

The experiment is the part of the leaf covered by the foil, as it does not receive light. The part of the leaf left uncovered is the control as it receives all of the requirements for photosynthesis, including light.

Results:

Experiment (leaf covered with tinfoil): the iodine solution remains light brown.

Control (leaf left uncovered): the iodine solution turns blue-black.

Conclusion:

The parts that turn blue-black in colour contain starch. The part which remains light brown does not contain starch.

Light is essential for photosynthesis to take place.

Investigating the effect of light intensity on the rate of photosynthesis: https://www.youtube.com/watch?v=id0aO_OdFwA

Investigation 3: Carbon dioxide is required for photosynthesis

Carbon dioxide is a requirement for photosynthesis. An investigation can be performed to show that without carbon dioxide, starch will not be produced and no photosynthesis will take place. To do this, sodium hydroxide, potassium hydroxide or soda lime can be used to **remove** carbon dioxide. Sodium bicarbonate or potassium bicarbonate can be used to **add** carbon dioxide.

Aim: To prove that carbon dioxide is required for photosynthesis

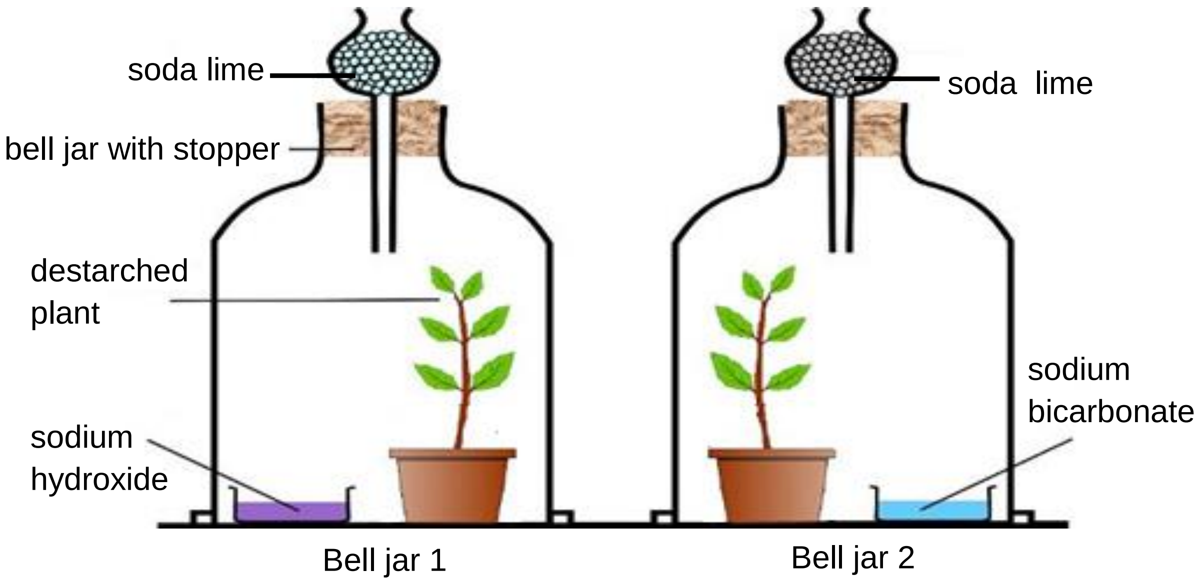


Figure 11: Set-up to investigate effect of CO_2 concentration on photosynthesis

Method:

- Destarch two potted plants by placing them in a dark cupboard for 48 hours
- Set up the apparatus as shown in Figure 11 above and water plants well.
- Sodium hydroxide is used to absorb carbon dioxide from the air in bell jar 1
- Sodium bicarbonate releases carbon dioxide into bell jar
- Place the sealed bell jars into a sunny area for 48 hours
- Pick a leaf from each plant and test for the presence of starch (using the method in investigation 1.

Results:

- Bell jar 1 leaf: iodine solution remains light brown.
- Bell jar 2 leaf: iodine solution turns from light brown to blue-black.

Conclusion:

- Bell jar 1 leaf: No starch is produced. No photosynthesis can take place in the absence of carbon dioxide.
- Bell jar 2 leaf: Starch is produced. Photosynthesis takes place in the presence of carbon dioxide.

Carbon dioxide in photosynthesis: https://www.youtube.com/watch?v=lji6Zx3_E30

Investigation 4: Chlorophyll is required for photosynthesis

Chlorophyll is one of the requirements for photosynthesis. A variegated leaf is used to prove that without chlorophyll, starch will not be produced and therefore no photosynthesis took place. A variegated leaf contains green parts (with chlorophyll) and white parts (without chlorophyll) (see Figure 12). This leaf does not require destarching as the experiment and control are on the same leaf.

Aim: To prove that chlorophyll is required for photosynthesis

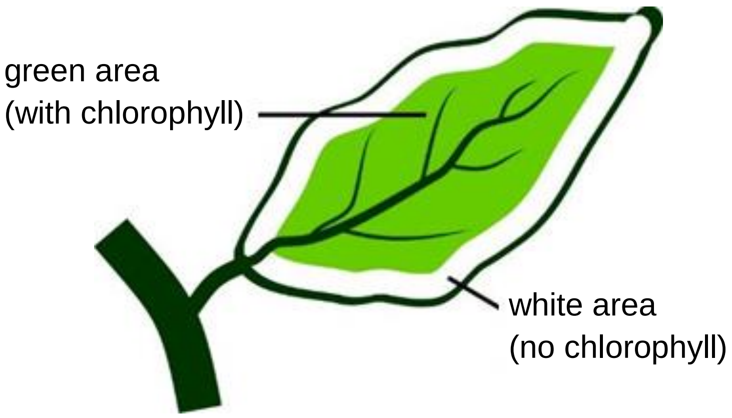


Figure 12: Chlorophyll is required for photosynthesis

Method:

- Place a potted plant with variegated leaves (white and green parts) in a sunny place for a few hours
- Remove a leaf from the potted plant
- Test for the presence of starch (using the method in investigation 1)

Results:

- Experiment (White part): iodine solution remains light brown.
- Control (Green part): iodine solution turns from light brown to blue-black.

Conclusion:

- Experiment (White part): Contains no starch. No photosynthesis can occur without chlorophyll.
- Control (Green part): Contains starch. Photosynthesis takes place using chlorophyll.
- Chlorophyll is essential for photosynthesis.

Investigation 5: Photosynthesis produces oxygen

Oxygen is produced during photosynthesis. A glowing splint test is used to show that oxygen is produced during photosynthesis. A test uses a small wooden stick that has been lit. The splint glows more brightly or re-ignites in the presence of oxygen.

Aim: To prove that oxygen is produced during photosynthesis

Method:

- Set up the apparatus as shown the diagram in Figure 13 below

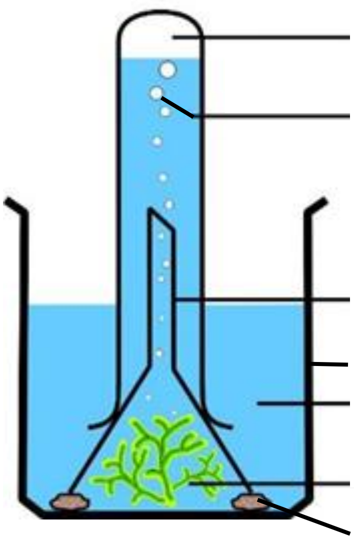


Figure 13: Experimental set-up to show that oxygen is produced in photosynthesis

- Place the apparatus in a sunny area for a few hours
- A small amount of sodium bicarbonate can be dissolved in the water. Sodium bicarbonate will add carbon dioxide to the water
- After a while gas bubbles will start to form. These gas bubbles will collect in the test tube.
- Once enough gas has been trapped in the test tube, remove the test tube from the funnel but keep the opening of the test tube submerged under the water
- Seal the test tube using a rubber stopper while under the water
- Once it has been sealed, remove the test tube from the water
- Insert a glowing wooden splint into the test tube

Results:

The glowing splint re-ignites or burns more brightly.

Oxygen is present in the test tube.

Conclusion:

Oxygen is produced during photosynthesis.

Activity 2: Investigating photosynthesis

A learner has conducted an experiment in the classroom by following various steps. Study the procedure and diagram below to answer the questions that follow.

a) A variegated plant was left in the dark for 3 to 4 days
b) A starch test was conducted by removing one of the leaves
c) The plant was then left in the light for four hours
d) A leaf was removed and a drawing of it was made to show the distribution of green and white areas (Diagram 1)

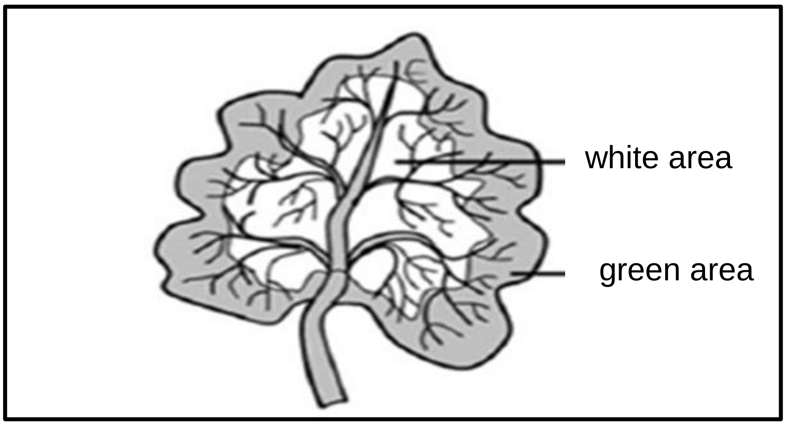


Diagram 1: leaf before second starch test

e) The leaf was then tested for the presence of starch
f) After the addition of a few drops of diluted iodine solution, a second drawing of the leaf was made to show the distribution of blue- black and brown areas of the leaf (Diagram 2 – not shown here)

Questions

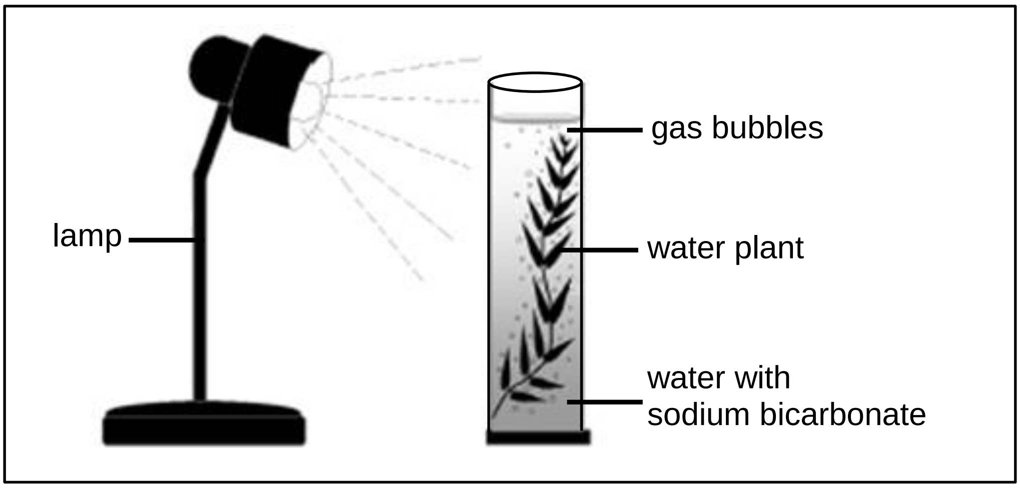
1. State the aim of this experiment. (1)
2. Why was the plant left in the dark for 3 to 4 days? (1)
3. Why should the plant have been tested for the presence of starch after step (a), before exposing the plant to light? (2)

4. Draw and label Diagram 2 that shows the result of the second starch test as mentioned in step (f). (Diagram 1 should be used as a template) (5)
5. Is it necessary to set up a control for this investigation? (1)
6. Supply a reason for your answer to question 5. (2)
7. What conclusion can be drawn from this experiment? (2)

(14)

Activity 3: Investigating gas bubbles released

The diagram below illustrates an investigation in progress. The distance between the light source and the apparatus have been altered at regular intervals to record the number of bubbles released at various distances. The data gathered has been represented in a table below. Study the diagram and the data table below to answer the following questions.



1. What is the function of sodium bicarbonate? (1)
2. Name the gas released during the experiment. (1)
3. Provide a suitable hypothesis for the above experiment. (2)
4. Explain a simple test that can be done to confirm the presence of the gas mentioned in question 3. (2)
5. Name any two environmental factors, besides light intensity, that could affect the chemical process shown in the diagram above. (2)
6. The table below contains the following data: The number of air bubbles counted when the distance between the lamp and apparatus is altered at regular time intervals.

Distance between lamp and plant (mm)	40	80	120	160	200	240	280	320	360	400	440
Number of bubbles per minute	30	30	30	25	15	10	5	3	2	0	0

Plot a line graph to represent the data obtained during the experiment. (6)

7. Identify:

(a) the dependent and

(b) independent variables in the experiment. (2)

8. What conclusion can be derived from the graph? (2)

(18)

Photosynthesis: End of topic exercises

Section A

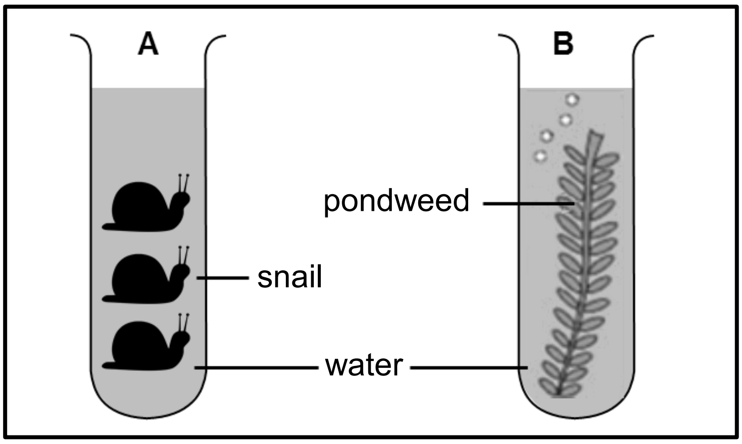
Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Plants use oxygen…

A continuously.
B during the day only.
C during the night only.
D during photosynthesis only

1.1.2 Test tubes A and B below were placed in bright light.



Which of the following is correct regarding the test tubes?

A The amount of CO_2 in test tube A will decrease.
B The amount of CO_2 in test tube B will increase.
C The amount of O_2 in test tube B will increase.
D The amount of O_2 in test tube A will increase.

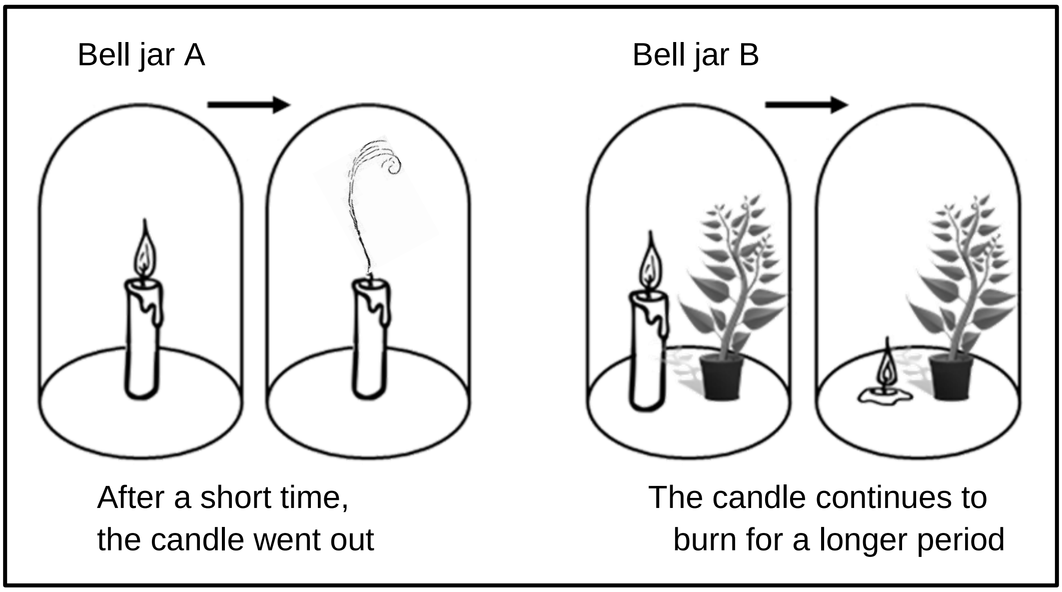
1.1.3 What are the products of the light reactions of photosynthesis that are used in the light independent phase?

A CO_2 and glucose
B H_2O and O_2
C ATP
D ADP

1.1.4 Which factor does not affect the rate of photosynthesis?

A Oxygen concentration
B Light intensity
C Temperature
D Carbon dioxide concentration

1.1.5 An experiment was set up to investigate whether oxygen is released during photosynthesis. The result of the experiment is represented in the following diagram.



The following deductions were made before arriving at the conclusion.

(i) Photosynthesis reduces the amount of CO_2 inside bell jar B
(ii) The oxygen in bell jar A was completely used up and combustion is not supported
(iii) Photosynthesis increases the amount of oxygen inside bell jar B
(iv) The smoke produced inside bell jar A is due to the extinguished burning candle.

Which one of the following sets of deductions is correct?

A (i) and (iv) only
B (i), (ii) and (iii) only
C (i), (iii) and (iv) only
D (iii) and (iv) only

(5 × 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The green, light-trapping pigment in photosynthesis found in plant leaves.

1.2.2 The splitting of water molecules into hydrogen and oxygen in the presence of light.

1.2.3 Site of reactions of the light independent phase in the chloroplast.

1.2.4 The process in plants in which radiant energy is converted into chemical energy.

1.2.5 Expected colour change of diluted iodine solution when the presence of starch in a leaf is confirmed.

1.2.6 The general energy carrier in the cells of living organisms.

1.2.7 The form of carbohydrate in which energy is stored in most plants.

1.2.8 The organelle that absorbs radiant energy during photosynthesis.

1.2.9 The reagent used to test for the presence of starch.

1.2.10 The organic molecules that act as catalysts and control the chemical reactions during photosynthesis.

(10 × 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

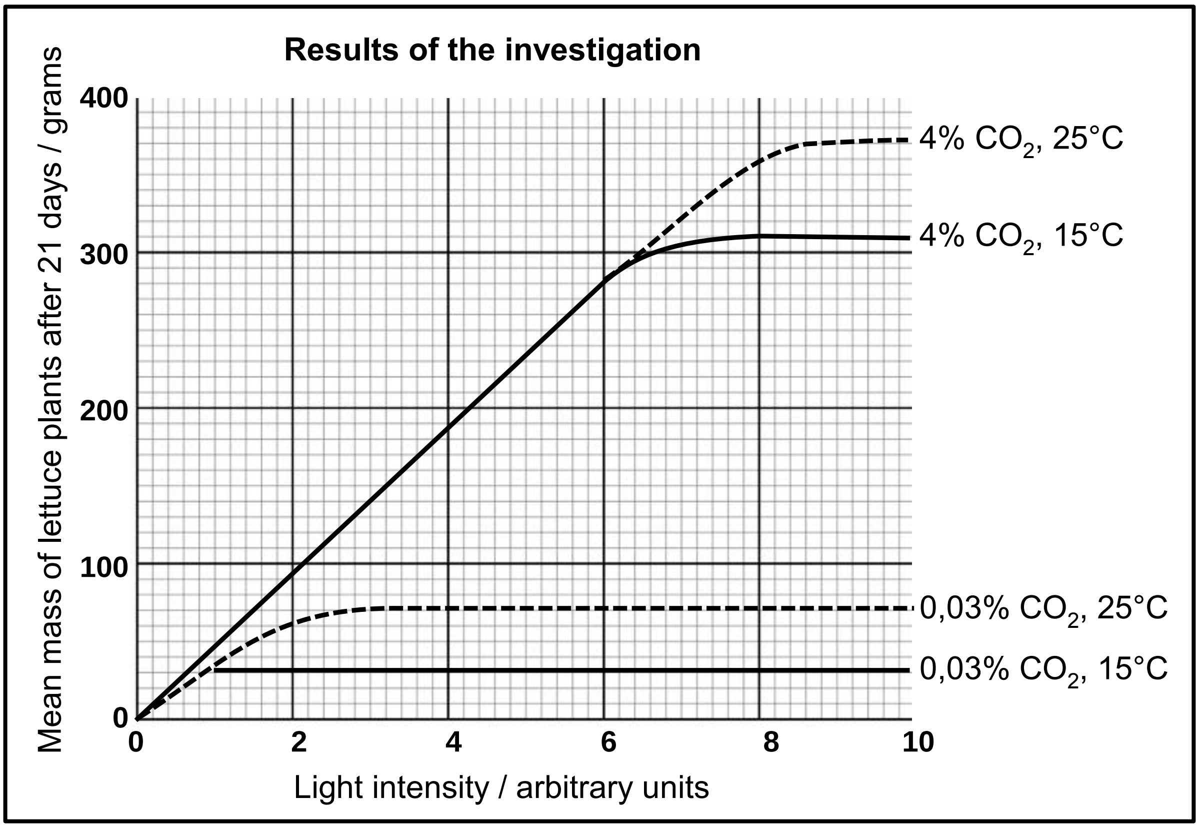
Column I	Column II
1.3.1 Molecule that stores energy	A: ATP B: ADP
1.3.2 The organelle in which photosynthesis takes place	A: mitochondria B: chloroplast
1.3.3 Storage of chlorophyll	A: grana B: lamella
1.3.4 Light dependent phase of photosynthesis	A: matrix B: stroma
1.3.5 Gas given off by green plants during photosynthesis	A: O_2 B: CO_2

(5 × 2) = (10)

1.4 Scientists set up an apparatus to investigate the effect of temperature, light intensity and carbon dioxide concentrations on plant growth. Using this apparatus, they could control each factor.

- The scientists set different temperatures, CO_2 concentrations and light intensity for four different groups of lettuce plants.
- The average mass of lettuce plants serves as an indication of the rate of photosynthesis.

Study the results below and answer the questions that follow.



1.4.1 What is the influence of light intensity on average mass of lettuce plants? (3)

1.4.2 Name two limiting factors that influence the rate of photosynthesis as the light intensity increases? (2)

1.4.3 How were the scientists able to increase the rate of photosynthesis to the maximum level? (3)

1.4.4 What would happen to the rate of photosynthesis if the temperature is raised beyond 35°C? Give a reason for your answer. (2)

(10)

Section A: [40]

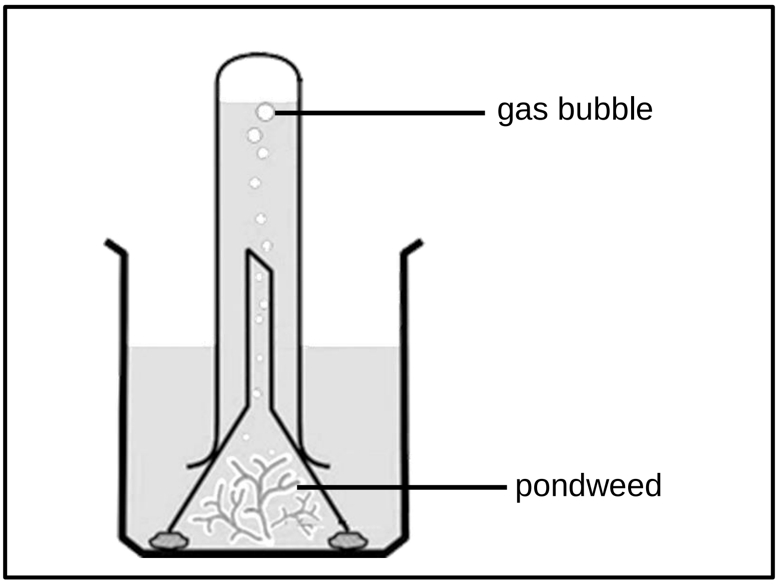
Section B

Question 2

2.1 When light shines on pondweed, *Elodea Sp*, bubbles of gas are released. The rate at which bubbles of gas are produced can be used to measure the rate of photosynthesis.

An investigation was carried out to study the effect of different colours of light on the rate of photosynthesis in the pondweed.

- The pondweed was exposed to one colour of light and left for 5 minutes before measurements were taken.
- The time taken for the release of 20 bubbles was recorded.
- The procedure was repeated using light of a different colour of equal intensity.
- The apparatus was set up as shown in the diagram below.



The results are shown in the table below:

Colour of light	Time taken to release 20 bubbles (seconds)
Violet	80
Blue	40
Green	160
Yellow	140
Red	70

2.1.1 Which colour light is the best for photosynthesis? (1)

2.1.2 State the:

a) independent variable (1)

b) dependent variable (1)

2.1.3 Calculate the average time taken for the release of 20 bubbles for all colours. Show all working. (3)

2.1.4 Express bubble production under violet, blue and green light as a ratio. (2)

2.1.5 Explain why the apparatus is left for 5 minutes under each colour of light before taking measurements. (2)

2.1.6 Without modifying the apparatus, how could the reliability of the results be increased? (2)

2.1.7 Using the results, explain how, when white light shines on the plant, the leaves appear to be green. (2)

2.1.8 Draw a bar graph of the results shown in the table. (6)

(20)

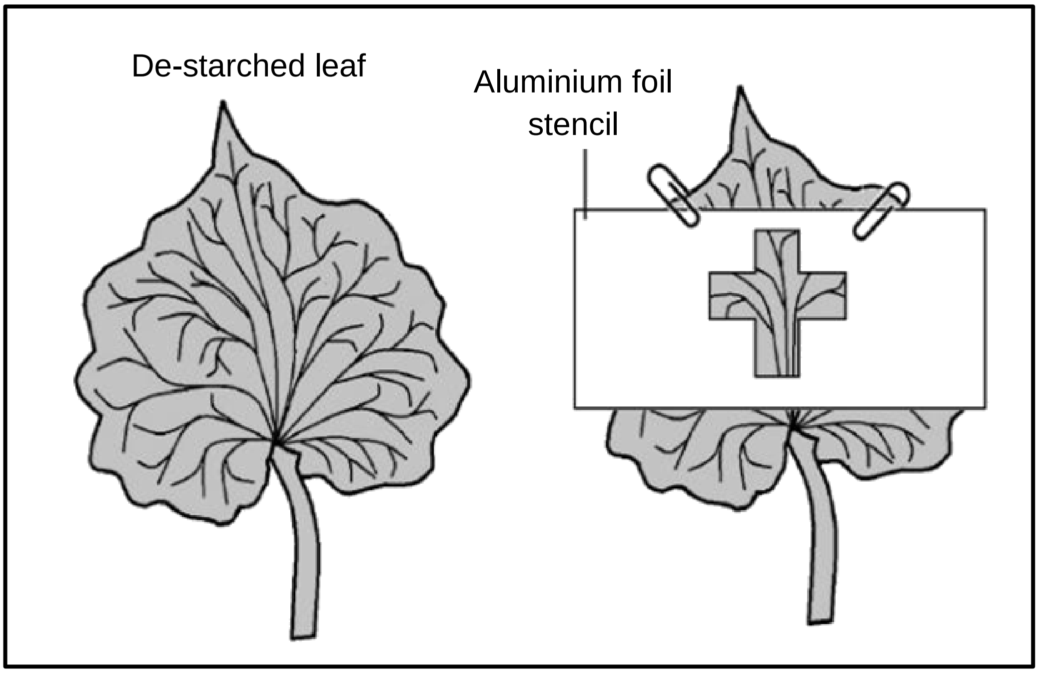
2.2 Draw a labelled diagram of an organelle present in the leaves of plants where photosynthesis takes place. (5)

[25]

Question 3

An experiment was conducted to determine whether light is necessary for photosynthesis. The procedure followed is given below:

- A geranium potted plant was de-starched.
- A cross-shaped light slit was cut out on an aluminium foil.
- The aluminium foil stencil was then clipped onto one of the de-starched leaves as shown in the diagram below.
- The potted plant was exposed to bright sunlight for 4 to 5 hours.
- After 5 hours the aluminium foil stencil was removed, and the leaf was tested for starch.



3.1 Describe in the correct sequence the various steps that were followed during a starch test. (6)

3.2 Mention one safety precaution that should be taken during this experiment. (2)

3.3 Draw a labelled diagram of the leaf showing the result of the investigation. (5)

3.4 Provide a conclusion for this experiment. (2)

[15]

Section B: [40]

Total marks: [80]

5: Animal nutrition

CHAPTER 5: ANIMAL NUTRITION

Introduction

All animals need to eat food to give them nutrients that they will use every day. An animal's digestive system is designed to break down and absorb these nutrients. These nutrients are used in the body to provide energy, repair damaged tissue and to regulate bodily processes.

Overview of Animal Nutrition: https://www.youtube.com/watch?v=RArb-2RxZ7c

Key terminology

herbivore	animal that eats only plants or parts of plants
carnivore	animal that eats only other animals or the remains of other animals
omnivore	animal that eats plants, animals or dead animal flesh

Types of teeth

There are **four** main types of teeth found in animals namely incisors, canines, premolars and molars. (Table 1; Figure 1).

Table 1: Different types of teeth found in animals (including humans)

Types of teeth	Structure and function
incisors	• chisel-shaped • used for biting or cutting of food
canines	• pointed • used for catching, holding, tearing and/or killing prey
premolars	• flat and uneven • used for grinding and crushing food
molars	• flat and uneven • used for grinding and crushing food
carnassial teeth	• specialised molars and pre-molars with jagged, triangular edges • used for cutting meat

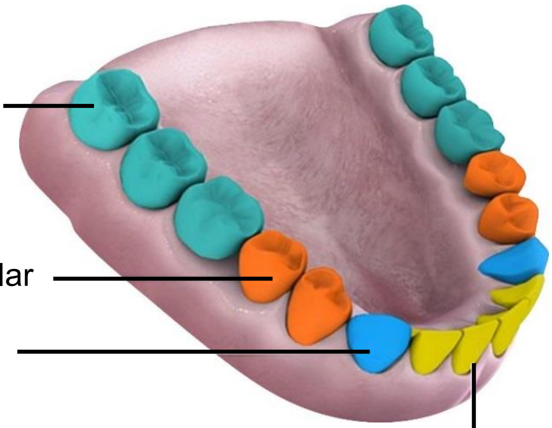


Figure 1: The different types of teeth found in a human

Human dental formula (not for exam purposes)

Teeth are a vital component of physical digestion. The arrangement of teeth in a human is represented as a dental formula (see below). The part above the line represents the number and type of teeth in the upper jaw, while the numbers below the line represent the number and type of teeth in the lower jaw. These numbers represent only the teeth that are found in one half of the jaw. Humans are bilaterally symmetrical which means that we have an identical left and right side.

Human dental formula: $\frac{2.1.2.3}{2.1.2.3}$

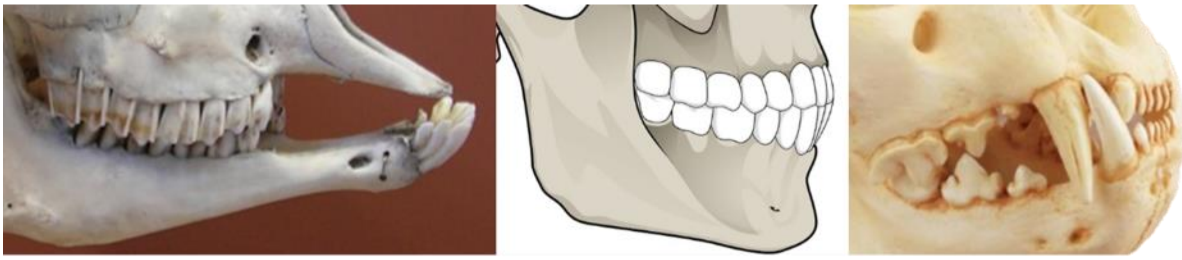
The dental formula above shows that humans have 2 incisors, 1 canine, 2 premolars, and 3 molars in one half of the upper jaw and the exact same in the lower jaw (Figure 1). Therefore, humans have a total of 32 teeth.

The shape and type of teeth that an animal has, gives a good indication of the type of food that the animal consumes (Table 2; Figure 2).

Table 2: A comparison of the teeth for different types of nutrition

Type of nutrition	Types of teeth
herbivores	• use incisors to cut the plant material • usually lack canines • use molars and premolars to grind food

carnivores	• use incisors to slice or shred meat • large, well-developed canines used for catching, holding and tearing meat • molars and premolars are modified to form carnassial teeth (see Figure 2 below)
omnivores	• have teeth that are modified for eating both plant material and meat similar to those in humans



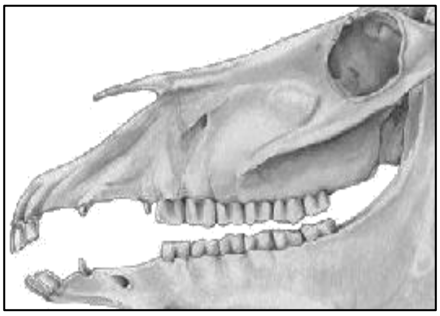
Herbivore (sheep) Omnivore (human) Carnivore (leopard)

Figure 2: Typical dentition of herbivores, omnivores, and carnivores

Activity 1: Dentition

Study skull A and skull B below and answer the questions that follow.

Skull **A**



Skull **B**

1. Identify which skull (A or B) belongs to a …

    a) herbivore

    b) carnivore (2)

2. Provide reasons for your answers to the above questions 1.a) and b). (2)
3. Does skull B have carnassial teeth? Explain your answer. (2)

(6)

Human nutrition

Key terminology

bolus	a ball-like mixture of food and saliva that forms in the mouth during the process of chewing
bile	is a fluid produced by the liver, and stored in the gall bladder, that aids the digestion of lipids in the small intestine
exocrine gland	a gland that uses ducts to drain and transport secretions or chemicals out of the body or onto body surfaces
endocrine gland	an organ that secretes hormones directly into the blood stream or lymphatic system instead of through ducts
peristalsis	an automatic wave of muscle contraction and relaxation that moves food in one direction through the digestive tract
chyme	a semi-liquid mass of partially digested food which has gone through mechanical and chemical digestive processes while passing through the stomach into the duodenum
villus (pl. villi)	tiny finger-like projections lining the wall of the small intestine and increasing the surface area for food absorption
ingestion	intake of food
digestion	physical and chemical breakdown of food into its simplest form
absorption	the products of digestion diffuse into the blood stream
assimilation	nutrients such as amino acids are incorporated into the cells
egestion/defecation	the removal of undigested and unabsorbed waste from the body through the anus in the form of faeces

The digestive system

The digestive system is responsible for breaking down complex molecules into their simplest forms to be absorbed into the body to sustain life. The human digestive system is made up of an alimentary canal (tube from mouth to anus) and accessory organs (e.g. liver, pancreas) that aid in the digestive process (Figure 3).

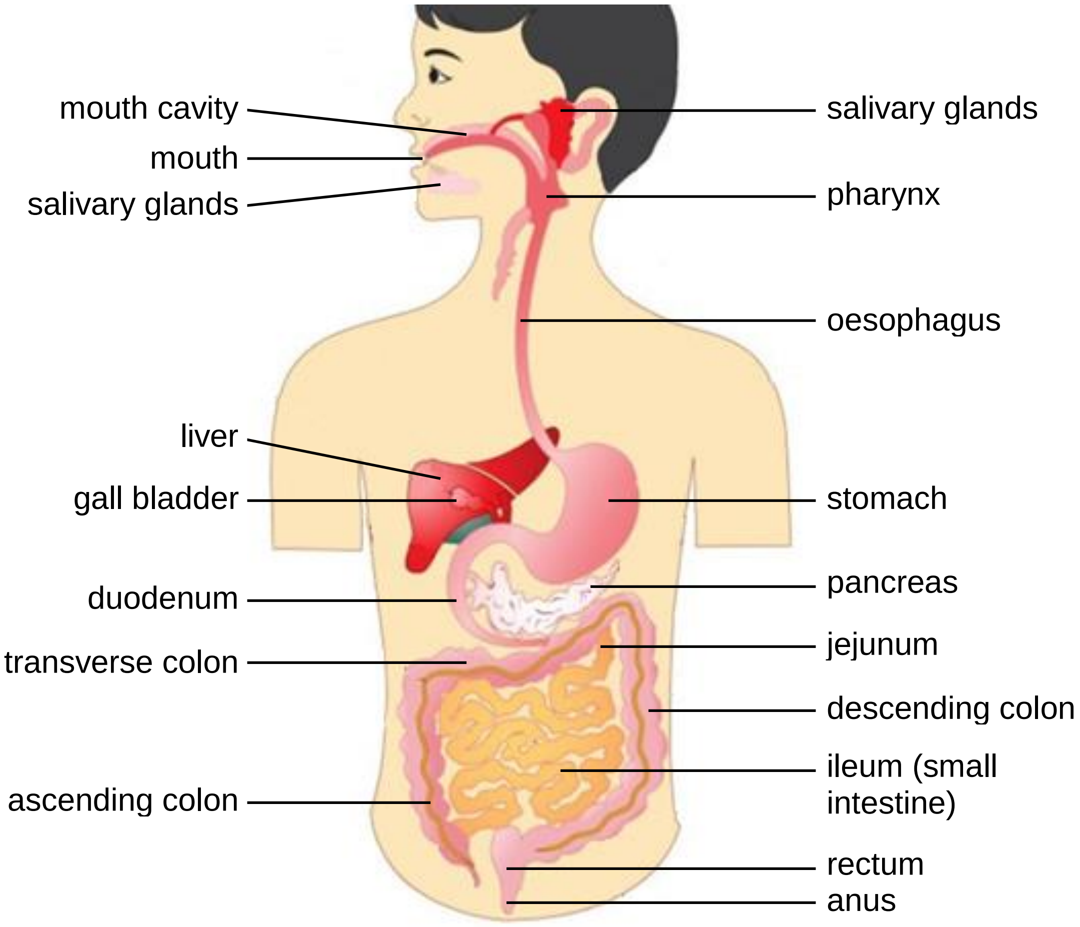


Figure 3: The human digestive system

There are five steps in the digestive process as shown in Figure 4 below.

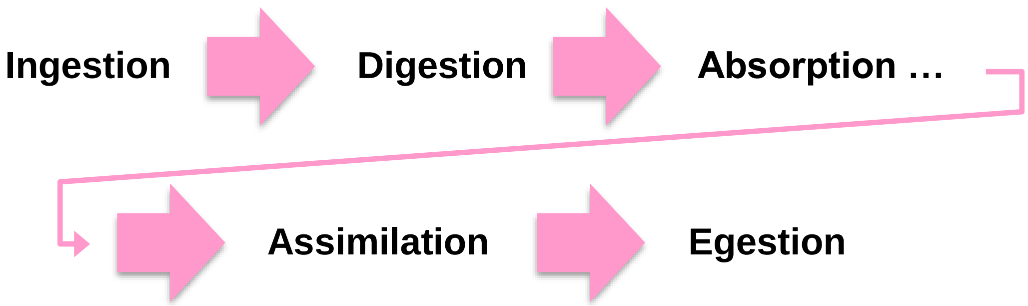


Figure 4: Flow diagram of the main steps in digestion

Digestive process: https://www.youtube.com/watch?v=Og5xAdC8EUI

Table 3 below provides a description of the digestive organs and regions of the human digestive system.

Table 3: The functions of different parts of the human digestive system

Structure	Function
mouth cavity	The mouth cavity consists of many parts: • Teeth which break down and grind food • **Tongue** which mixes food and is used for swallowing of food • Hard and soft palate which forms the roof of the mouth • **Salivary glands** release saliva which contains enzymes (called carbohydrases) to chemically break down carbohydrates
pharynx & oesophagus	• After food is swallowed (now called the **bolus**), it moves into the pharynx which is the tube used to take in food and air • The food moves down to the larynx where the epiglottis (a cartilage flap) stops food from going into the trachea • Food goes down the oesophagus • The oesophagus pushes food down to the stomach by **peristalsis**
stomach	• The stomach is a muscular sac with thick walls • It churns the food and mixes it with gastric juice (hydrochloric acid – HCl) and enzymes (this mixture is called **chyme**) • The stomach has two **sphincters** (a ring of muscles to close a tube) to keep both openings to the stomach closed while food is being digested

liver & gall bladder	• Liver cells produce **bile** which is stored in the gall bladder until being released into the duodenum of the small intestine
	• Bile has a number of functions in digestion:
	    ○ Bile emulsifies large fat globules into small fat droplets which aids digestion
	    ○ It neutralises the acidic fluid (chyme) which comes from the stomach
	    ○ It promotes peristalsis in the small intestine
	    ○ It acts as an antiseptic which prevents decay of food particles in the small intestine

pancreas	• Secretes pancreatic juices which digest carbohydrates, proteins and lipids in the small intestine (exocrine gland). • Also neutralises chyme from the stomach • Controls blood glucose levels in the body (endocrine gland)
small intestine	• The small intestine in humans is 6 m long and divided into three regions: duodenum; jejunum and ileum • **Duodenum** is the first portion which receives bile from the liver and pancreatic juices from the pancreas • **Jejunum** is the middle portion which secretes intestinal juices • **Duodenum** is the final portion which is the region of most absorption in the small intestine

	• The small intestine has transverse folds and microscopic **villi** which greatly increases the surface area for absorption
colon	• The colon (also called the large intestine) is divided into three regions: ascending colon, transverse colon and descending colon • **Most water and mineral salts** are absorbed in the colon • The descending colon leads to the rectum followed by the anus where undigested food is **egested**

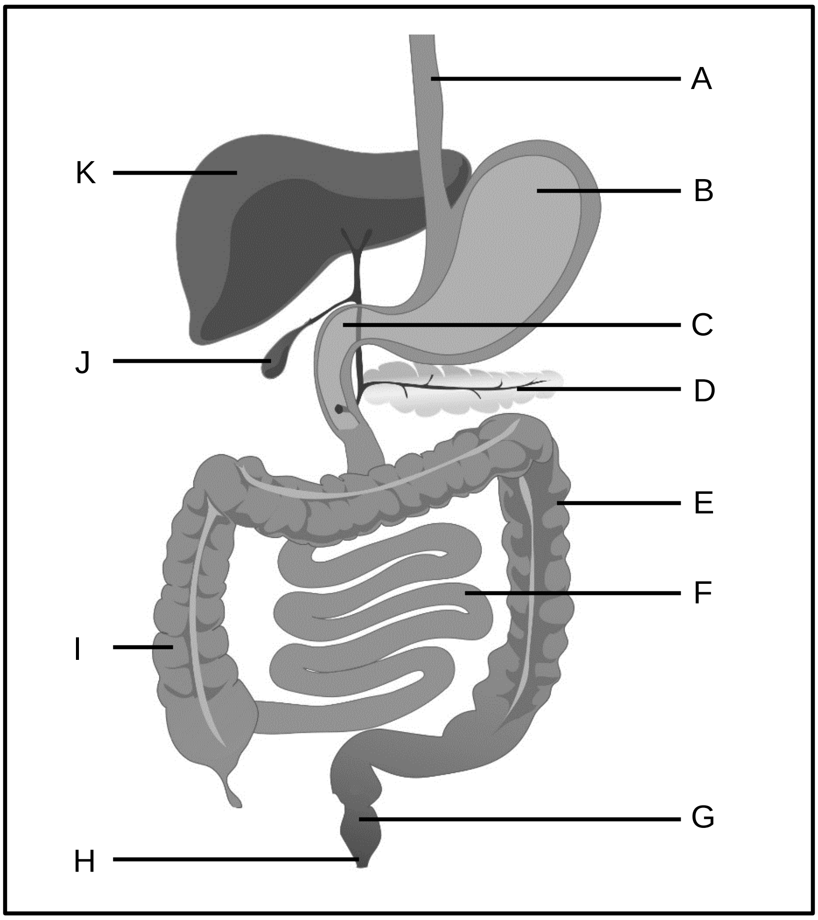
Activity 2: Dissection of a sheep's digestive system

A sheep's carcass can be obtained from an abattoir to investigates its digestive system.

1. Identify the different types of teeth found in the animal.
2. Follow the pharynx that leads to the division of two pipes: the trachea to the lungs and the oesophagus to the stomach.
3. Follow the oesophagus to the stomach, into the small intestine and the colon.
4. Notice the large size of the rumen (first stomach).
5. Compare the inner surfaces of the stomach, small intestine and the colon.

Activity 3: Human digestive system

Study the diagram of the digestive system and answer the questions that follow.



1. Provide labels for A - K. (11)
2. Give the letter of the structure that:
   (a) produces bile
   (b) controls blood glucose
   (c) absorbs most of the nutrients
   (d) absorbs most of the water. (4)
3. Name the structure where chyme can be found. (1)

(16)

Digestion

Key terminology

mastication	to chew food
enzyme	a protein that acts as a catalyst to regulate or speed up most biochemical reactions in living cells
emulsion	a fine dispersion of minute droplets of one liquid (e.g. fats & oils) in another in which it is not soluble or miscible.
carbohydrase	a group of enzymes that catalyses the breakdown of carbohydrates into simple sugars
protease	a group of enzymes that catalyses the breakdown of proteins into amino acids
lipase	a group of enzymes that catalyses the breakdown of lipids (fats and oils) into glycerol and fatty acids
lacteal	a lymph capillary in the villi of the small intestine where fats are absorbed
deamination	removal of an amino group from amino acids
metabolism	the chemical processes that occur within a living organism in order to maintain life

Mechanical digestion (no enzymes)

- Mechanical digestion is the physical breakdown of large food particles into smaller particles.
- Physical digestion does not alter the chemical structure of the compounds but it increases the surface area.

- Physical digestion occurs during **mastication**, churning in the stomach and during peristalsis.
- Food is moved through the digestive system by the rhythmic contraction and relaxation of circular muscles along the alimentary canal (Figure 5). This process is called **peristalsis**.
- Peristalsis is a reflex action and is triggered by the presence of the food in the alimentary canal.

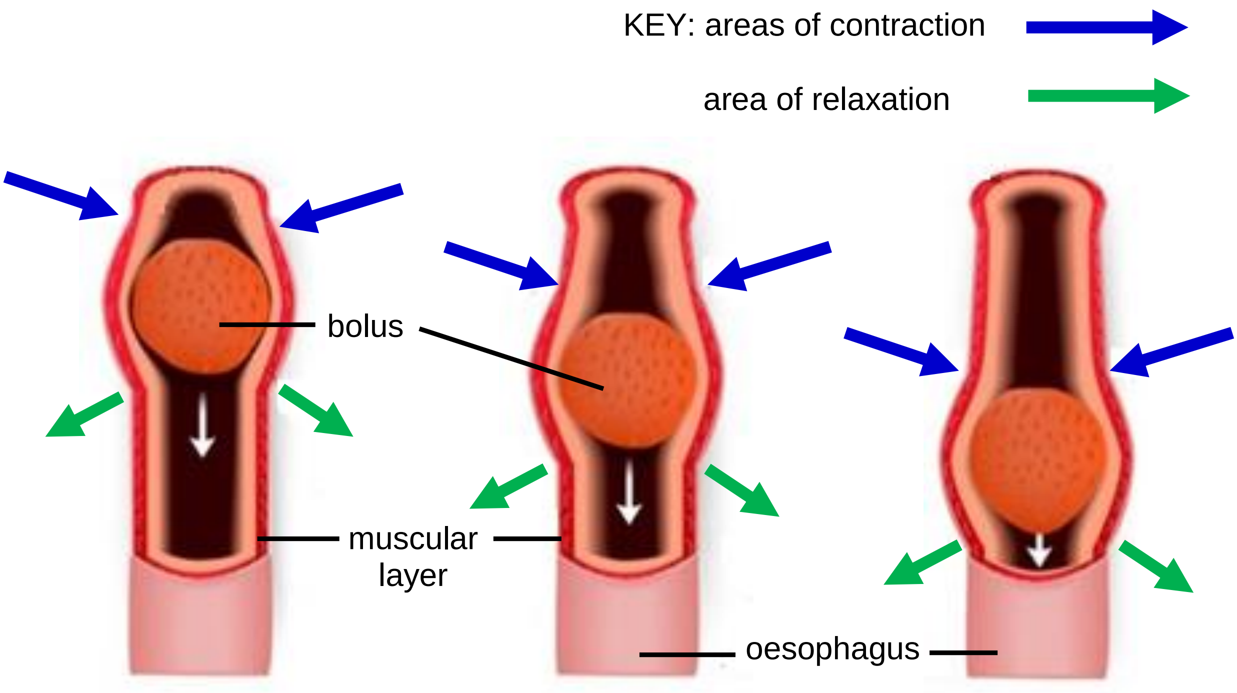


Figure 5: The process of peristalsis in the oesophagus

> Peristalsis will still transport food and water to your stomach even if you stand on your head

Once the bolus reaches the stomach, it is physically broken down further by the strong contractions of the stomach muscles. The bolus is also mixed with stomach acid and digestive enzymes which forms a creamy mixture called **chyme**.

> Lipids are broken down by bile into tiny droplets which provide a larger surface area on which enzymes can act to break them down. The breaking down of lipids into tiny droplets is called **emulsification** and is a type of physical digestion.

Chemical digestion (enzymes involved)

Chemical digestion is the breaking down of large food compounds into smaller food compounds using digestive **enzymes**. Most food particles are too large to be absorbed from the alimentary canal into the blood and therefore chemical digestion is necessary.

Enzymes are very sensitive to changes in temperature and pH and only work in optimal temperatures and pH ranges. Table 4 provides a summary of the action of enzymes. Figure 6 illustrates the chemical digestion of proteins, carbohydrates and lipids.

Table 4: Summary of groups of enzymes, where they are produced, substrate they break down, optimal pH and end-product of digestion.

Group of enzymes	Carbohydrases	Proteases	Lipases
Where they are produced	Saliva, pancreatic juices, intestinal juices	Stomach, pancreatic juices intestinal juices	Pancreatic juices, intestinal Juices
Substrate	Carbohydrates (starch)	Proteins	Lipids (fats and oils)
Preferred pH	Slightly alkaline	Acidic in stomach, Alkaline in small intestine	Slightly alkaline
End product of digestion	Glucose	Amino acids	Glycerol & fatty acids

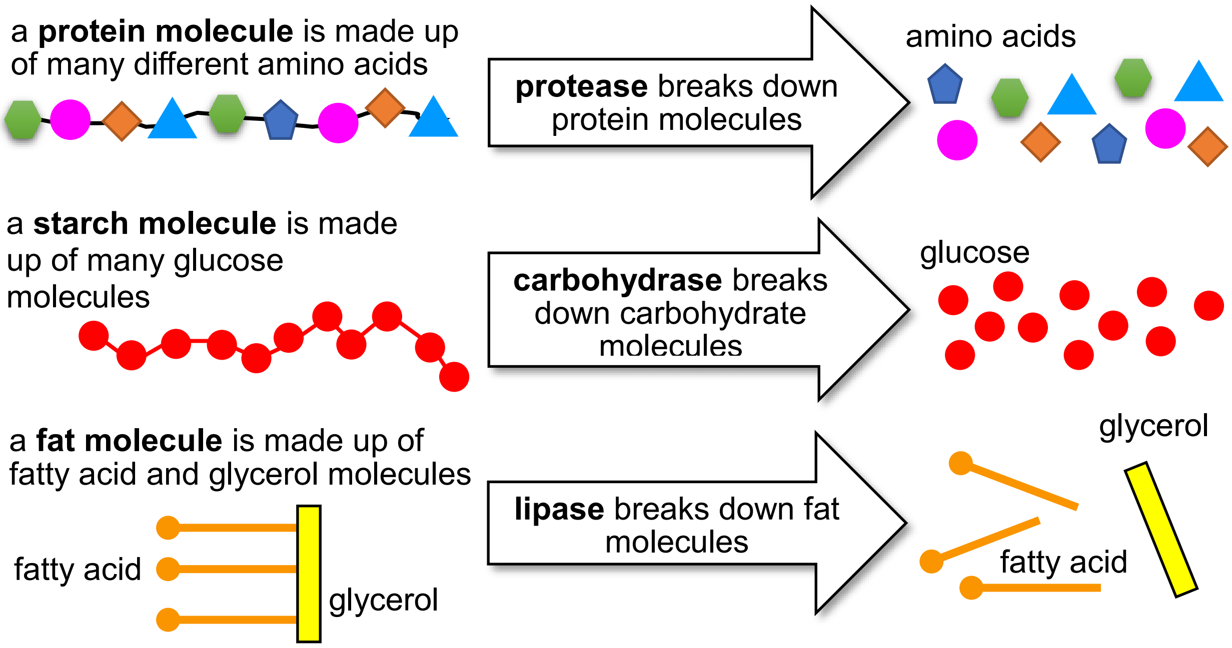


Figure 6: The chemical digestion of large compounds into smaller compounds

Activity 4: Stages of animal nutrition

1.	Name the five main stages of animal nutrition.	(5)
2.	What are the three main food groups?	(3)
3.	Where does the chemical digestion of protein first take place?	(1)
4.	Briefly describe the process of peristalsis.	(3)
5.	Name the parts of the alimentary canal where peristalsis is used to move food along.	(3)
		(15)

Digestive process: https://www.youtube.com/watch?v=s06XzaKqELk ; https://www.youtube.com/watch?v=yIoTRGfcMqM

Absorption

Most absorption takes place in the small intestine because most of the digestion has taken place by the time the food reaches the small intestine. The food particles in the small intestine are therefore small enough to be absorbed. The small intestine has a large surface area to absorb nutrients:

- The small intestine is approximately 6 m long.
- The walls of the small intestine contain **transverse** folds.
- The inner wall of the small intestine has millions of finger-like projections called villi (Figure 7).
- Each villus contains microvilli to further increase the surface area.

The villi that are responsible for nutrient absorption are adapted for absorption in the following ways:

- The epithelium is only one-cell layer thick allowing nutrients to pass through quickly.
- Goblet cells secrete mucus to ensure the absorptive surface is moist and to allow nutrients to be dissolved and then to be absorbed.
- The epithelium contains many mitochondria to supply energy for **active absorption** of nutrients.
- Microvilli further increase the surface area.
- There is a lymph vessel called a lacteal in each villus which absorbs and transports lipids.

- The villus is richly supplied with blood capillaries to transport glucose and amino acids.

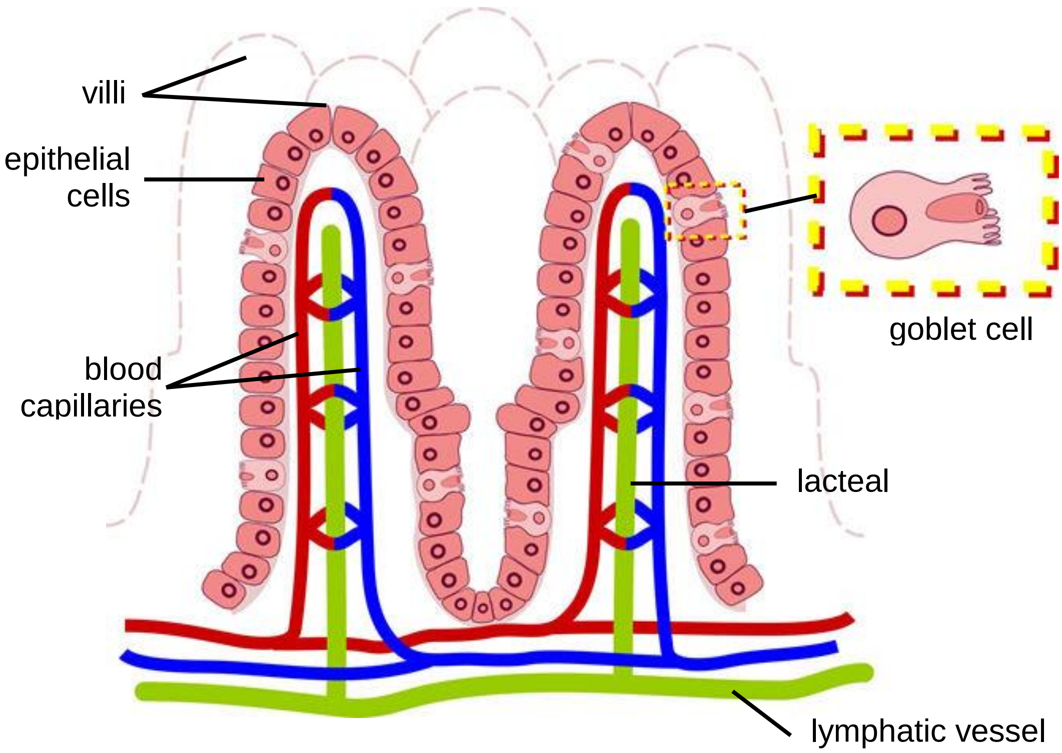


Figure 7: Intestinal villi

Table 5: A summary of how and where the end products of digestion are absorbed

Absorption	Glucose	Amino acids	Glycerol and fatty acids	Vitamins	Minerals	Water
Active/Passive absorption	Active	Active	Passive (diffusion)	Active & passive	Active & passive	Passive (osmosis)
Structure where absorption takes place	Blood capillary	Blood capillary	Lacteal	Blood capillary	Blood capillary	Blood capillary

Active absorption requires energy for the nutrient to be absorbed against a concentration gradient (low to high). Passive absorption does not require energy because it moves with the concentration gradient (high to low).

Transport of amino acids and glucose

Glucose and amino acids are absorbed from the small intestine and transported in the blood circulatory system as shown in the flow diagram (Figure 8).

Amino acids & glucose are absorbed into blood capillaries of the villi in the small intestine

↓

Capillaries join together to form large venules to form the hepatic portal vein transports amino acids and glucose to the liver

↓

Glucose and amino acids flow through hepatic vein to the heart

↓

The liver converts excess glucose to glycogen and stores it

↓

Excess amino acids are deaminated by the liver to form urea (waste product) and are removed from the body

Figure 8: Flow diagram representing the transport of glucose and amino acids

Assimilation

- Assimilation is the incorporation of absorbed nutrients into the cells of the body. The body cells absorb the required nutrients which are necessary for the building and maintenance of compounds.
- For example, muscle cells will absorb amino acids to be converted to proteins and glucose will be absorbed by cells to provide energy.
- The liver plays a vital role in the assimilation of nutrients.
- The liver is responsible for the **metabolism** of glucose, **deamination** of amino acids, the **breakdown** of alcohol, drugs and hormones.

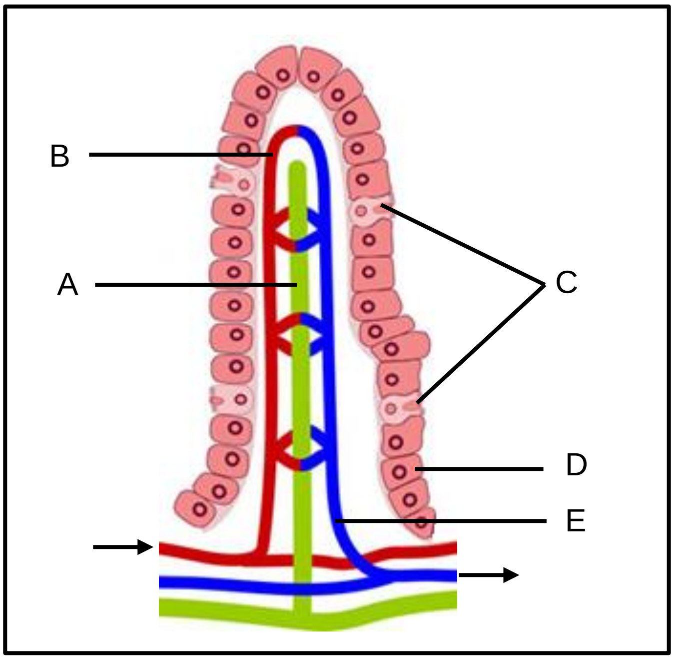
Egestion

- All undigested materials are transported through the colon where most water and mineral salts are absorbed.

- The undigested material is temporarily stored in the rectum until it is excreted through the anus. The undigested waste is then referred to as faeces.

Activity 5: Villi

Study the diagram below and answer the questions that follow.



1. Provide an appropriate title for this diagram. (1)
2. Provide labels for A to E. (5)
3. What structures would you expect to find on cells labelled D? (1)
4. Provide the letter of the structure where absorbed glucose and amino acids will be found. (1)
5. Is the absorption of glucose and amino acids active or passive? (1)
6. Give the letter for the structure into which fatty acids and glycerol are absorbed? (1)

(10)

Homeostatic control of blood glucose levels

Key terminology

homeostasis	the ability of an organism to maintain stability of internal conditions (e.g. temperature, chemical balance) despite changes in its environment

negative feedback mechanisms	mechanisms in the human body that detect changes or imbalances in the internal conditions and restore homeostasis
blood glucose	amount of glucose in the blood
insulin	a hormone made in the pancreas and released into the blood to help convert glucose to glycogen to reduce blood glucose
glucagon	a hormone made by the pancreas that raises blood glucose levels by converting stored glycogen to glucose
glycogen	form in which glucose is stored in the liver and cells

The following is a **general sequence of events** in a negative feedback mechanism:

- Step 1: An imbalance is detected
- Step 2: A control centre is stimulated
- Step 3: Control centre responds
- Step 4: Message is sent to target organ/s
- Step 5: The target organ responds
- Step 6: It opposes / reverses the imbalance
- Step 7: Balance is restored.

The following explains the regulation of blood glucose levels.

Blood glucose refers to the amount of glucose in the blood. Glucose is absorbed into the blood from the digestive system. Glucose found in the blood is taken up by the body's cells to be used for cellular respiration which releases energy.

If blood glucose levels are too low, the body cells cannot release enough energy and the body cannot function at its best. If blood glucose levels are too high, water is drawn out of the cells and into the bloodstream. This results in dehydration of the cells and therefore dehydration of the body. The pancreas monitors the amount of glucose in the blood.

After a meal, blood glucose levels will increase because more glucose is absorbed from the small intestine into the blood (Figure 9). The **pancreas** detects an increase in blood glucose and releases the hormone **insulin** which causes the glucose to be converted into glycogen. Glycogen is stored in the liver and skeletal muscles in the body. The body cells are also stimulated to take up glucose. This lowers the blood glucose level and returns it to normal.

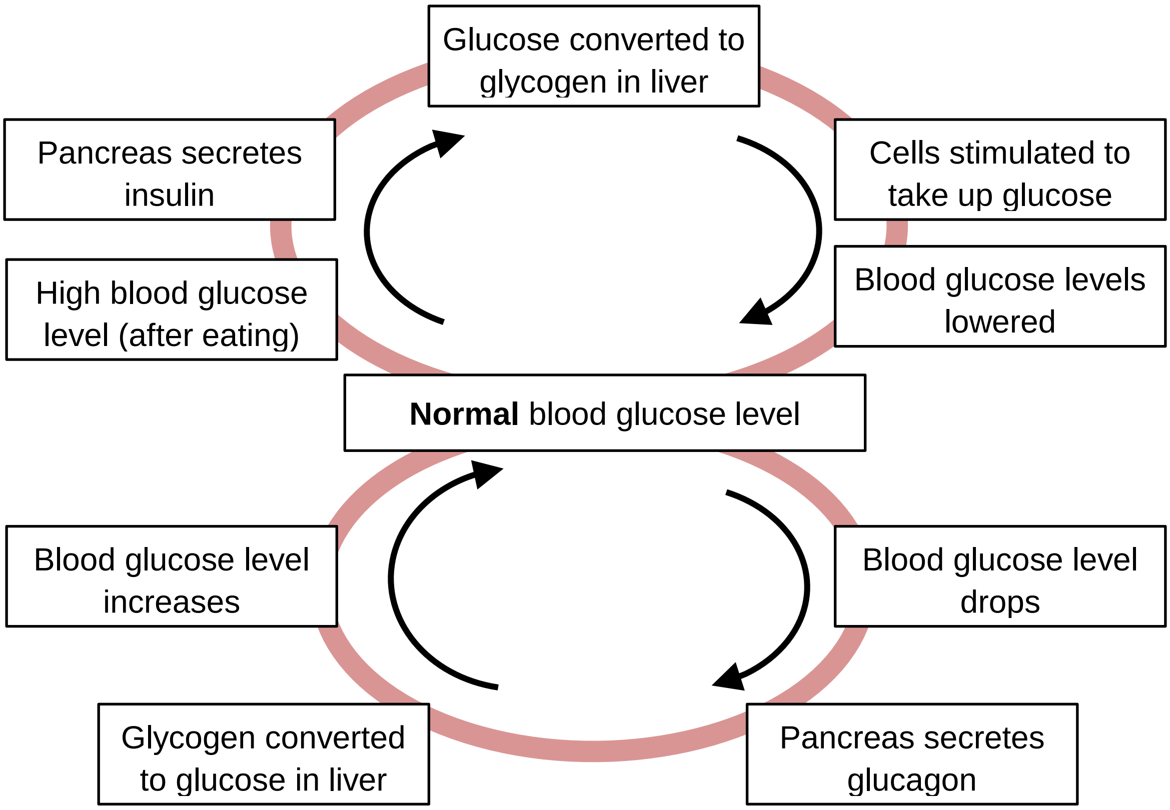


Figure 9: The influence of insulin and glucagon on blood glucose levels

Blood glucose levels decrease because the body cells are constantly using glucose for cellular respiration. When blood glucose levels decrease, the pancreas will release the hormone **glucagon** which converts stored glycogen (from the liver and skeletal muscles) into glucose. This increases the blood glucose level and returns it to normal (see Figure 9 above). Figure 9 can be summarised as follows:

$$\textbf{Glucose} \underset{\text{glucagon}}{\overset{\text{insulin}}{\rightleftharpoons}} \textbf{Glycogen}$$

- Blood glucose levels are maintained at a constant level (homeostasis).
  - When **blood glucose** levels are too **high**, insulin is released from the pancreas to convert blood glucose into **glycogen** in the liver and muscles to return the blood glucose level to normal.
  - When blood glucose levels are **too low**, **glucagon** is released from the pancreas to **convert glycogen** stored in the liver and muscles into **glucose**, which enters the blood and returns glucose levels to normal.
  - The metabolic disorder, **diabetes mellitus,** occurs when insulin is not released or does not function properly resulting in high glucose levels.

Diabetes mellitus

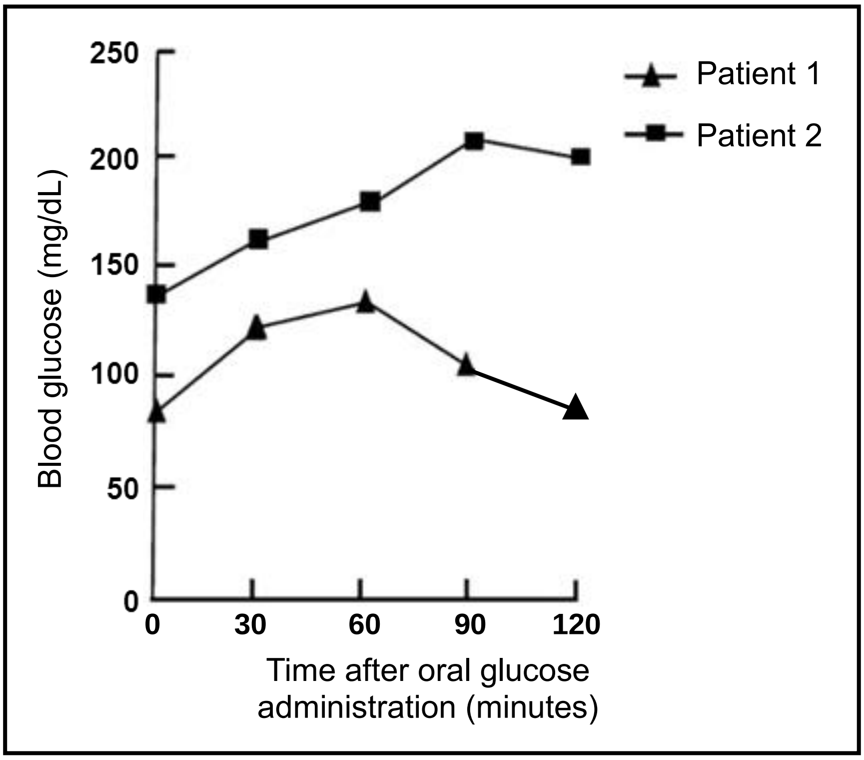
Diabetes mellitus is a disorder characterised by high blood glucose levels resulting in increased fatigue (tiredness), dehydration and lack of energy. Table 6 provides a comparison of the two different types of diabetes.

Table 6: Comparison of the different types of diabetes.

Types of diabetes mellitus	
Type 1 diabetes	**Type 2 diabetes**
Cause: Usually an inherited disorder or a loss of insulin-producing cells in the pancreas **Treatment**: Lifelong disorder that requires daily injections of insulin and specially adapted diet	**Cause**: Insulin resistance where body does not produce or react to insulin, usually as a result of poor lifestyle choices **Treatment**: Maintaining a balanced diet, regular exercise and medication

Activity 6: Diabetes mellitus

An oral glucose tolerance test is used to determine if a person is diabetic. This test was performed on two people. After fasting for 12 hours, each person was given the same glucose solution to drink and then their blood glucose levels were measured every 30 minutes for two hours. The results of the investigation are shown below.



1. Which patient is diabetic? (1)

2. Give two reasons for your answer in question 1. (2)

3. How long does it take for the blood glucose level of patient 1 to return to the level it was before they drank the glucose? (1)

4. What is the name of the hormone that:

   a) increases blood glucose levels? (1)

   b) decreases blood glucose levels? (1)

(6)

Balanced diet

A balanced diet is required to maintain good health. A balanced diet should consist of all the necessary nutrients in their correct quantities. Carbohydrates and fats provide the body with energy, protein is used for building and repair of cells and vitamins and minerals for maintenance of immune system and bodily processes. The amount of nutrients required is dependent on age, gender and level of activity. For example, growing children need more protein to build and repair cells; active people require more energy foods and men need more energy foods than women.

Different diets

There are a number of different diets followed by people from different cultures and religions, and for personal and health choices (Table 7).

Table 7: Comparison of different diets.

Diet	Description
vegan	Do not eat any animal products such as meat, eggs and milk
vegetarian	Do not eat meat but do eat dairy products and eggs.
halaal	Followers of Islamic faith do not consume pork, alcohol, carnivorous animals or any food that comes into contact with carnivorous animals. The slaughter of animals must follow strict rules.
kosher	Followers of Jewish faith do not eat pork, shellfish, fish without fins or scales, no predatory birds etc.

Malnutrition

Malnutrition occurs when a person does not follow a balanced diet. It can result in under-nourishment (eating too little food) or over-nourishment (eating too much food). This can lead to a number of different disorders or diseases (Table 8).

Table 8: Nutritional disorders

Disorder	Cause	Symptom
kwashiorkor	lack of protein occurs mainly in children	swollen stomach and liver; sores on skin; stunted growth
marasmus	lack of energy foods such as carbohydrates and fats	thin muscles; no fat deposits; lack of energy; sunken eyes
anorexia nervosa	psychological condition where a person refuses to eat in fear of gaining weight	excessive weight loss; can be fatal
bulimia	psychological condition where a person regularly overeats and induces vomiting to avoid weight gain	dehydration; tooth decay; tears in the oesophagus; electrolyte imbalance
coronary heart disease	a diet too high in fats and sugars; obesity; high blood pressure; smoking; lack of exercise	plaque and cholesterol build up in blood vessels going to heart; heart failure; heart attack
diabetes	poor diet (high in sugar) and lack of exercise	tiredness; heart attack; stroke; kidney disease; blindness; numbness in fingers and toes; toe and/or leg amputations
obesity	a diet too high in energy foods such as sugars and fats	excessive deposits of body fat; increased risk of heart disease; type 2 diabetes; hypertension; arthritis

Food allergies

Some people have food allergies which are triggered when they consume or come into contact with a particular food or group of food types. The body considers the food item to be a pathogen and the immune system attacks the compounds of the food item. Symptoms of a food allergy usually include swelling, itching and shortness of breath or wheezing.

Common foods that people are allergic to include milk, peanuts, shellfish, egg and gluten.

Food supplements

When a diet is deficient in certain nutrients, food supplements can be taken. Additional supplements are often taken for health, sport or beauty reasons and should only be taken on the advice of health professionals.

Calcium and Vitamin D are often added to a diet to maintain strong bones and prevent osteoporosis particularly in pregnancy and old age.

Body builders and extreme sportsmen and women add protein supplements to their diets to build and repair muscle tissue.

Tooth decay

Tooth decay occurs when the outer tooth layer or tooth enamel is damaged. Plaque consisting of a sticky film of bacteria, forms on your teeth after eating. When you eat or drink foods containing a high percentage of sugars, the bacteria in plaque produce acids that attack tooth enamel.

Fluoride helps to make teeth stronger and prevent cavities. Fluoride can be added to drinking water, salt and toothpaste to reduce tooth decay in a population.

Dietary information on packaging

A table which lists the nutritional value of a food product is usually included on the packaging. The food label includes:

- a list of ingredients
- the amount of carbohydrates, proteins, fats and oils etc.
- allergens
- recommended serving size
- kilojoules

Activity 7: Food

1. Name the diet that does not include any meat products. (1)
2. Which disorder arises when a diet lacks protein. (1)
3. Differentiate between the two psychological nutrition disorders. (4)
4. Study the nutritional information from a carbonated cool drink below and answer the questions that follow.

Typical values	Standard serving (240 ml)	This package (360 ml)
Energy	400 kJ	600 kJ
Total fat	0 g	0 g
Sodium	40 mg	60 mg
Total carbohydrates	28 g	42 g
of which total sugars	28 g	42 g
Protein	0 g	0 g

4.1 Which nutrient occurs in the highest amount in this cool drink? (1)

4.2 Name the mineral that is mentioned on this packaging. (1)

4.3 Is this cool drink a good option for an inactive individual to drink regularly? Explain your answer. (4)

4.4 Name three disorders/diseases that are the result of diets that contain too many foods rich in sugar. (3)

(15)

Alcohol and drug abuse

The abuse of alcohol and drugs is linked to many negative consequences. Alcohol abuse can cause:

- lack of coordination
- blurred vision
- slurred speech
- loss of memory
- nausea
- anxiety and / or depression
- liver cirrhosis
- unconsciousness and death

Some of the effects of drug abuse include:

- anxiety
- paranoia
- tremors
- sleeplessness
- mood swings
- depression
- changes in appetite
- death if overdosed

Animal nutrition: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A- D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D.

1.1.1 Which one the following substances can directly be absorbed by blood without further digestion?

A Proteins
B Starch
C Glucose
D Fats

1.1.2 The concentration of which of the following substances are normally higher in the hepatic portal vein than in most other veins in the human body?

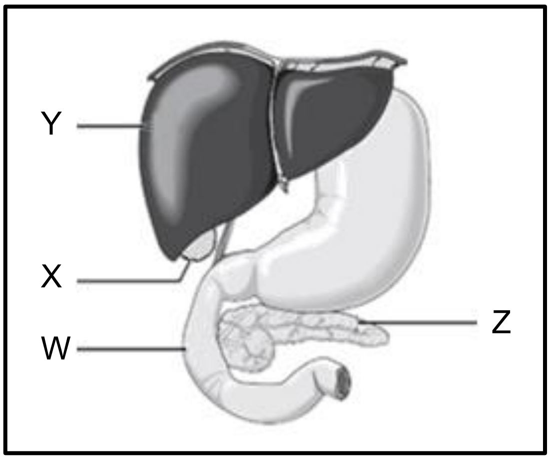
A Oxygen
B Glucose
C Urea
D Carbon dioxide

1.1.3 Where does the emulsification of fat occur?

A In the liver
B In the colon
C In the gallbladder
D In the small intestine

1.1.4 This question refers to the diagram on the next page. Which labelled structure secretes a hormone which causes an increased production in glycogen?

A W
B X
C Y
D Z



1.1.5 Irritable bowel syndrome (IBS) is a medical term used to describe a disease of the digestive system. Symptoms usually occur after certain foods or drinks are consumed. It can cause sudden and severe diarrhoea. What consequence can this have for a person?

A Too much water and nutrients will be absorbed in the digestive tract.
B Too little water will be absorbed, but the nutrients will be absorbed.
C Too little nutrients will be absorbed, but water will be absorbed
D Too little water and nutrients will be absorbed.

(5 × 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The disorder resulting from an insufficient intake of proteins.
1.2.2 A type of malnutrition in which the person consumes large quantities of high-energy food.
1.2.3 The ejection of solid waste from the body.
1.2.4 The tiny finger-like projections in the small intestine.
1.2.5 The process where the products of digestion become part of the protoplasm of the body cells.
1.2.6 Substance secreted by the liver to emulsify fats.
1.2.7 The form in which excess glucose is stored in humans.
1.2.8 The wave-like contractions of the muscles of the alimentary canal that move food along.
1.2.9 Ball of chewed food mixed with saliva formed in preparation for swallowing.
1.2.10 The muscular tube that connects the mouth cavity to the stomach.

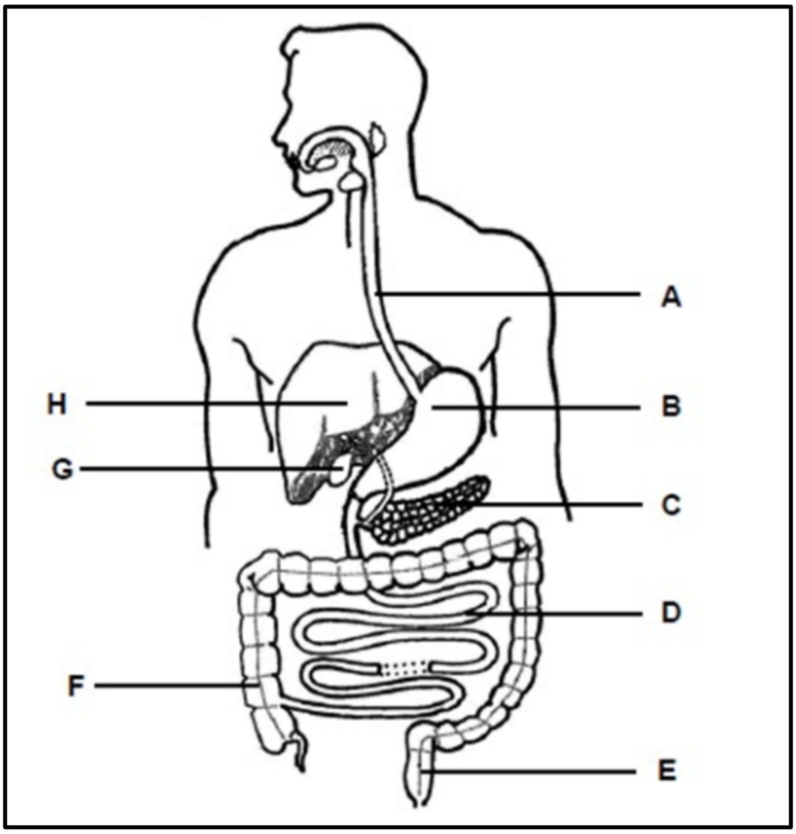
(10 × 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B,** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B,** or **none** next to the question number.

Column I	**Column II**
1.3.1 Substances that need to be digested before absorption	A: amino acids B: glucose
1.3.2 A lymph vessel in the villus of the small intestine	A: lacteal B: lymphatic node
1.3.3 The enzymes secreted by the pancreas	A: proteases B: carbohydrases
1.3.4 The structure where chemical digestion does not take place.	A: oesophagus B: large intestine

(4 × 2) = (8)

1.4 Study the diagram below which shows the human digestive system.



1.4.1 Labels parts A, B, C, D, E, F and H**.** (7)

1.4.2 Write the letter only of the part:

a) that stores bile (1)

b) where chemical digestion of proteins begins (1)

c) where most water and mineral salts are absorbed (1)

1.4.3 Why can the part labelled C be regarded as …

a) an exocrine gland? (1)

b) an endocrine gland? (1)

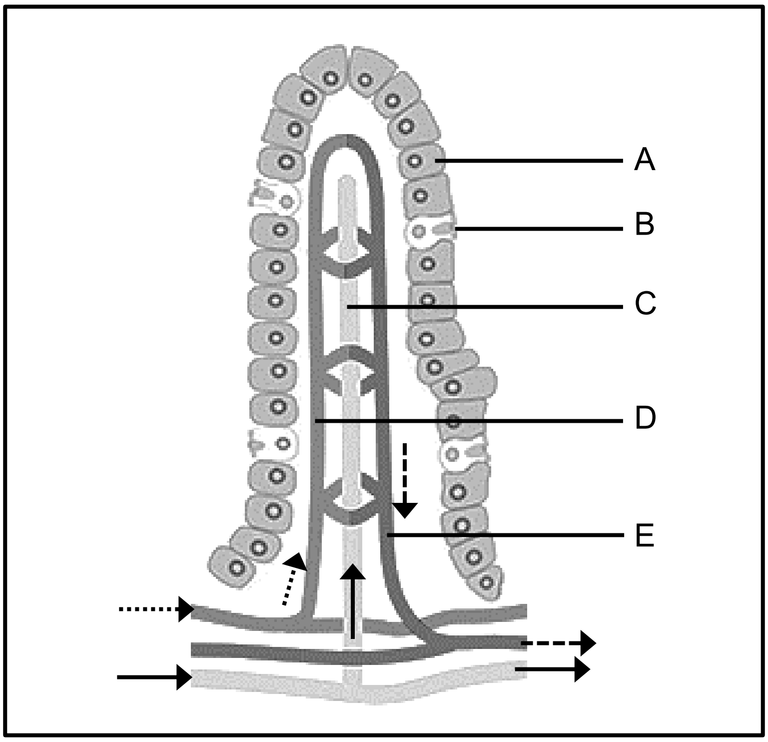
(12)

Section A: [40]

Section B

Question 2

2.1 The diagram below shows a structure associated with the digestive system.



2.1.1 Identify the structure shown in the diagram. (1)

2.1.2 Name part C in the diagram. (1)

2.1.3 In which part of the digestive tract would this structure be found? (1)

2.1.4 Explain three structural adaptations of the part mentioned in question 2.1.3 that enables it to perform its functions. (6)

2.1.5 In which part (D or E) would you expect to find more nutrients? (1)

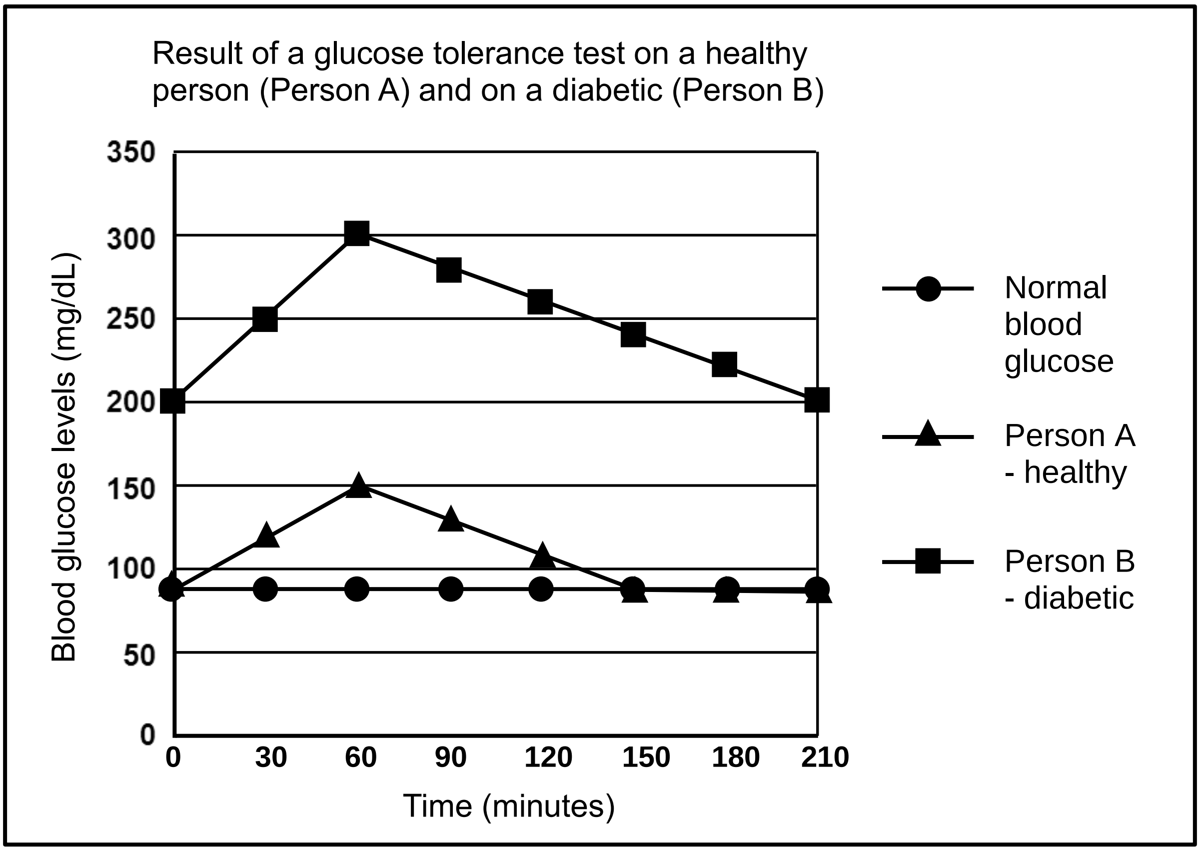
2.1.6 Explain your answer to question 2.1.5. (2)

2.1.7 Name the process that enables humans to absorb the nutrients in part E. (1)

2.1.8 Celiac disease is a disorder that makes human bodies react to gluten (a protein found in wheat, etc.). The response by the immune system eventually damages the structures illustrated in the diagram above. Explain the effects of this disease on the human body. (2)

(15)

2.2 The graph below shows the results of a glucose tolerance test on a healthy individual (Person A) and on a diabetic person (Person B). After fasting for ten hours they each were given a drink of glucose solution containing 50 g glucose. The amount of glucose in their blood was then measured every 30 minutes for the next 3 hours.



2.2.1 What was the greatest concentration of glucose in the diabetic's blood? (1)

2.2.2 From the graph, determine how long it would take for the glucose concentration of:

a) the healthy person to return to the level when the glucose solution was consumed. (2)

b) the diabetic person to return to the level when the glucose solution was consumed. (2)

2.2.3 What effect would injecting insulin into the diabetic person have on the results of the test? (1)

2.2.4 What is the function of insulin? (1)

2.2.5 Explain briefly why insulin, which is a protein, is injected into a diabetic person, rather than given orally. (2)

(9)

2.3 Briefly describe the homeostatic control of blood glucose. (6)

(15)

Section B: [30]

Total marks: [70]

6: Cellular respiration

CHAPTER 6: CELLULAR RESPIRATION

Introduction

By now we know that all living things require energy to live. In this chapter, we will study the process by which this energy is transformed so that organisms can make use of it.

Key terminology

metabolism	chemical processes in organisms which are controlled by enzymes
catabolic	a metabolic process in which complex molecules are broken down into simple ones to release energy
anabolic	the synthesis of more complex substances from simple molecules

Definition of cellular respiration

Cellular respiration is the chemical process where glucose is broken down gradually, in the **presence** of oxygen (aerobic respiration) or in the **absence** of oxygen (anaerobic respiration), to release **energy**.

Importance of energy

Energy is used by organisms in various ways. Some of the main ways in which energy is used include the following:

- growth
- cell division
- movement
- transport of substances
- active transport

Process of cellular respiration

Key terminology

aerobic respiration	respiration in the presence of oxygen

mitochondrion	organelle / site for respiration
ATP	general energy carrier molecule in cells

Aerobic respiration (needs oxygen)

Aerobic respiration takes place:

- in the presence of oxygen;
- inside the cytoplasm and mitochondria of cells.

Figure 1 shows the internal structure of a mitochondrion.

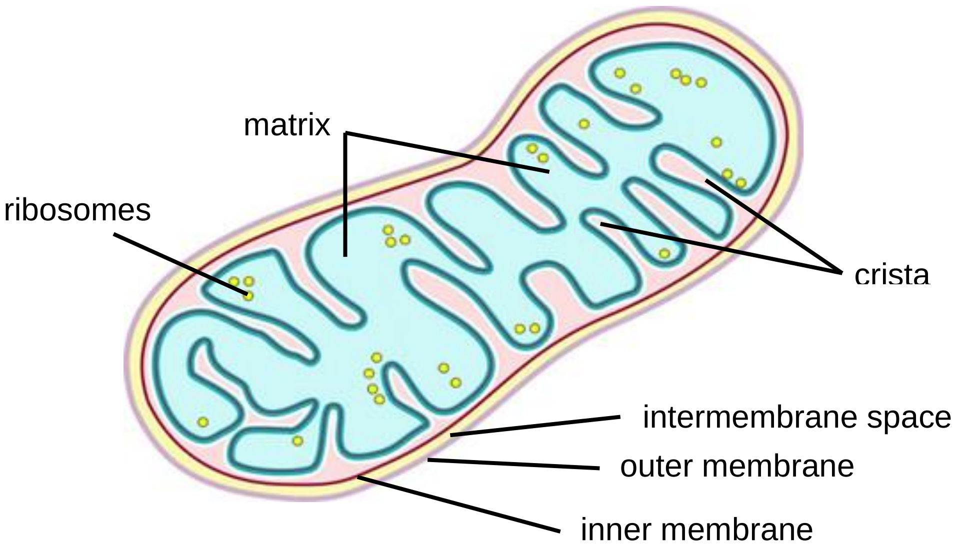


Figure 1: The internal structure of a mitochondrion

The requirements for the process are oxygen and glucose and the by-products released are carbon dioxide and water as well as ATP energy. This can be shown in the following word equation:

Glucose + Oxygen ⟶ Carbon Dioxide + Water + ATP

The stages of aerobic respiration

Aerobic respiration takes place in three stages:

1. Glycolysis – takes place in the cytoplasm
2. Krebs Cycle – takes place inside the mitochondrion

3. Oxidative Phosphorylation – takes place inside the mitochondrion

Glycolysis

- takes place outside the mitochondrion, in the cytoplasm of the cell
- no oxygen is required during this stage
- glucose is broken down into smaller molecules, releasing a small amount of energy that is stored in energy-rich ATP molecules
- releases high energy hydrogen ions (H^+) that are used in the third stage of cellular respiration (oxidative phosphorylation)

No biochemical detail is required in the exam.

Krebs Cycle

- can only take place if oxygen is present
- occurs inside of the mitochondrion
- releases carbon dioxide and high energy hydrogen ions (H^+)
- transports hydrogen atoms to the third stage (oxidative phosphorylation) via hydrogen carrier enzymes

Oxidative Phosphorylation

- takes place inside of the mitochondrion and requires oxygen
- passes high energy hydrogen atoms from one hydrogen carrier enzyme to the next, releasing energy in the process
- uses released energy to combine a phosphate molecule to an ADP (Adenosine Di-phosphate) molecule to form ATP – called **phosphorylation**
- is represented in the formula: $\text{ADP} + \text{P} \longrightarrow \text{ATP}$
- oxygen acts as a final hydrogen acceptor binding with the hydrogen forming water which is released as a waste product of cellular respiration

Anaerobic respiration (without oxygen)

Key terminology

anaerobic respiration	respiration in absence of oxygen
fermentation	type of anaerobic respiration in yeast (and other) cells

alcoholic fermentation	breaking down of glucose in absence of oxygen, to give rise to the production of alcohol in plant cells
lactic acid fermentation	breaking down of glucose in absence of oxygen to form lactic acid in animal cells
lactic acid	acid formed in muscle cells, during anaerobic respiration; leads to muscle exhaustion / cramping

Anaerobic respiration takes place:

- **without oxygen** being present
- it occurs for short periods of time, mainly during physical exercise
- occurs differently in plants and animals
- produces less ATP than aerobic respiration

Anaerobic respiration in animals

- is known as **lactic acid fermentation**
- occurs in muscles during intense exercise
- enables glycolysis in the cytoplasm of animal cells
- results in the accumulation of lactic acid causing the muscles to become tired and painful
- produces only a small amount of ATP

The lactic acid can be converted back to pyruvic acid when the muscles receive oxygen.

Anaerobic respiration in plants

- is known as **alcoholic fermentation**
- enables glycolysis in the cytoplasm of plant cells
- results in the accumulation of pyruvic acid
- breaks down pyruvic acid forming ethanol (alcohol) and releasing carbon dioxide in the process
- can be summarised as:

$$\text{glucose} \rightarrow \text{ATP + pyruvic acid} \rightarrow \text{ethanol + carbon dioxide}$$

Anaerobic respiration (fermentation): https://youtu.be/YbdkbCU20_M

Uses of anaerobic respiration in industry

Yeast and other fungi respire anaerobically and are used to produce alcoholic beverages such as beer and wine. Yeast cells are also used to cause bread to rise during the baking process.

The fermentation process is also used to produce cheese. Watch this video on how cheese is made: https://www.youtube.com/watch?v=TVVpjVk4Gy8

Comparison between aerobic and anaerobic respiration

Table 1 summarises the differences between aerobic and anaerobic respiration.

Table 1: The differences between aerobic and anaerobic respiration

Aerobic	Anaerobic
oxygen is required	oxygen is not required
products: carbon dioxide + water	products: lactic acid (animals) or carbon dioxide + alcohol (plants /yeast)
occurs in the cytoplasm and mitochondria	occurs in the cytoplasm
large amount of ATP energy is released, glucose is completely broken down	small amount of ATP energy is released, glucose is only partially broken down

The differences between aerobic and anaerobic respiration:
https://www.youtube.com/watch?v=ZkqEno1r2jk&index=17&list=PLW0gavSzhMlQYSpKryVcEr3ERup5SxHl0

https://www.youtube.com/watch?v=HZtXLhm7ISA&index=60&list=PLW0gavSzhMlQYSpKryVcEr3ERup5SxHl0

Investigations on cellular respiration

lime water	solution used to test for carbon dioxide
glycogen	form in which glucose is stored in animal cells
germination	the process where a plant grows from a seed

There are a number of Investigations to show the requirements and products of cellular respiration.

To test for oxygen

A glowing splint test can be used to test for the presence of oxygen. A wooden splint/ stick is lit and then extinguished. In the presence of oxygen, the glowing end of the splint will re-ignite or glow brighter.

To test for carbon dioxide

A clear lime water solution will turn milky in the presence of carbon dioxide

Investigation 1: Oxygen is used during cellular respiration

Micro-organisms such as bacteria and fungi also need oxygen for cellular respiration. In germinating beans, cellular respiration takes place at a high rate releasing large amounts of energy for growth. In beans that have been killed by boiling them, cellular respiration cannot take place and these serve as a control.

Aim: to show that oxygen is used during cellular respiration

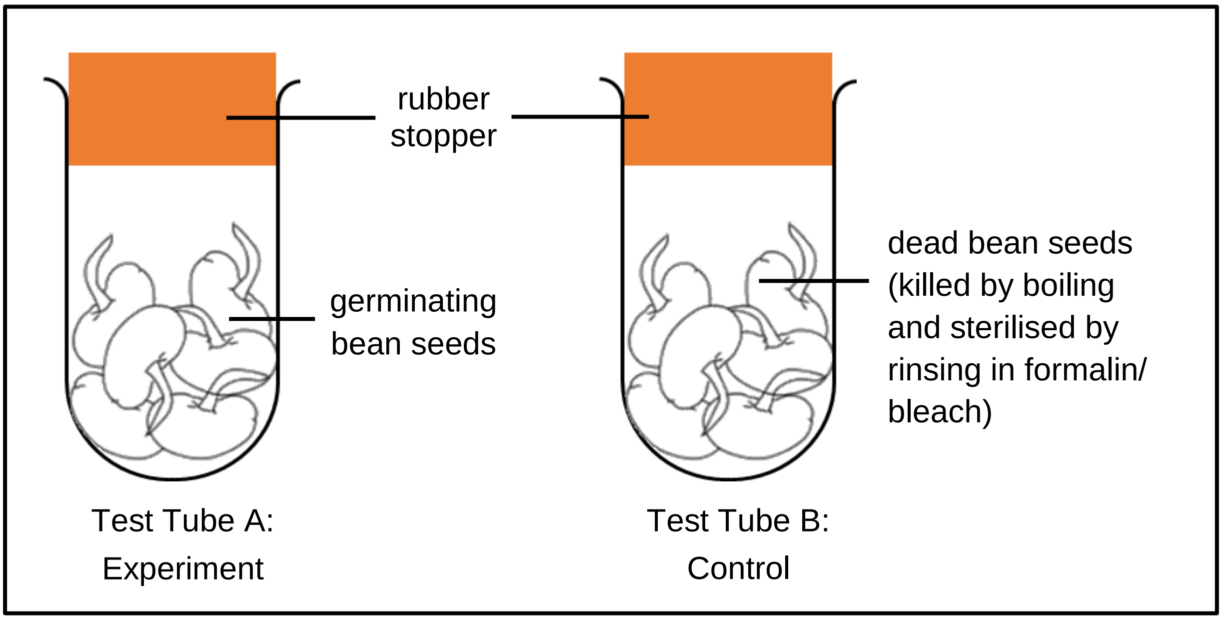


Figure 2: Apparatus to show that oxygen is used during cellular respiration

Method:

- Use germinating beans.
- Ensure the equipment and beans are sterilised so that no micro-organisms can influence the results.

- Place some of the beans into boiling water to kill them, so that cellular respiration cannot take place in these beans.
- Set-up the apparatus as shown in Figure 2 above, making sure that the test tubes are tightly sealed.
- Leave the test tubes set-up overnight.
- Take the stoppers off of the test tubes the next morning and insert a glowing splint into each one.

Results

- Test tube A (the experiment): the glowing splint dies out - no oxygen is present, it has been used up by the germinating beans during cellular respiration.
- Test tube B (the control): the glowing splint ignites or burns brighter - no oxygen is present, it has been used up by the germinating beans during cellular respiration.

Conclusion

Oxygen is used by living organisms during cellular respiration.

Investigation 2: Carbon dioxide is produced during aerobic cellular respiration

Living organisms produce carbon dioxide as a by-product of **aerobic** respiration. We can test for the presence of carbon dioxide by using clear lime water which will turn a milky colour when in the presence of carbon dioxide.

Soda lime can be used to remove carbon dioxide from the atmosphere and sodium hydroxide can be added to a solution to remove carbon dioxide found in a liquid. This will ensure that no carbon dioxide can enter into any experiment so that we can prove the carbon dioxide is a result of aerobic respiration performed by an organism.

Aim: To prove that carbon dioxide is produced during aerobic respiration

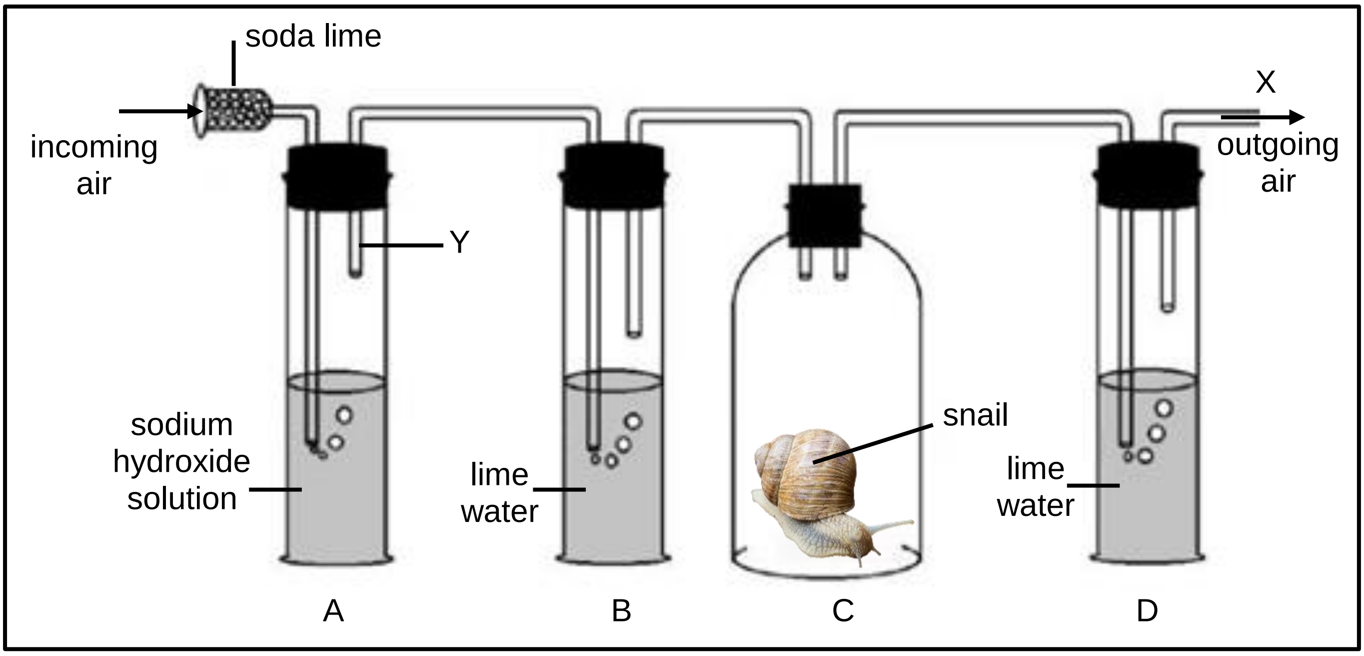


Figure 3: Experimental set-up to show CO_2 is produced during aerobic respiration

Method:

- Use a small organism (e.g. snail).
- Sterilise the equipment so that no micro-organisms can influence the result.
- Place the snail into a large jar.
- Set- up the apparatus as shown in Figure 3 above, making sure that the test tubes are tightly sealed.
- Examine the test tubes the following day and record the results.

Results:

- Test tube B: the lime water remains clear, carbon dioxide is removed by the soda lime and sodium hydroxide.
- Test tube D: the lime water turns milky due to carbon dioxide produced by the snail.

Conclusion:

Carbon dioxide is produced during aerobic respiration by living organisms (the snail).

Investigation 3: Carbon dioxide is produced during anaerobic cellular respiration

Living organisms produce carbon dioxide as a by-product of **anaerobic** cellular respiration. We can test for the presence of carbon dioxide in the same way we did before by using clear lime water.

Aim: To prove carbon dioxide is produced during anaerobic cellular respiration

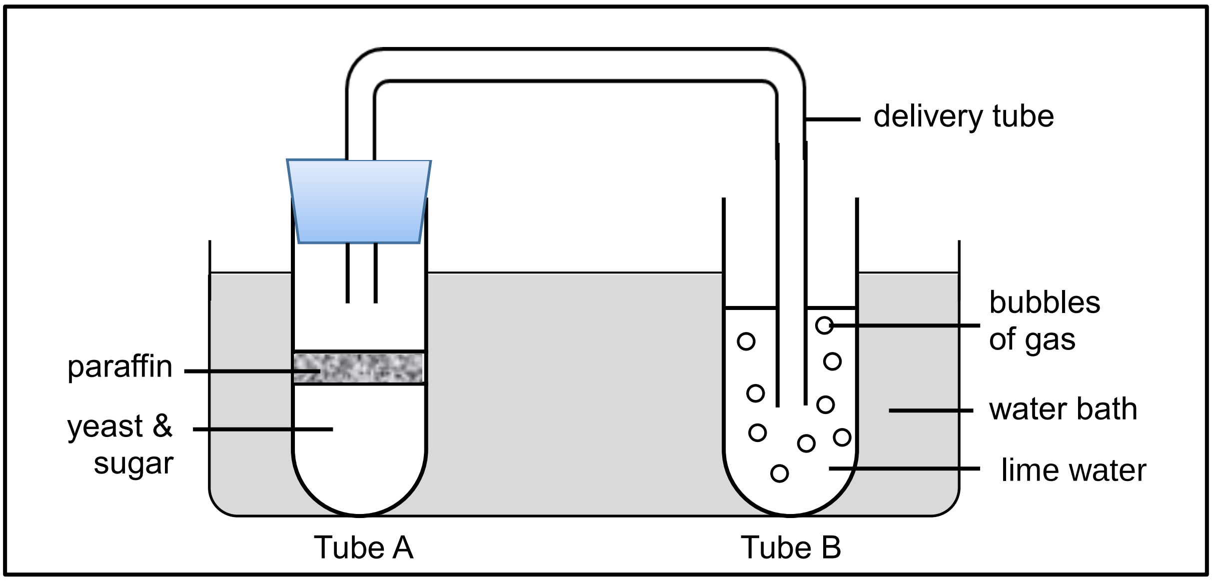


Figure 4: Experimental set-up for investigating the production of CO_2 during anaerobic cellular respiration

Method:

- Sterilise the equipment so that no micro-organisms can influence the result.
- Boil the sugar solution ahead of time to ensure that all of the oxygen is removed from the solution.
- Set-up the apparatus as shown in Figure 4.
- The yeast and sugar solution should be in Test Tube A and clear lime water should be in Test Tube B.
- Cover the sugar solution with a thin layer of paraffin so that no oxygen from the air can dissolve into the solution. Make sure that the test tube is tightly sealed.
- The apparatus must be placed in a warm water bath because yeast grows quickly in warm conditions.
- Record the results after a few hours.

Results:

The clear lime water becomes milky in colour.

Conclusion:

Carbon dioxide is produced during anaerobic cellular respiration in living cells (yeast).

A simple Investigation using peas and worms: https://youtube/r9oVdToClE

Cellular respiration: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Cellular respiration in a green leaf takes place

A during the day only.
B continuously.
C during the night only.
D during photosynthesis only.

1.1.2 The following components are involved in cellular respiration:

(i) Energy
(ii) Carbohydrates
(iii) Carbon dioxide
(iv) Water
(v) Oxygen

Which ONE of the following combinations show the correct way in which the components are involved?

A (ii) + (iii) → (i) + (iv) + (v)
B (ii) + (iv) → (i) + (iii) + (v)
C (i) + (ii) → (iii) + (iv) + (v)
D (ii) + (v) → (i) + (iii) + (iv)

1.1.3 The conversion of pyruvic acid into lactic acid occurs during

A photolysis.
B glycolysis.
C anaerobic respiration.
D oxidation of glucose.

1.1.4 A phase that does not require oxygen during cellular respiration is:

A Krebs cycle.
B Glycolysis.
C Oxidative phosphorylation
D All of the above

(4 × 2) = (8)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The process during which glucose is converted into pyruvic acid.
1.2.2 The reagent used to test for the presence of carbon dioxide.
1.2.3 The acid that accumulates in the muscles of humans during continuous strenuous physical activity.
1.2.4 The gas which is essential for the Krebs cycle to occur.
1.2.5 Folded structures found on the inner membrane of a mitochondria.
1.2.6 The stage of aerobic respiration that releases carbon dioxide.
1.2.7 Genetic material found in the mitochondrial matrix.
1.2.8 The stage during aerobic respiration when water is released as a waste product.
1.2.9 The type of anaerobic respiration that occurs in yeast cells.
1.2.10 The organelle in which respiration takes place.

(10 x 1) = (10)

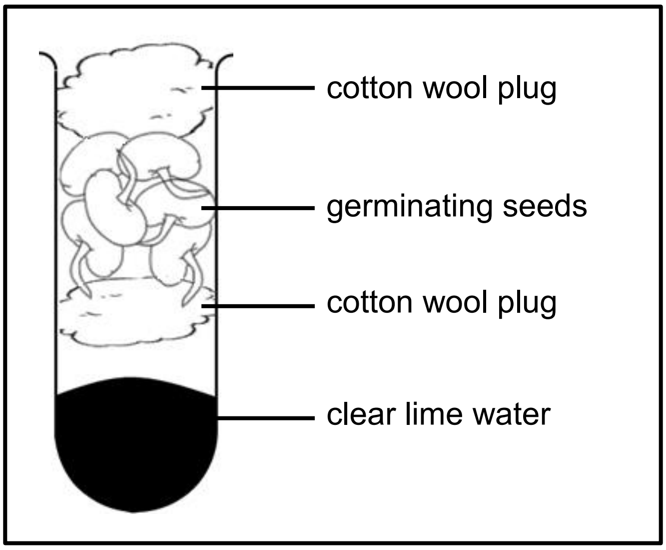
1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	**Column II**
1.3.1 The end product of anaerobic respiration in humans	A: lactic acid B: ethanol
1.3.2 A product of cellular respiration which supplies energy needed for metabolic reactions in cells	A: ATP B: oxygen
1.3.3 The fuel required for cellular respiration	A. glycogen B. glucagon
1.3.4 Molecule that stores energy	A: ADP B: ATP

(4 x 2) = (8)

1.4 The apparatus below was used to carry out an experiment on aerobic respiration. The experiment was set up as follows:

- 17 seeds of the same kind were used
- The seeds and the apparatus were sterilised before the investigation
- Once set up, the apparatus was placed in a dark cupboard at 35°C
- A control was also set up



1.4.1 What was the aim of the experiment? (2)

1.4.2 What is the significance of sterilising the seeds before they are used? (1)

1.4.3 Give one controlled variable in this investigation. (1)

1.4.4 Explain how you would set up a control for this investigation. (3)

1.4.5 Explain why germinating seeds were used in this investigation. (2)

(9)

1.5. Study the following extract and answer the questions which follow.

Many food and beverage industries are entirely dependent on the fermentation process to manufacture their products. Some of the products manufactured are being distributed and sold locally while the others are exported to foreign countries.

1.5.1 Name one food or beverage product which makes use of the fermentation process in its manufacture. (1)

1.5.2 Explain one way in which the production of foods and beverages made by fermentation benefit the South African economy. (2)

1.5.3 Describe how yeast cells benefit from the fermentation process? (2)

1.5.4 Draw a labelled diagram of the organelle in which respiration takes place. (5)

(10)

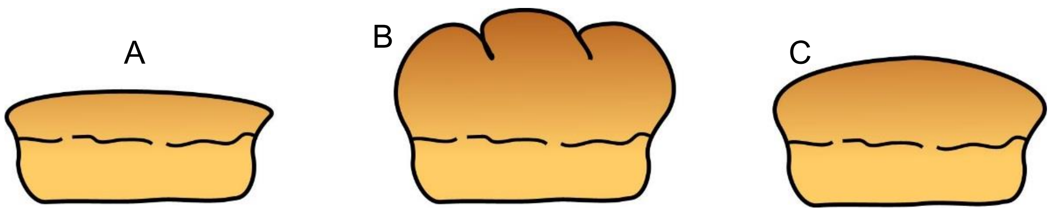
Section A: [45]

Section B

Question 2

2.1 A baker is testing a new recipe in order to bake the perfect loaf of bread. The two main ingredients in the bread dough are flour and yeast. She divides the dough into three equal parts and subjects the loaves to different treatments before baking.

- Loaf A: She immediately bakes the bread.
- Loaf B: She covers the dough with a damp cloth and leaves it in a warm area for an hour before baking it.
- Loaf C: She covers the dough with a damp cloth and leaves it in the fridge for an hour before baking it.
- After baking the three loaves she measured the height which each loaf rose. The results are shown below:



2.1.1 Formulate a hypothesis for this investigation. (2)

2.1.2 Identify:

a) the dependent variable

b) the independent variable

c) one controlled variable (3)

2.1.3 Which loaf do you consider to be the control for this experiment? Give a reason for your answer. (2)

2.1.4 One of the main ingredients is yeast.

a) Name the function of the yeast in this investigation. (1)

b) Which biochemical process allows the yeast to perform its required function? (1)

c) What is the yeast's source of glucose? (1)

2.1.5 Why is the dough of loaves B and C covered with a damp cloth? (2)

2.1.6 What conclusions can be made from the resulting baked loaves? (4)

2.1.7 How can the baker improve the reliability of her experiment? (2)

(18)

2.2 Read the information below and answer the questions that follow.

Traditional African Beer

Traditional beer forms a very important part of African culture. It is called *umqombothi* in isiXhosa and *iJuba* in isiZulu. The beer is mostly brewed from indigenous sorghum. The thick creamy African beer is very rich in vitamin B, it has a low alcohol content of less than 3% and it is inexpensive. The recipe for brewing beer is passed down through the generations.

The traditional method of testing to see if the brew is ready is to light a match close to the container of beer. If the flame dies quickly, the brew is ready. If the flames remain lit, the brew is not ready.

2.2.1 Name the biochemical process used to brew this African beer. (1)

2.2.2 What causes the flame to die? (1)

2.2.3 Why would this test be an indication of whether the brew is ready or not? (2)

A survey was done to determine the amount of people who drink industrially produced beer and traditional beer. The results for 1970 and then 1996 were as follows:

Type of beer	**Percentage of beer consumed**	
	1970	**1996**
Traditional beer	90%	30%
Industrially produced beer	10%	70%

2.2.4 Plot a bar graph to show the results of the survey. (6)

2.2.5 Describe the trend shown by the graph. (2)

(12)

Section B: [30]

Total marks: [75]

7: Gaseous exchange

CHAPTER 7: GASEOUS EXCHANGE

Introduction

It is important to distinguish between breathing, gaseous exchange and cellular respiration.

- **Breathing** is a mechanical process of taking oxygen into the lungs. Why do we need to breathe? All organisms, from simple, unicellular to more advanced multicellular organisms need oxygen (O_2) to sustain cellular functions.
- **Cellular respiration** refers to a chemical process which takes place within cells in order to release energy. Plants and animals need energy for survival.
- **Gaseous exchange** is a physical process which involves the exchange of gases between the air and the blood in the lungs. Organisms are structurally suited to ensure that the process of the exchange of gases is optimised. Mammals have a mechanism of breathing that ensures that gases enter their bodies, and this enables gaseous exchange and cellular respiration to occur efficiently.

Important aspects of gas exchange:

- **Structure to function**: how the organism is designed to carry out gaseous exchange
- **Regulation and control** of breathing in humans
- How the **amounts of gases** are kept at manageable levels in the blood
- **Disease** and certain **life choices** can impact negatively on effective gaseous exchange. Breathing can be impaired, and this affects the general health of an individual

Key terminology

diffusion	the movement of molecules from a region of high concentration to a region of low concentration until equilibrium is reached
catabolism	the breaking down of complex molecules into simple molecules to release energy
aerobic	occurring in the presence of oxygen
anaerobic	occurring in the absence of oxygen
cellular respiration	the breakdown of organic compounds (glucose / sugar) in the mitochondria of cells into inorganic products (CO_2 and H_2O) with the release of cellular energy (ATP); either aerobic or anaerobic

Efficiency of gaseous exchange surfaces in living organisms

For gases to effectively diffuse across respiratory surfaces, certain **requirements** need to be met. This is important in organisms living in both terrestrial and aquatic habitats. Table 1 below summarises the requirements of an efficient gaseous exchange surface.

Table 1: The requirements for an efficient gaseous exchange surface.

Requirement	Reason
large	a large surface area to volume ratio allows enough oxygen and carbon dioxide to diffuse
thin and permeable	diffusion can occur more rapidly and efficiently if the surface is thin and permeable
moist	oxygen and carbon dioxide diffuse when in dissolved in water
protected	all gaseous exchange surfaces need to be protected from mechanical injury as well as from drying out (desiccation)
well-ventilated	ensuring that oxygen rich air for terrestrial organisms and oxygen rich water for aquatic organisms are continually brought into contact with the gaseous exchange surface
vascular	an efficient method of transporting gases to and from the gaseous exchange surfaces is required

All organisms, from simple unicellular to complex multicellular, rely on gaseous exchange for survival. The amount of O_2 taken up and CO_2 released depends on the ratio of surface area to volume of the organism. What does this mean?

- Surface area is the combination of all the exposed surfaces of the organism.
- The volume is the space taken up by the same organism.
- Therefore, the surface area to volume ratio would be the amount of surface an organism has relative to its size.

In general, the smaller the organism the larger the surface area to volume ratio.

Relationship between respiratory structures and efficient gaseous exchange in different organisms

Both terrestrial and aquatic plants and animals have gaseous exchange surfaces and respiratory structures that ensure effective exchange of gases (O_2 and CO_2).

Key terminology

terrestrial	(plants and animals) living on land
aquatic	(plants and animals) living in water
gaseous exchange	the exchange of O_2 and CO_2 at a respiratory surface occurs at **two** places in mammals: • at a gaseous exchange surface (lungs) and the blood • between the blood and the body cells at the tissue level
breathing / ventilation	mechanical process of **inhalation** and **exhalation** through which air moves in and out of the respiratory organs enabling the uptake of oxygen and the removal of carbon dioxide.

Table 2 below compares ways in which these requirements are met in a variety of organisms: dicotyledonous plants, earthworms, insects, bony fish and mammals. For each organism, the primary organ or surface of gaseous exchange is named.

Table 2: Comparison of the respiratory surfaces of various groups of organisms

Requirement for effective gaseous exchange surface					
large	**thin & permeable**	**moist**	**well-ventilated**	**protection**	**transport system**
dicotyledonous plant (leaf and spongy mesophyll cells)					
flat surface increases exposure to air	thin-walled cells allow for diffusion	water vapour passes through stomata	air movement around leaves	cuticle and lower epidermis	simple diffusion
earthworm (skin)					
elongated, cylindrical shape	body surface is thin	mucous glands keep the worm moist	not needed – gas exchange surface on outside of body		through the skin
insect (tracheal system)					
extensively branched tracheoles	lining of tracheoles thin	tracheoles are moist	rhythmic body movements move air in and out	exoskeleton	gases in direct contact with tissues
bony fish (gills)					
branched gill filaments increase surface area	thin membranes	aquatic animals live in water	water taken in through mouth is forced out over gills	gills protected by bony cover, the operculum	heart and blood vessels present

mammals (lungs)					
bronchiole divide into many alveoli	alveoli have thin squamous epithelium	alveoli have thin layer of moisture	inhalation and exhalation during breathing	ribs protect the lungs	circulatory system

Human gaseous exchange

The human gas exchange system consists of the following distinct sections:

- air passages
- lungs
- muscles involved in the mechanism of breathing (ventilation)

The system is well designed to carry out the function of gaseous exchange. Figures 1 and 2 show parts of the respiratory system that are directly involved in breathing and gaseous exchange and Table 3 relates the structure to function of these parts.

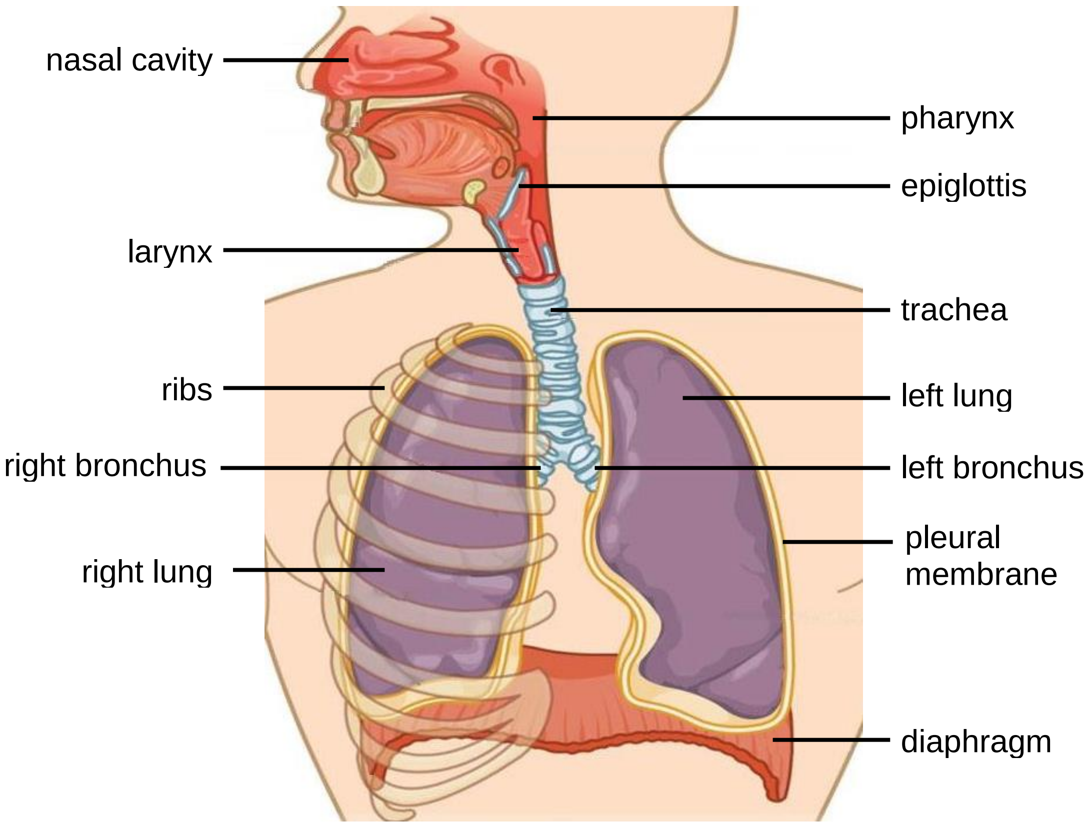


Figure 1: Human respiratory system

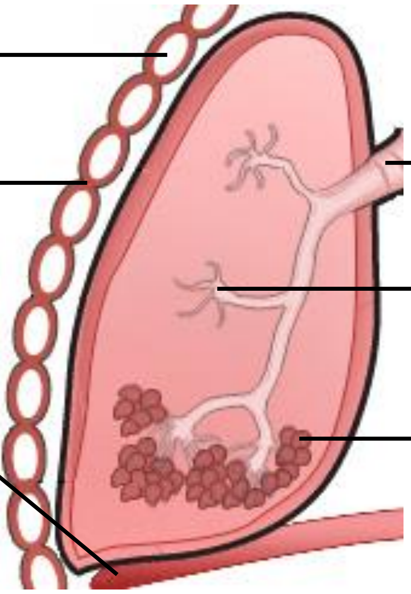


Figure 2: Right lung with alveoli

Table 3: Structures of the respiratory system with their gaseous exchange functions

Structure	Function
air passages	
2 nostrils	air inhaled through nostrils
2 nasal cavities	• cavities are lined with epithelial and goblet cells • mucous from the goblet cells together with the cilia trap dirt and sweep it out of the nose; keeps cavity moist • blood capillaries warm the incoming air
trachea	• windpipe is situated in front of the oesophagus • C-shaped cartilage rings protect trachea and keep it open for easy movement of air
bronchus / bronchi	• trachea branches into left and right bronchi that enter the upper lobes of the left and right lungs • held open by O-shaped cartilage rings; lined with mucous membranes
bronchiolus / bronchioli	• each bronchus divides into many branches, the bronchioli • these passages are smaller and narrower and do not have cartilage for reinforcement
alveoli	• bronchioli end in a collection of alveoli (air sacs) that are sites for gaseous exchange • many alveoli increase the surface area to maximise the gas exchange

	• have thin walls of squamous epithelial cells allowing for easy diffusion of gases • tissue fluid keeps the walls of the alveoli moist • a large blood capillary network surrounds the alveoli
throat and lungs	
pharynx	• connects the nasal cavity with larynx • lined with mucous membranes • leads into the trachea and the oesophagus
larynx	• larynx contains the vocal chords • air passes over the chords and sound is produced
epiglottis	• a cartilage structure on top of the larynx (voice box) • closes when food is swallowed preventing food from entering the trachea
lungs	• each of the two spongy, elastic lungs are surrounded by the double pleural membrane • pleural fluid acts as a lubricant and helps prevent friction during inhalation and exhalation
ribs and muscles involved in breathing	
ribs	• on either side of the sternum, **protect** the lungs from injury
intercostal muscles	• found between the ribs • contract and relax during inhalation and exhalation altering the volume of air in the chest (thoracic cavity)
diaphragm	• a sheet of muscle below the lungs • contracts and flattens altering the volume of the chest cavity and is important in the breathing

The Human Respiratory System:
https://www.youtube.com/watch?v=CGVOWh20ufA&list=PL9jo2wQj1WCOM7JMqSBTzhrEWFe9-0QzQ

Activity 1: Dissection

The following video (2 ½ minutes) is concise and detailed and is useful as a guide before carrying out the dissection.

Lung dissection in detail: https://www.youtube.com/watch?v=uDtZEM3FJnE

Aim: **Observe** and **investigate** the structure of the lungs, the diaphragm, associated pulmonary blood vessels and the heart of a sheep.

Requirements

N.B Safety precautions

- It is important that you listen to the safety instructions given by the teacher.
- You will be working with sharp instruments.
- Wash your hands thoroughly after completing the dissection.

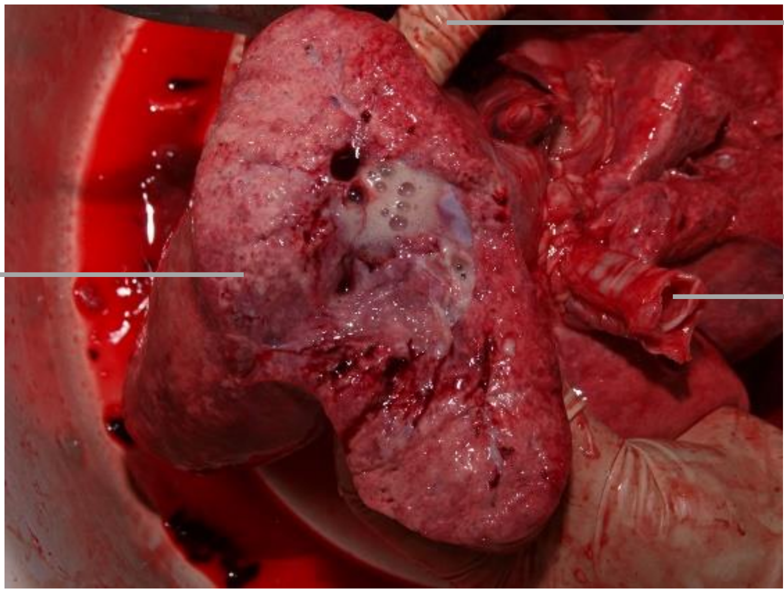
You will need the following apparatus*:*

- lungs and heart of the sheep
- a sharp scalpel or knife, and a dissecting needle
- a pair of scissors
- a dissection board
- disposable rubber gloves, soap, tissue paper
- writing paper and pen

Method

1. Lay out the sheep lungs on the dissection board and identify the left and right lungs as well as the position of the heart.
2. Observe the colour and texture of the lung tissue.
3. Run your fingers along the inside and outside of the large air passage or windpipe. What do you feel (identify structure)?
4. Follow the trachea as it branches into each lung. What are these two air passages called?
5. Follow these two air passages into the lung tissue and observe what happens as they go deeper into the lungs.
6. If the heart is still attached identify the main vessels entering and leaving the heart.
7. Identify the membrane surrounding the lungs.
8. You will now attempt to inflate the lungs using the straw. Place the straw in the windpipe and press the sides of the windpipe against the straw. Blow into the straw. DO NOT SUCK IN! Observe what happens.
9. Cut along the longitudinal axis of one of the lungs and open the lung up into two halves.
10. Cut a small piece of lung tissue off one of the lungs and place it in a small container of water. Observe what happens.

11. Clean all the apparatus and your workstation. Discard the dissection material as the teacher instructs.
12. Wash your hands thoroughly and answer the activity questions.



Sheep lung with attached air passages

Questions

1. Describe the look, texture (feel) and colour of the lungs.
2. What structures keep the trachea open?
3. Are the lungs hollow bags or spongy tissue?
4. Name the two air passages that branch off the trachea and into each lung.
5. How does the diameter of these air passages compare to the diameter of the trachea?
6. What happens to the piece of lung when you put it in water?
7. When you inflated the lung what happened after you stopped blowing in?

The mechanism of breathing (Ventilation of the lungs)

The process of breathing is a **mechanical process**. Air moves in and out of the lungs as a result of differences in atmospheric air pressure and the air pressure inside the lungs. It involves different **muscles** and **volume** and **pressure** changes in the **thoracic cavity**.

Key terminology

diaphragm	dome-shaped muscle that separates the thoracic (chest) and abdominal cavities in mammals; involved in breathing
inhalation	the breathing in of air
exhalation	the breathing out of air
spirometer	an instrument used to measure the volume of air that enters and leaves the human lungs during inhalation and exhalation

Breathing involves 2 distinct processes: **inhalation** and **exhalation**.

Inhalation – when air moves into lungs

- diaphragm muscle contracts, it flattens and moves downwards
- external intercostal muscles between the ribs contract
- ribcage lifts upwards and pushes outwards
- air pressure in the lungs decreases as the chest volume increases
- atmospheric pressure is greater than the pressure inside the lungs and air flows in
- inhalation is an **active** process involving muscle contraction

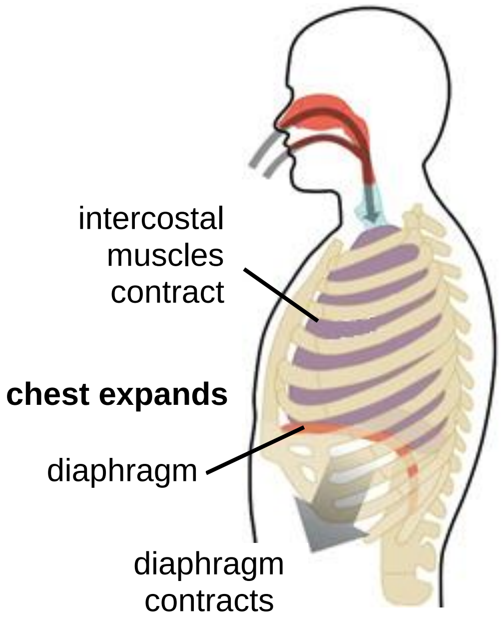


Figure 3A

Exhalation – when air is pushed out of lungs

- diaphragm relaxes and moves upwards
- external intercostal muscles relax
- ribcage moves down and inward
- air pressure in lungs increases relative to the outside air pressure
- air is forced out to equalize the pressure
- exhalation is a **passive** process when muscles relax

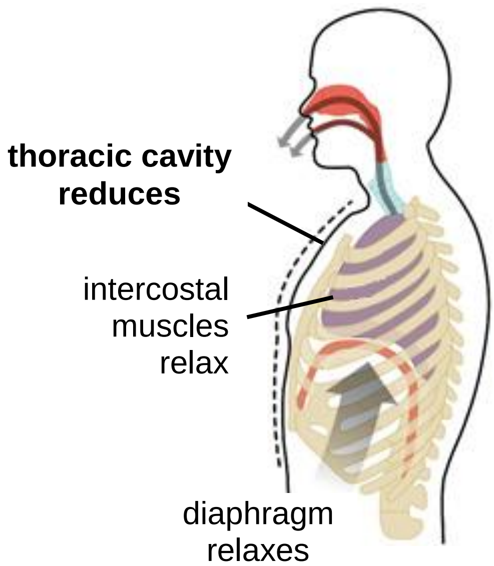
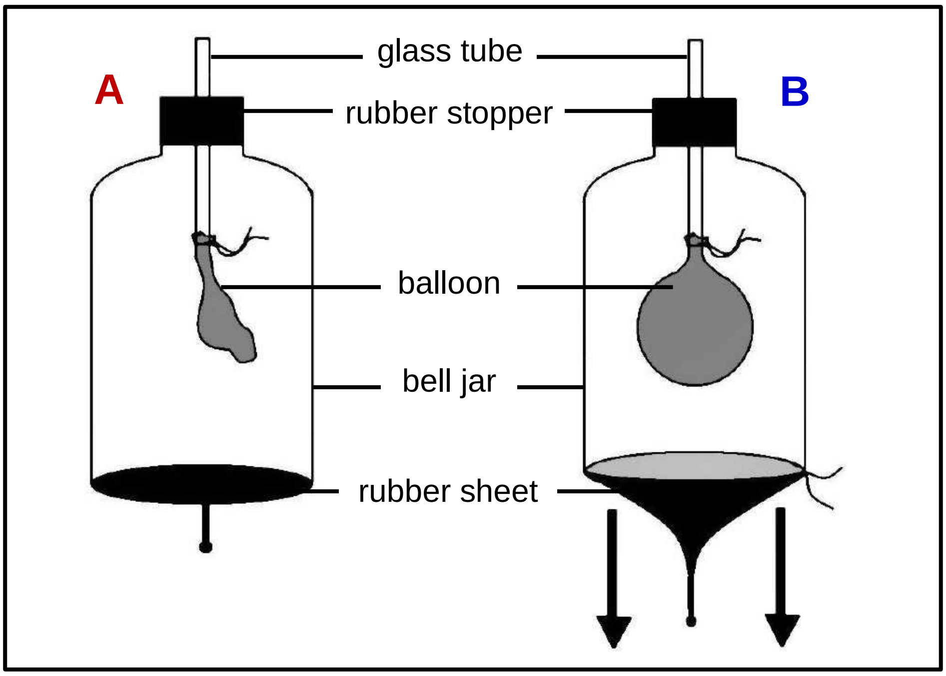


Figure 3B

Activity 2: Breathing

The following model can be used to demonstrate the mechanism of breathing.



Model of lung showing mechanism of breathing

1. For each of the model parts listed below, provide an appropriate name for the corresponding part in the human respiratory system.
   a) Glass tube (1)
   b) Balloon (1)
   c) Bell jar (1)
   d) Rubber sheet (1)
2. Does B represent an active or passive process in the human mechanism of breathing? (1)
3. What happens to the air pressure in the bell jar at B? (1)
4. What happens to the volume (size) of the space in the bell jar at B? (1)
5. What do you see as restrictions to the models when comparing them to the actual human body? Mention 2 possible **limitations** of the model shown in the Figure above. (2)

(9)

Composition of inhaled and exhaled air

The air in the atmosphere is made up mainly of nitrogen, oxygen, carbon dioxide and water vapour and traces of inert gases. Inhaled air has the same composition as atmospheric air but different to exhaled air. Table 4 shows the difference in composition of the three main gases after exercise and while sleeping.

Table 4: The composition of inhaled and exhaled air

Gas	Inhaled air (%)	Exhaled air (%) from a sleeping person	Exhaled air (%) from a person exercising
Nitrogen (N_2)	78	78	78
Oxygen (O_2)	21	16	12
Carbon dioxide (CO_2)	0,04	4	9

Nitrogen is not used in the human breathing system. Oxygen is used by the cells in cellular respiration and carbon dioxide is a product of cellular respiration and needs to be removed from the cells.

By looking at the table above:

- What is the difference between the percentage of oxygen inhaled and that exhaled from a sleeping person?
- What is the percentage oxygen used by the body in each inhalation of a person who is exercising?

- Exhaled air is often a higher temperature than inhaled air. Remember body temperature is 36,8°C.
- Lime water is a chemical that can be used to demonstrate that CO_2 is exhaled from the human lung. The lime water turns milky white when air is breathed through a straw and into it.

Effect of exercise on breathing and pulse rate in humans

Breathing is controlled by the respiratory centre in the medulla oblongata of the brain.

When a person actively exercises, the time between each breath shortens and breaths become deeper.

Activity 3: Breathing investigation

The table below shows results obtained from an experiment where 2 learners recorded their heart rates and breathing rates at rest, after walking up and down 2 sets of stairs and after running up and down two flights of stairs.

	Heart Rate (beats per minute)			**Breathing rate (breaths per minute)**		
	At rest	Walking	Running	At rest	Walking	Running
Learner 1	68	63	112	12	12	16
Learner 2	72	86	120	12	12	14

1. State the aim of the investigation. (3)
2. What do you observe happened to the heart rate of both learners after running up the stairs? (1)
3. What do you observe happened to the breathing rate of both learners after running up the stairs? (1)
4. Draw a histogram of the breathing rate of both learners at rest, after walking up and down 2 flights of stairs and after running up and down the 2 flights of stairs. (6)
5. Write a conclusion that can be drawn from the above experiment. (3)

(14)

Internal and external gaseous exchange in humans

The exchange of gases occurs in two areas in the body. At the **alveoli** surface (**external gaseous exchange**) and between the **blood and tissues** (**internal gaseous exchange**).

Key terminology

erythrocytes	red blood cells
haemoglobin	oxygen carrying protein pigment in the blood
altitude	height above sea level
iron (Fe)	the element found in the haemoglobin molecule to which oxygen atoms bind

As discussed in the mechanism of breathing, air is inhaled into the lungs and the air reaches the alveoli where gaseous exchange takes place. Gases are transported in the blood to the cells throughout the body.

Blood is transported to the lungs and alveoli surface via the **pulmonary artery**. This divides into numerous capillaries which 'wrap' around the alveoli and after gaseous exchange has occurred, they combine to form the pulmonary vein.

Gaseous exchange in the lungs at the alveoli surface

The gaseous exchange at the alveoli surface is illustrated in Figure 4 below.

- The air entering the alveoli after inhalation has a high oxygen concentration compared to the oxygen concentration in the blood of the surrounding capillaries.
- The inhaled air has a lower carbon dioxide concentration than that of the blood in the surrounding capillaries.
- This results in oxygen diffusing (moving) from the alveoli into the blood and carbon dioxide diffusing (moving) from the blood and back into the alveoli.

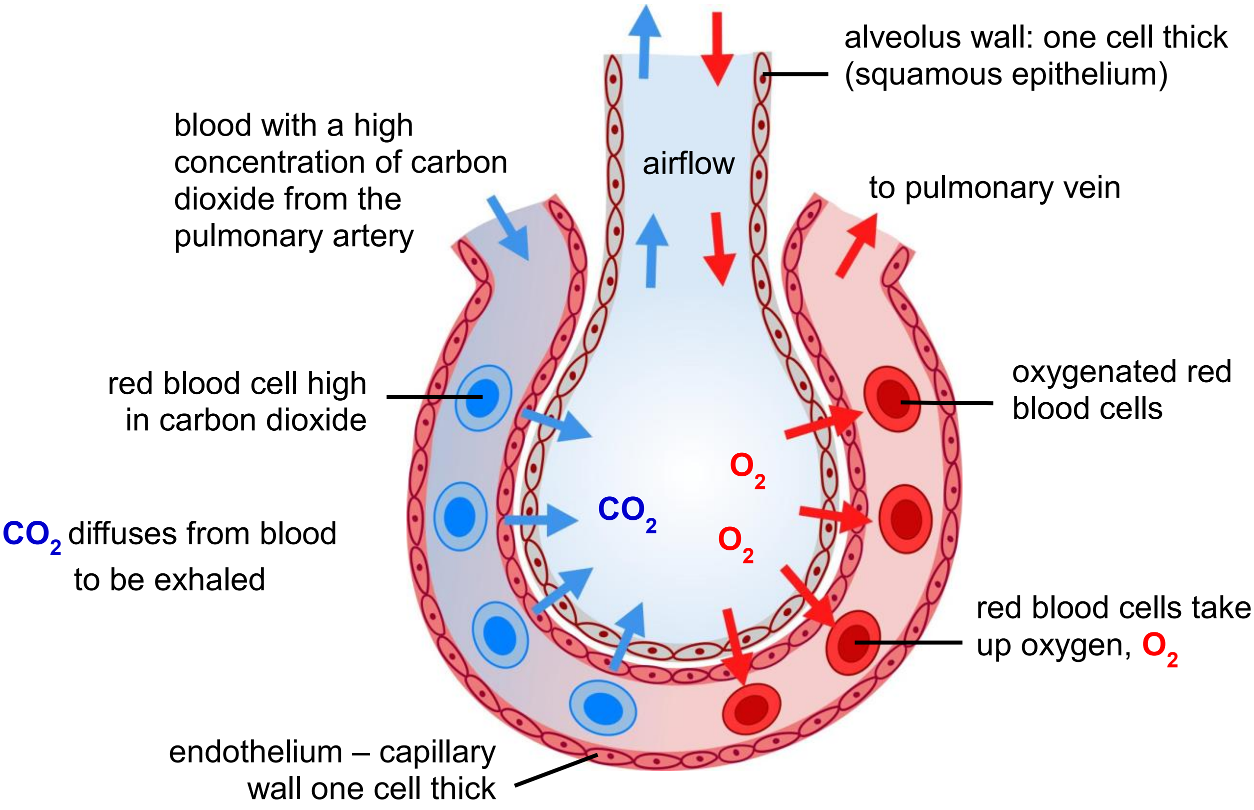


Figure 4: Gaseous exchange at the alveoli surface

- Gases are exchanged due to concentration gradients. Blood coming from the heart and past the alveoli has a low oxygen concentration – deoxygenated blood.

- The blood that leaves the alveoli has a high concentration of oxygen – oxygenated blood. The blood will take the oxygen to the cells where it is needed.
- The air in the alveoli will be exhaled with more carbon dioxide then the air that had been inhaled.

Transport of respiratory gases

Oxygen is transported mainly by the red blood cells. Most of the oxygen combines with haemoglobin present in the red blood cells (erythrocytes) to form oxyhaemoglobin. It is transported via the circulatory system to all body cells.

Most of the CO_2 is transported in the blood plasma in the form of bicarbonate ions.

Gaseous exchange in lungs: https://www.youtube.com/watch?v=aPUPfzsqDgs

Gaseous exchange between the blood and tissues

Oxygenated blood arrives from the heart in the capillary network close to tissue cells (see Figure 5). Oxygen will diffuse from the blood and into the neighbouring cells due to the concentration gradient.

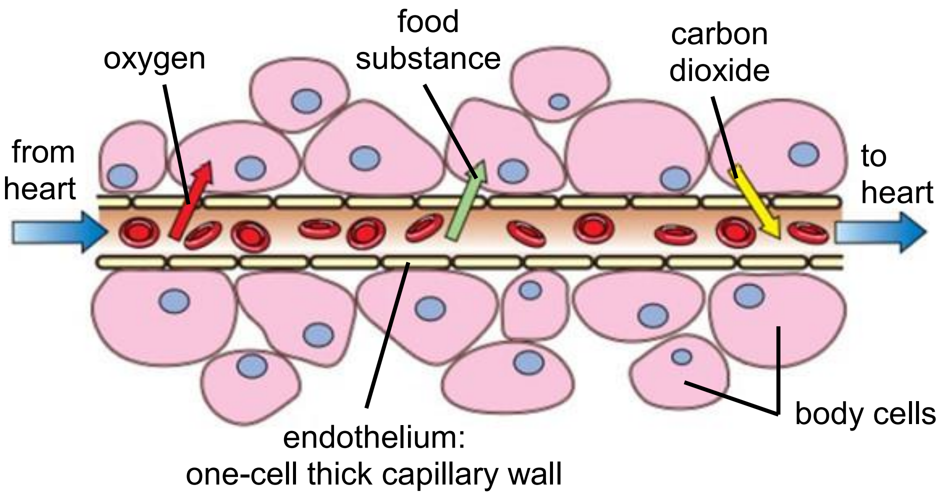


Figure 5: Exchange of gases at the tissue level

The cells will have high carbon dioxide concentrations due to continuing cellular respiration. This carbon dioxide moves out of the cells and into the blood and is transported back to the heart and then to the lungs where it is exhaled.

The cells are also bathed in a tissue fluid which supplies the necessary moisture for gaseous exchange.

The exchange and transport of gases is simplified in Figure 6. Oxygen is continually entering the blood stream at the alveoli surface and is transported to the body cells. Carbon dioxide is transported from the cells to the alveoli where it is removed from the body.

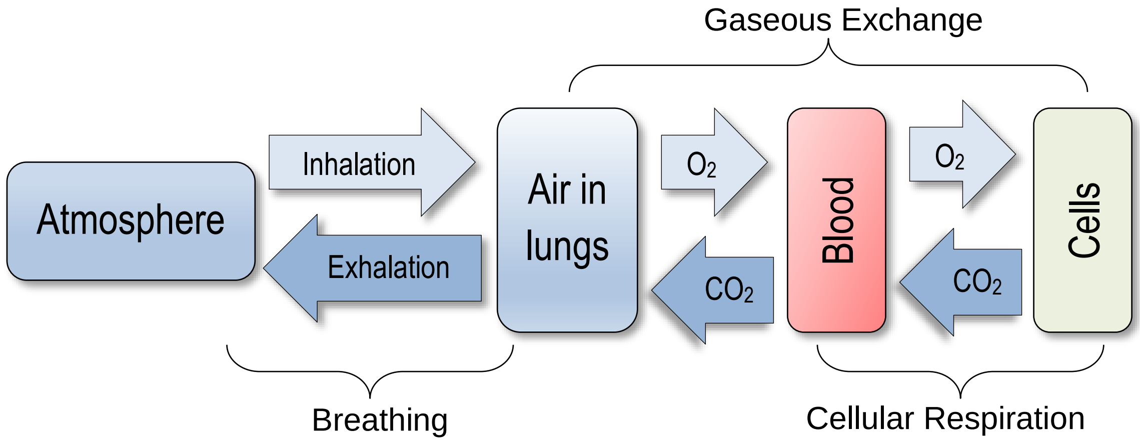


Figure 6: Flow chart summarising the exchange and transport of gases

Homeostatic control of breathing

Feedback loops may be described as systems which are initiated when an internal alarm is set off and where the body responds. Negative feedback mechanisms stabilize a system and return it to its normal state (refer to negative feedback mechanisms discussed in Chapter 5).

When at rest, humans have a normal, rhythmic breathing rate. The levels of carbon dioxide in the blood determine the rate and depth of breathing.

When a person begins exercising, cellular respiration is increased due to the demand for oxygen and energy in the muscles. Carbon dioxide levels rise and the cells in the respiratory centre of the medulla oblongata of the brain detect this.

The body will respond to ensure that these levels do not reach dangerous levels and respiratory muscles will be targeted. The ability of the body to return the levels to normal is known as homeostasis.

Figure 7 below illustrates the regulation of carbon dioxide levels in the internal environment.

Carbon dioxide (CO_2) levels in the blood increase **above normal levels**

↓

Receptor cells in the carotid artery in the neck are stimulated

↓

Cells send impulses to the medulla oblongata in the brain

↓

Medulla oblongata stimulates breathing muscles (intercostal muscles and diaphragm) and heart

↓

Breathing muscles contract more actively – increases the rate and depth of breathing; the heart beats faster

↓

More CO_2 is taken to and exhaled from the lungs

↓

The **CO_2 levels** in the blood **return to normal**

Figure 7: Negative feedback for homeostatic control of breathing

In homeostatic control:

- the heart rate increases – blood flow increases. Rapid transport of gases to and from the cells.
- Increased rate and depth of breathing – the intercostal muscles and the diaphragm contract and relax – more oxygen is inhaled, and more carbon dioxide is exhaled.

The effect of altitude on gaseous exchange

Altitude is a measure of the height of a place above sea level and is measured in metres. Altitude affects the exchange of gases. Johannesburg is at a high altitude. It is 1753 m above sea level.

The air is 'thinner' or less dense than in a city like Durban which is at sea level or zero altitude. This means that there is **less oxygen** in the air in Johannesburg and more air needs to be inhaled to supply the body with enough oxygen.

The concentration gradient of oxygen between the outside air and inside the body is low in Johannesburg so diffusion of oxygen is slower. Less oxygen is absorbed by the red blood cells at high altitudes. The body will compensate for this by trying to produce more red blood cells to help carry more oxygen.

Activity 4: Effect of altitude

A study was carried out on eight swimmers (2 females and 6 males). They were all record holders and had participated in National championships and the Olympic games. These swimmers attended a 23 day camp which was at an altitude of 2300 metres above sea level. Before and after the camp their blood was tested for their red blood cell count and haemoglobin concentration. Their performance was also measured before and after the camp by looking at their times in races. Six out of the eight swimmers improved upon their performances after the camp.

The table below shows the average changes in the swimmer's blood before and after the high altitude training camp.

	Before camp	**After camp**
Red blood cells (millions/mm^3)	4,69	5,37
Haemoglobin (g/dL)	14,8	16,8

(adapted from Biol.Sport 2012: Athletic performance of swimmers after altitude training (2300M above sea level) in view of their blood morphology changes https://researchgate.net/)

1. Name two observations that could be made relating to the altitude training. (2)
2. Provide another name for red blood cells. (1)
3. What is the function of haemoglobin in the blood? (1)
4. Which important element is found in haemoglobin? (1)
5. Calculate the average increase in red blood cells of the swimmers after camp training. (3)
6. Identify a dependent variable in the above table. (1)
7. What would the advantage be for a swimmer to train at high altitudes before participating in an Olympic event? (2)
8. How can the reliability of the results obtained in the above experiment be improved? (2)

(13)

Diseases of the respiratory system

Pathogens (viruses and bacteria), environmental pollutants (pollen and smoke) and carcinogens (cancer causing substances) can negatively affect the human respiratory system.

Table 5 gives a summary list of diseases of the respiratory system, their causes, symptoms, treatment and prevention.

Disease / Disorder	Cause/s	Symptoms	Treatment / Prevention
Bronchitis	• Viral, bacterial or fungal infection of bronchi and bronchioli	• Bronchi /bronchiole red and swollen (inflammation) • Mucous • Fever	• Antibiotics • Pain tablets • Rest
Hay Fever	• Allergy to dust, pollen and spores(mould) • *Allergens* are triggers	• Itchy eyes, nose and throat • Inflammation of lining of respiratory surfaces • Mucous • The release of *histamines* causes these symptoms	• Antihistamines • Eye drops • Nose spray
Asthma	• Allergic reaction to substances	• Tight chest • Difficulty in breathing • Wheezing and coughing	• Preventative medicines • Steroid pumps • Anti-allergy medication
Emphy-sema	• Inhalation of cigarette smoke • Exposure to dust from mining and noxious (poison-ous) gases	• Inefficient gas exchange • Breathing difficulties • Fluid in lungs • Thick phlegm	• Oxygen ventilator
Lung Cancer	• Smoking of tobacco • Exposure to carcinogens	• Breathing difficulties • Blood in the sputum (phlegm)	• Surgery • Radiation • Chemotherapy • Oxygen
Tuber-culosis	• Bacterium, *Mycobacterium tuberculosis*	• Excessive coughing • Tiredness, weakness • Loss of appetite and weight	• Antibiotics

The effects of smoking on respiratory organs

Cigarette tobacco is known to cause a variety of **respiratory diseases**. Smoking of cigarettes has a link to diseases such as: lung cancer, heart disease, high blood pressure, emphysema and bronchitis. The three main ingredients, **carbon monoxide, tar and nicotine** have adverse effects on the respiratory surfaces, and this can lead to reduced lung function.

Smoking legislation in South Africa

South Africa instituted the Tobacco Products Control Act. This legislation limits the habits of smokers and is aimed at protecting children and non-smokers from the dangers of cigarette smoke. Laws that are in place are:

- No smoking in public places like restaurants
- No advertising or promotion of tobacco products
- Health warnings visible on packaging of cigarettes
- Nicotine and tar content to appear on packaging

Members of the public that break these laws are liable for heavy fines.

The introduction of the electronic or e-cigarette, has also created controversy. There is ongoing research to determine the effects of this habit on respiratory health for the smoker as well as the general public.

Artificial respiration and resuscitation (CPR)

A person who has stopped breathing and is non-responsive needs urgent attention. There are many reasons why this situation arises. It may be caused by a heart attack, drowning, electric shock and even choking. The person cannot breathe for themselves and will need their lungs to be ventilated artificially. This can be done by mouth to mouth resuscitation or with a ventilator. Chest compressions also need to be applied.

3 important steps (A, B and C) can be used to assist a person in this situation:

A Airway – open the airway. Lift the head and tilt the chin

B Breathing – check breathing and if not breathing apply CPR

C CPR – 30 compressions: 2 breaths. Continue until help arrives

Gaseous exchange: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A- D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Cilia are found lining which of the following structures?

A larynx
B alveoli
C trachea
D pleural membranes

1.1.2 Air breathed out is different from air breathed in because it:

A contains less carbon dioxide.
B is cooler.
C is drier.
D contains less oxygen.

1.1.3 The lungs of a long-term smoker will have:

A constricted bronchioles.
B thinner walls.
C a larger surface area.
D an increased capacity for gaseous exchange.

1.1.4 Which of the following does not occur during inhalation in a human?

A Pressure within the thoracic cavity increases.
B The lungs expand.
C The diaphragm contracts.
D Pressure in the abdominal cavity increases.

1.1.5 The rate of breathing is regulated by the medulla oblongata, mainly…

A under voluntary control.
B according to oxygen level of blood.
C according to the blood pressure.
D according to carbon dioxide level of blood.

(5 × 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The double membrane that covers the outer surface of the lungs.
1.2.2 A chronic medical disorder of the lungs in which the air sacs are dilated or enlarged and lack flexibility.
1.2.3 The cartilaginous structure that contains the vocal chords.
1.2.4 Instrument that measures the rate and depth of breathing.
1.2.5 The liquid part of blood.
1.2.6 A measure of the height above sea level.
1.2.7 Tiny air sacs at the end of each bronchiole.
1.2.8 Dome-shaped muscle separating the thorax from the abdomen.
1.2.9 Movement of air into the lungs.
1.2.10 The main branches of the trachea that lead to the lungs.

(10 × 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	**Column II**
1.3.1 Mouth-to-mouth respiration	A: artificial respiration B: resuscitation
1.3.2 Breathing muscles	A: intercostal muscles B: diaphragm muscles
1.3.3 C-shaped cartilaginous rings	A: oesophagus B: bronchioles
1.3.4 The structure that prevents food particles entering the lungs	A: epiglottis B: glottis
1.3.5 Transport of carbon dioxide in the blood	A: calcium carbonate B: bicarbonate ions

(5 × 2) = (10)

1.4 Read the extract below and answer the questions that follow:

Miss SA talks about her battle with TB, launches new campaign

Miss SA for 2018, Tamaryn Green, was diagnosed with TB in 2015. She has launched Tamaryn's #BreakTheStigma campaign and hopes to highlight the TB epidemic. She had the following to say: "My campaign is based around breaking the stigma with regards to TB. It's about raising awareness that TB is curable, but it's still killing so many people, so action needs to be taken. … I'm going to be the voice behind TB". One of the side effects she suffered from the treatment to fight the disease was drug-induced hepatitis (inflammation of the liver). As part of her campaign she plans to create short educational videos that will teach people about the signs and symptoms of the disease, testing for the disease and the treatment of the disease.

https://www.channel24.co.za/The-Juice/News/miss-sa-talks-about-her-battle-with-tb-launches-new-campaign-20180830-2

1.4.1 Which pathogenic organism causes TB? (1)

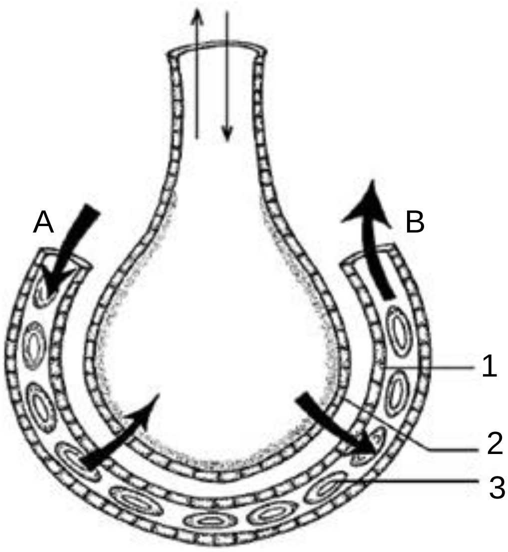
1.4.2 Tamaryn suffered with side-effects while on treatment for her TB. What is the recognised treatment for the disease? (1)

1.4.3 Give three symptoms that a TB sufferer might experience. (3)

1.4.4 What viral disease has caused TB infection to rise in the South African population? (1)

(6)

1.5 The diagram below represents a section through an alveolus and a surrounding blood capillary in the human body.



Structure of an alveolus

1.5.1 Name the type of epithelial tissue numbered 1 and 2. (2)

1.5.2 Identify the blood cell labelled 3. (1)

1.5.3 What pigment is found in the cell mentioned in question 1.5.2? (1)

1.5.4 Which type of blood:

a) enters the blood capillary at A? (1)

b) leaves the blood capillary at B? (1)

1.5.5 In which form is most oxygen carried in the blood? (1)

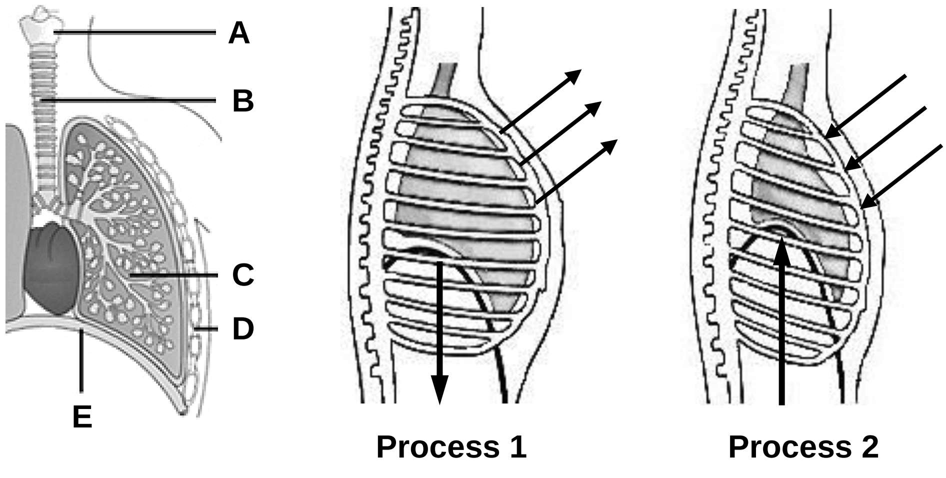
1.5.6 Supply two structural adaptions of the alveoli which make them well suited for gaseous exchange. (2)

(9)

Section A: [45]

Section B
Question 2

2.1 Study the diagrams below showing some parts of the human respiratory system. Answer the questions that follow.



2.1.1 Identify parts A, B and C. (3)

2.1.2 Which process in the above diagram illustrates inhalation (Process 1 or Process 2)? (1)

2.1.3 Give three reasons from the diagrams to support your answer to question 2.1.2. (3)

2.1.4 Give the letters and the names of the muscles shown in the diagram that are involved in inhalation. (4)

2.1.5 Draw and label a diagram showing gaseous exchange at the tissue level. Use arrows to show the direction of the gas movement. (5)

2.1.6 When one makes use of a heater to warm a room, one is advised to place a small bowl of water next to the heater. Explain the purpose of this practice. (4)

2.1.7 A person's thoracic wall is punctured in an accident. Explain how this injury will affect the breathing process. (2)

(22)

2.2 An investigation was conducted to determine the effect of smoking on the prevalence of other diseases. Study the table below and answer the questions that follow.

	Mortality rate per 100 000		
Diseases	**Active-smoker**	**Passive smoker**	**Non-smoker**
Lung cancer	200	190	11
Cancer of the mouth or larynx	30	20	6
Other cancers	195	80	105
Respiratory diseases	60	56	12
Heart diseases	220	138	80
Other medical conditions	70	40	35
Suicide, homicide, accidents	70	75	20

2.2.1 State the dependent variable for this investigation. (1)

2.2.2 Draw a bar graph representing the above information for active smokers. (6)

2.2.3 State how many smokers per 100 000 die of heart disease. (1)

2.2.4 Indicate the ratio between active smokers, passive smokers and non-smokers that die of respiratory disorders. (2)

2.2.5 Suggest two controlled variables that can improve this investigation. (2)

2.2.6 What is the effect of smoking on the prevalence of cancer? Use the information in the table to explain your answer. (1)

2.2.7 Discuss the effect that smoking has on the bronchioles and alveoli of the lungs. (3)

2.2.8 Suggest why South Africa has strict laws that control smoking in public places. (2)

(18)

2.3 Jane is training for a race by running 20 km every day. Describe how carbon dioxide produced in her body during training is controlled to maintain normal levels. (5)

Section B: [45]

Total marks: [90]

8: Excretion in humans

CHAPTER 8: EXCRETION IN HUMANS

Introduction

An accumulation of waste is dangerous to the cells, tissues, organs, systems and the body as a whole. The human body is designed to effectively remove waste.

This chapter will briefly look at excretion in various organs, the substances excreted by each and the origins of these substances. There will be a detailed focus on the human urinary system and the structure and functioning of the human kidneys. It is these organs that filter the blood, regulate water and salt levels and play an important role in the control of blood pH levels.

Kidney functioning can be weakened by diseases, lifestyle choices and accidental injuries. Renal or kidney failure can be effectively treated with dialysis or kidney transplants which are successfully carried out in many hospitals in South Africa.

Key terminology

excretion	the removal or elimination of metabolic waste from an organism
secretion	the release of a useful substance (enzymes, saliva) from cells or glands
egestion	the removal of undigested food solid waste from the digestive tract in the form of faeces = defaecation
metabolism	chemical reactions that take place within every cell of the body. these can be building up (anabolic) or breaking down (catabolic) reactions
renal	relates to the kidney
deamination	removal of an amino group from amino acids

Excretory organs

In human digestion, carbohydrates, proteins, fats and vitamins are broken down into their simplest form and enter the blood stream to be utilized where they are needed.

Excretory waste products include CO_2, H_2O, bile pigments, urea and mineral salts. Table 1 summarises how they are produced, the organs involved in their excretion and the final products of excretion.

Table 1: Excretory organs and their waste / excreted product

Waste products	Origin	Excreted product
Lungs		
carbon dioxide and water vapour	cellular respiration	CO_2 and $H_2O(g)$ in exhaled air
Skin (sweat glands)		
mineral salts, traces of urea, water	extracted from the blood	perspiration (sweat)
Liver		
urea	deamination of excess amino acids	faeces
bile pigments	breakdown of haemoglobin	
Colon		
bile pigments, excess mineral salts	from the breakdown of haemoglobin in the liver	faeces
Kidney		
urea	deamination of excess amino acids in the liver	urine
mineral salts	excess taken in with food	
water	excess water consumed and taken in as food	

The urinary system

Key terminology

osmoregulation	the control of water levels in the body
adipose	fat tissue
aorta	the main artery leaving the heart, supplying body with blood
renal artery	brings oxygenated, unfiltered blood to the kidneys
renal vein	carries deoxygenated, filtered blood, from the kidneys
renal capsule	outer membrane covering the kidney

The human urinary system: https://www.youtube.com/watch?v=H2VkW9L5QSU

The two kidneys, two ureters, bladder and urethra form the urinary system. The renal blood supply, including an extensive network of blood capillaries, ensures that a steady flow of blood reaches and leaves the kidneys.

The kidney performs the following four **main functions** of the urinary system

- **Osmoregulation** – regulation of levels of H_2O in body fluids
- **Excretion** – removal of nitrogenous waste e.g. urea
- **Regulation of pH** of body fluids
- **Regulation of salt** concentration of body fluids

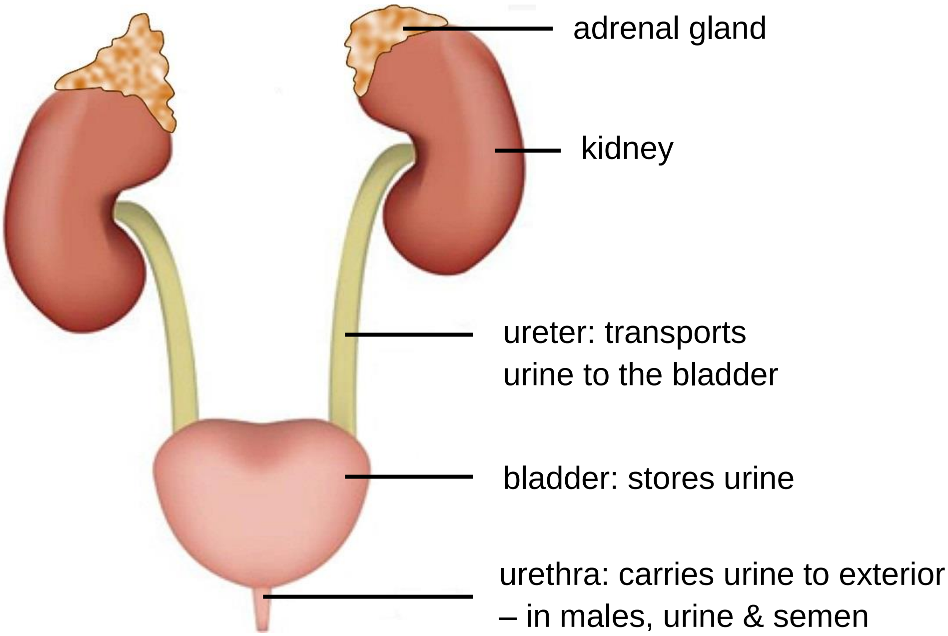


Figure 1: Structure and functions of the different parts of the urinary system

The structure of the kidney

- The kidneys are bean shaped structures (Figure 2) that are found half-way down the back just under the ribcage.
- They weigh between 115 and 170 grams each depending on the age and gender of the person and are about 11 cm long.
- The kidneys are protected by adipose (fat) tissue and each kidney is covered by a renal capsule which protects the kidney and its internal structures from infections.
- Blood carrying waste products but rich in oxygen, is taken to the kidneys by the renal artery which branches off the aorta.
- The blood is filtered by the kidney.
- Deoxygenated blood with the waste products removed, leaves the kidney through the renal vein.

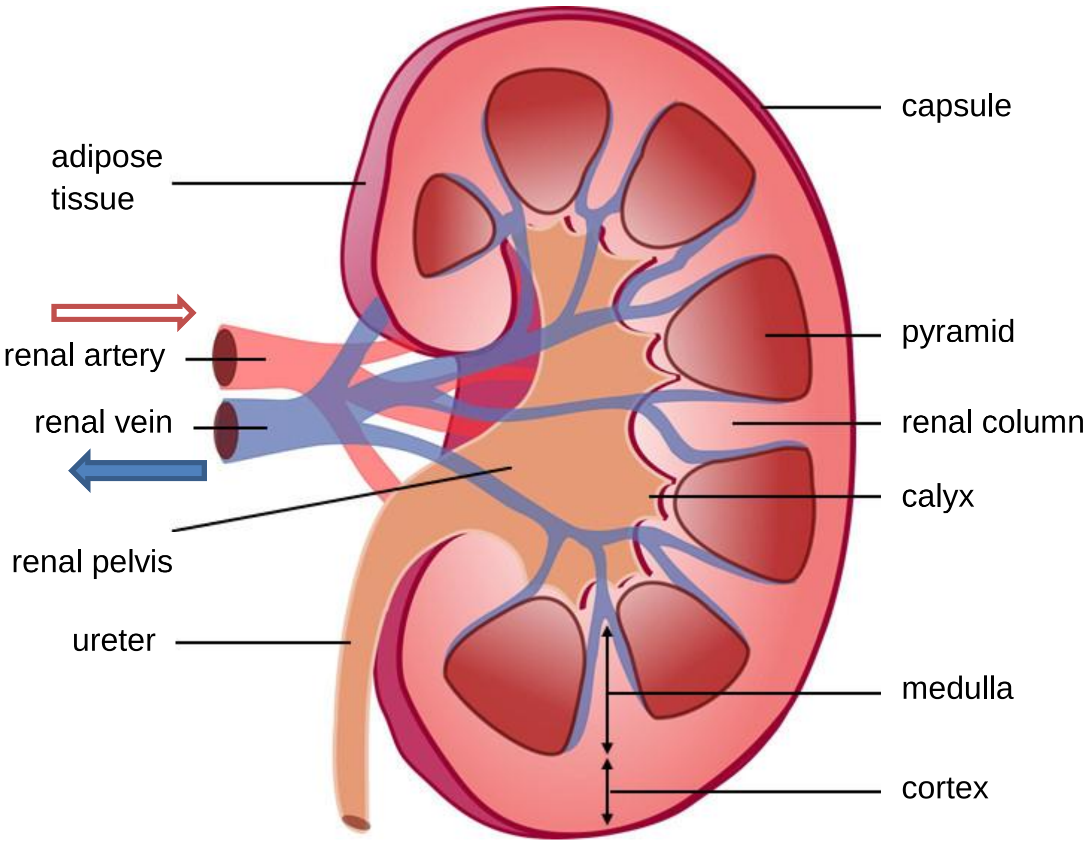
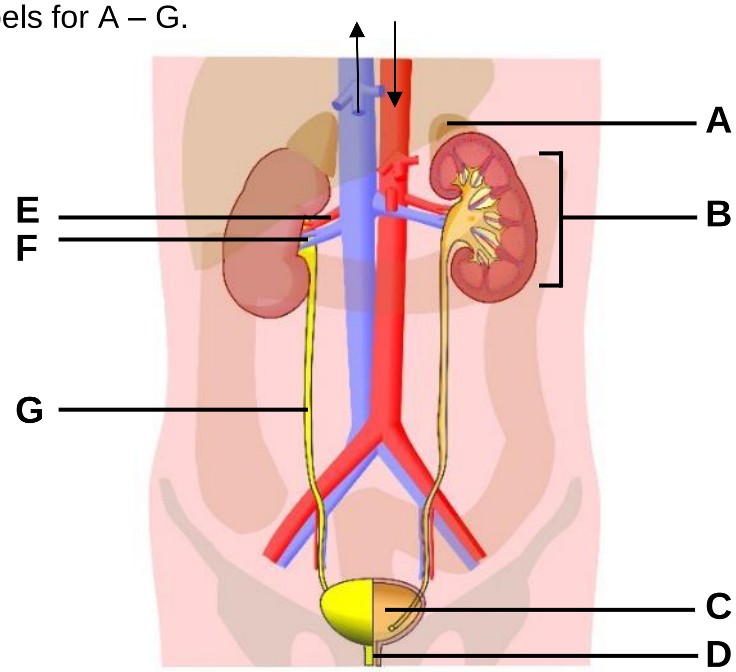


Figure 2: Longitudinal section through a kidney

Activity 1: Excretory organs

1. Supply a caption for the diagram below. (1)
2. Supply labels for A – G. (7)



3. What type of blood does E bring to the kidney? (1)
4. What is the function of the part labelled C? (1)

5. Name 4 important functions of the part labelled B. (4)
6. What 2 substances does the part D carry in adult males? (2)

(16)

Activity 2: Sheep kidney dissection

Dissection of a sheep's kidney, showing the external and internal structure: https://www.youtube.com/watch?v=nPhzYkq5YWE

Aim: To examine the external and internal structure of a mammalian kidney and related structures.

What you will need:

- sheep kidney (obtained from local butchery)
- a sharp scalpel or knife, a dissecting needle and a pair of scissors
- a dissection board, dissecting pins, and a hand lens
- disposable rubber gloves and soap
- a ruler, some white paper, writing paper and pen, tissue paper

Instructions

1. Lay out the sheep kidney on the dissection board. Remove the excess fat off the kidney.
2. Measure the length and width of the kidney.
3. Identify the 3 separate tubes entering and leaving the kidney. [renal artery; renal vein and the ureter]
4. The renal artery will have thicker walls than the renal vein.
5. Remove the thin strong membrane structure that covers the kidney.
6. Cut along the longitudinal axis of the kidney and open it up into two halves.

Figure: Longitudinal section through lamb kidney (internal structure)

7. Identify the outer cortex. This should be a deep red-brown colour.
8. Identify the light pink medulla region. Observe the appearance of this area by using a hand-lens.
9. Identify the pelvic region. This is creamy white in colour. It is the point where the 3 tubes enter/leave the kidney.
10. Clean all the apparatus and your workstation. Discard the dissection material as the teacher instructs.
11. Wash your hands thoroughly and answer the activity questions.

Questions:

1. Draw a line diagram of a longitudinal section through the kidney. Label the sections you can observe from your dissection and the colours you see. (6)
2. State the function of the (a) fat around the kidney?
   (b) renal capsule around the kidney? (2)
3. Explain why it is an advantage to have two kidneys instead of one. (2)
4. Name the artery that transports blood to the kidney. (1)
5. Where does the ureter lead to and what is its function? (2)

(13)

The structural and functional unit of the kidney

Key terminology

nephron	the microscopic functional unit of the kidney
podocytes	specialised cells lining the Bowman's capsule in the kidney
afferent arteriole	blood vessel bringing blood from the renal artery into the bowman's capsule of the nephron and forming the glomerulus
efferent arteriole	blood vessel taking blood from the glomerulus and into the peritubular capillary
glomerulus	a dense capillary network in the Bowman's capsule of the kidney
Bowman's capsule	a cup-shaped structure surrounding the glomerulus
Malpighian body / renal corpuscle	made up of the glomerulus plus Bowman's capsule
proximal convoluted tubule	the folded portion of the nephron that lies between Bowman's capsule and the loop of Henle

distal convoluted tubule	the folded portion of the nephron between the loop of Henle and the collecting tubule.
peritubular capillaries	tiny blood vessels, supplied by the efferent arteriole, that travel alongside nephrons allowing reabsorption and secretion between blood and the inner lumen of the nephron.

The kidneys are highly complex filtration organs. Once in the kidney the renal artery branches into narrower blood vessels until they are in contact with the core functional unit of the kidney, **the nephron** (Figure 3 and 4 below).

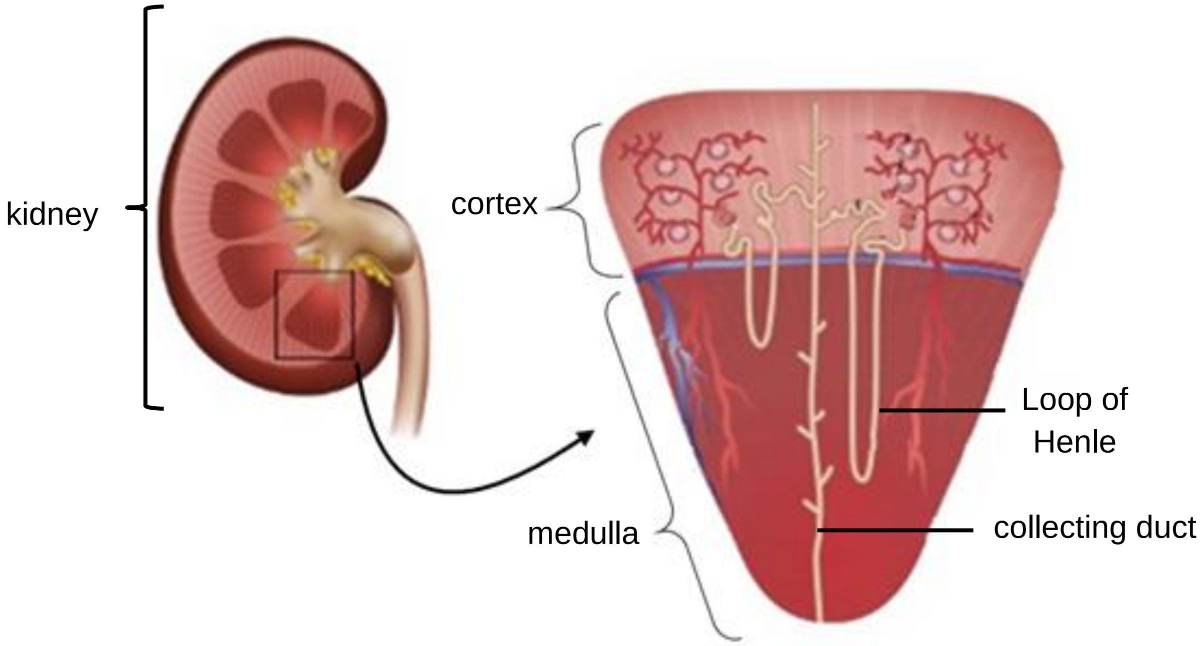


Figure 3: Kidney and position of the nephrons

Nephrons are **microscopic** coiled structures made up of tubes, arterioles, capillaries and ducts. Each human kidney has about 1 million nephrons.

Their main function is to filter the blood, regulate the waste, water and other important substances the body needs.

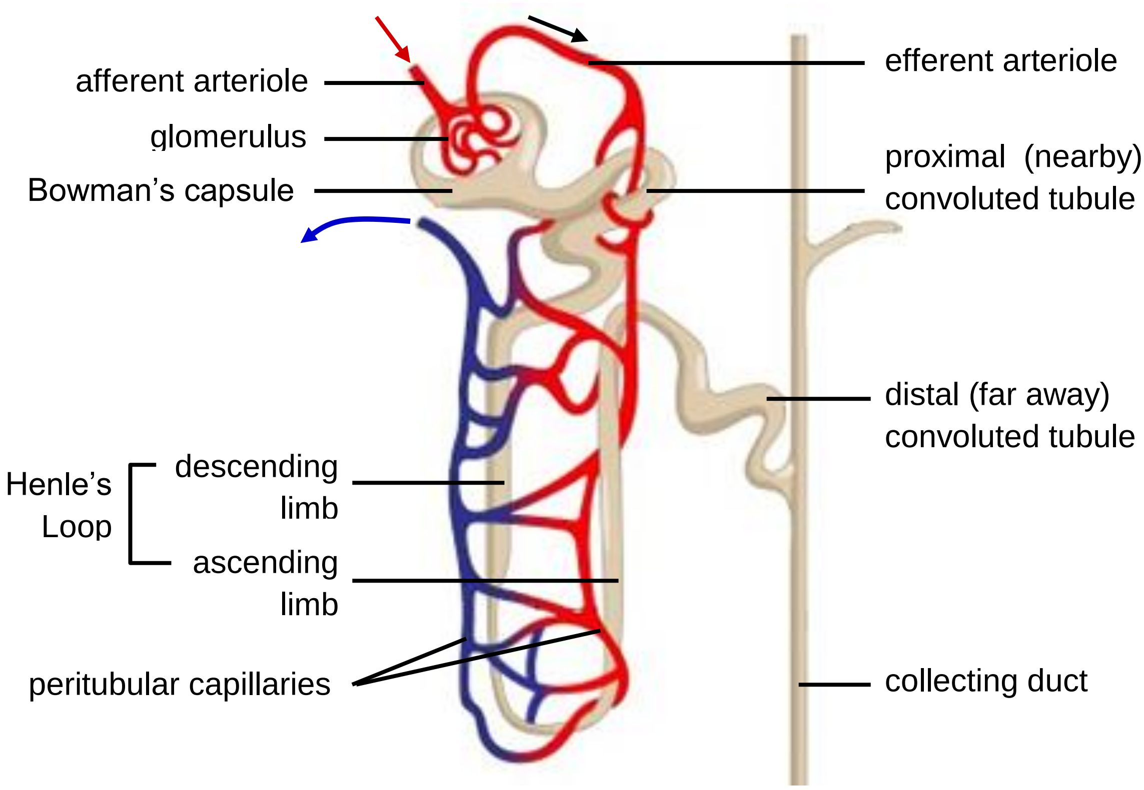


Figure 4: The structure of the nephron

The nephron can be divided into 2 separate sections – the **Malpighian body** (Figure 6) and the **renal tubule**.

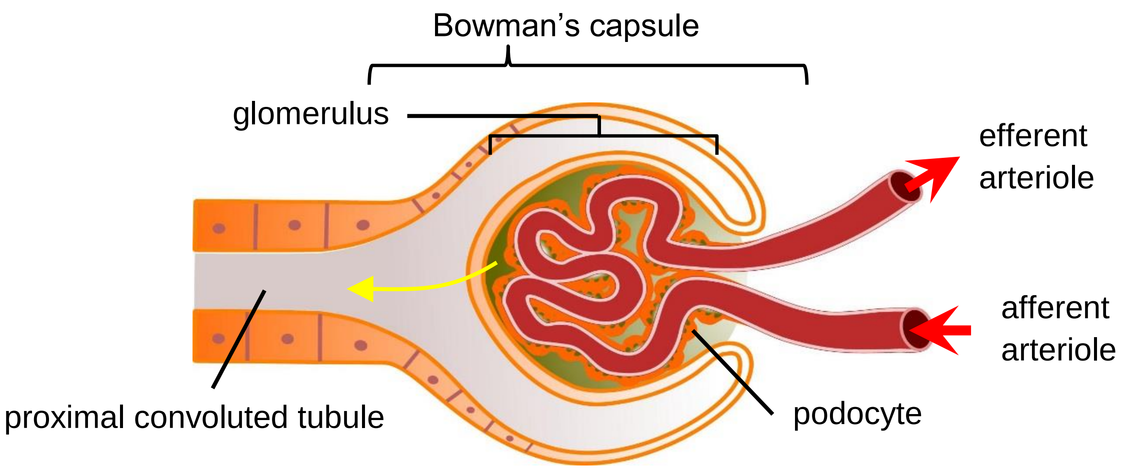


Figure 5: Malpighian body of the nephron

1. The **Malpighian body** (renal corpuscle) (Figure 6) occurs in the cortex region of the kidney: it includes the cup-shaped **Bowman's capsule** and a dense capillary network in the hollowed-out region of the capsule called the **glomerulus**.

   The inner lining of the Bowman's capsule has special cells called **podocytes**. These cells have finger-like extensions that wrap around the capillaries of the glomerulus. There are slits between these extensions to allow substances to pass through.

2. The **renal tubule:** This includes the **proximal** (first, or close to) **convoluted tubule** in the cortex, the **loop of Henle** which runs into the medulla and the **distal** (second, or distant, far from) **convoluted tubule** back in the cortex (see also Figure 4 / 5 above). The distal tubule feeds into the collecting ducts that lead to the pelvic region of the kidney. The renal tubule is surrounded by a secondary capillary network known as the **peritubular capillary network**.

   Cuboidal epithelial cells line the renal tubule and have microvilli extensions on their surface. Each of these cells has a rich supply of mitochondria. Energy supplied by cellular respiration can be used to move substances against a gradient.

Kidney functions performed by the nephron

Key terminology

hypertonic	a relatively low water and a high salt concentration
hypotonic	a relatively high water and a low salt concentration
permeable	allows substances to flow easily
dehydration	loss of water

The formation of urine involves the following (see Figure 6 below):

1. glomerular filtration or ultrafiltration
2. tubular re-absorption
3. tubular secretion
4. excretion

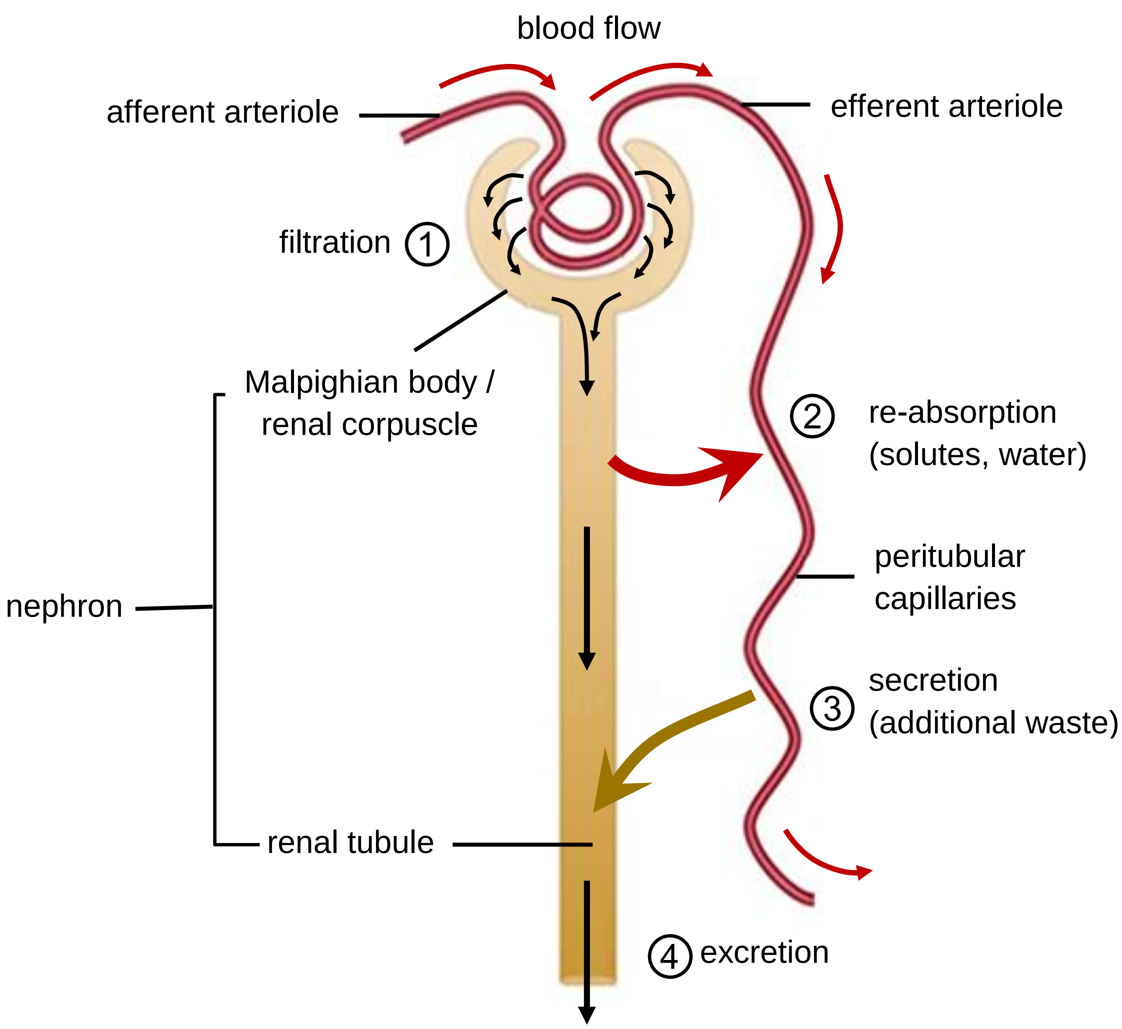
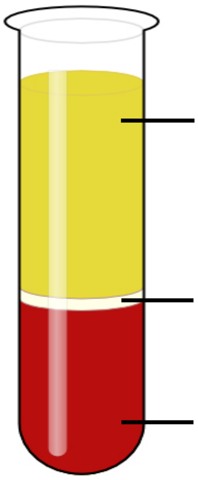


Figure 6: Diagram of the location of the main processes as they occur in the nephron

Figure 7 below is a summary of the composition of human blood. It will help your understanding of kidney functioning



liquid plasma: made up of water, dissolved gases, useful dissolved substances e.g. glucose, mineral salts, amino acids and fatty acids, dissolved waste e.g. urea, uric acid and creatinine and large proteins 55% of total blood

leukocytes (white blood cells) and platelets (< 1% of total blood)

erythrocytes (red blood cells) (45% of total blood)

Figure 7: The composition of human blood

1. Glomerular filtration

Glomerular filtration takes place in the Malpighian body of the nephron. Blood enters the glomerulus from the renal artery in the afferent arteriole and leaves the glomerulus in the efferent arteriole.

Various adaptations of the Malpighian body ensure that filtration takes place.

- The afferent arteriole is wider than the efferent arteriole. This results in the blood being put under high pressure forcing the plasma with dissolved substances into the capsular space of the Bowman's capsule.
- The walls of the glomerulus capillaries are thin and consist of a single layer of squamous epithelial cells. This together with the podocytes found on the inner wall of the Bowman's capsule make ultra-filtration possible.
- Only the smaller dissolved substances travel through the filtration slits between the podocytes. Larger proteins remain in the blood.
- Bowman's capsule is cup-shaped to enlarge the contact area with the glomerulus.

The formation of the glomerular filtrate is a non-selective process, i.e. both useful (e.g. glucose, amino acids, vitamins, minerals and water) and waste substances (e.g. urea and uric acid) are filtered through into the capsule.

2. Tubular re-absorption

Tubular re-absorption takes place in the **proximal convoluted tubule** and involves an **active re-absorption** of the glucose, amino acids, vitamins and other important substances that ended up in the glomerular filtrate.

About 65% of the water also moves back into the blood of the peritubular capillaries by osmosis. This process prevents dehydration and any unnecessary loss of important substances.

Why is tubular re-absorption efficient?

Active transport needs energy. Cuboidal epithelial cells lining the tubules have many mitochondria (site for cellular respiration). Microvilli on these same cells increase surface area for maximum re-absorption. The movement of water is by the passive process of osmosis. The fluid in the renal tubule is now called tubular filtrate.

The **Loop of Henle** (Figure 8) ensures that water is conserved and recovered from the filtrate and returned to the blood. The cells lining the ascending loop of Henle are impermeable (block movement) to water. Salt is actively pumped out of the loop and into the medulla tissue of the kidney. The medulla becomes hypertonic (very salty) which means it has a low water potential (water does not want to leave). A steep gradient develops between the tubular filtrate and the medulla tissue.

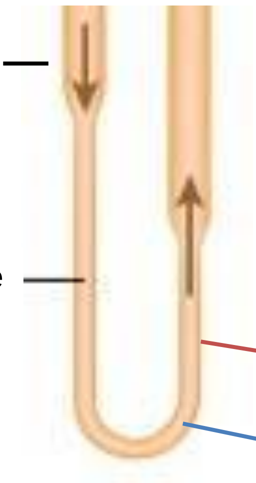


Figure 8: Section of a Loop of Henle where a steep gradient is created to conserve water (Sodium ions (Na^+) are actively pumped out and the chloride ions (Cl^-) follow.)

The **distal convoluted tubule** and the **collecting ducts** are very permeable to water so when the filtrate enters these areas water flows passively by osmosis into the medulla tissue and back into the blood of the peritubular capillaries. The amount of water that moves out of the filtrate is determined by the level of hydration of the body fluids and is regulated by the antidiuretic hormone (ADH).

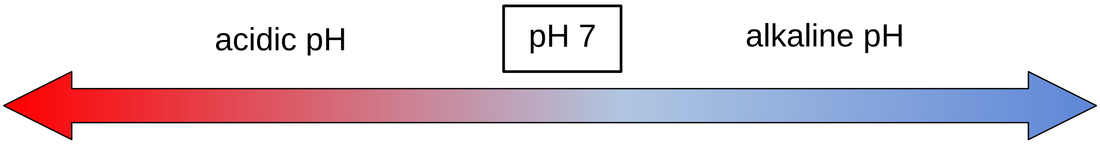
3. Tubular secretion

Tubular secretion involves the **active removal** of unnecessary substances from the blood in the peritubular capillaries into the tubular filtrate in the distal convoluted tubule. The substances removed include:

- creatinine
- ammonia
- potassium ions (K^+)
- hydrogen ions (H^+)
- sodium ions (Na^+)
- bicarbonate ions
- drugs e.g. penicillin

Homeostatic control of the blood pH

The ability of the distal convoluted tubule to take up hydrogen and bicarbonate ions is important in the **regulation of the pH** of the blood. Homeostasis is maintained.



Low pH in the blood due to **high hydrogen ion** (H^+) **concentration**

Hydrogen ions move from blood in peritubular capillaries and into distal convoluted tubule

Less hydrogen ions in the blood

pH returns to normal (pH 7,4)

High pH due to **high bicarbonate** (HCO_3^-) **ion concentration**

Bicarbonate ions move from the blood in the peritubular capillaries and into the distal convoluted tubules

Less bicarbonate ions in the blood

pH returns to normal (pH 7,4)

Figure 9: Homeostatic control of blood pH

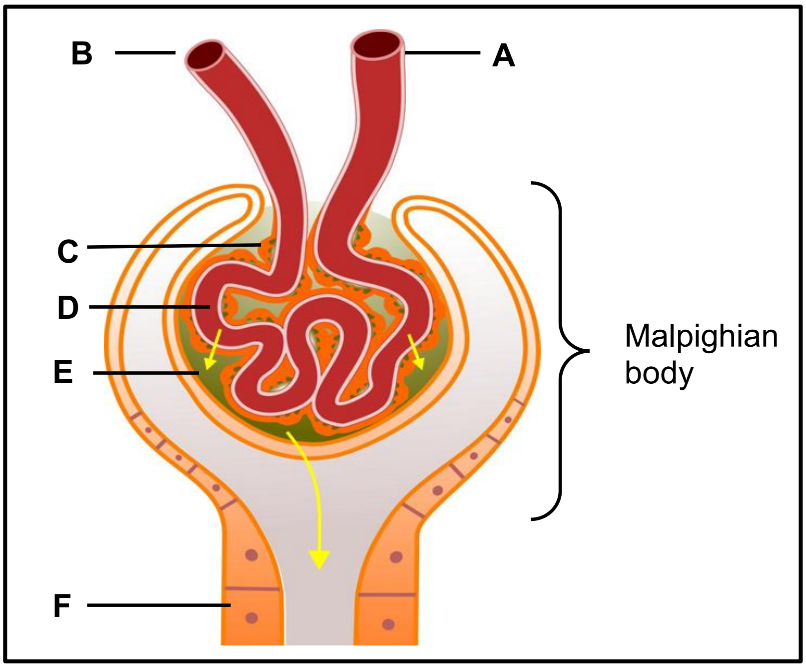
4. Excretion of urine

The filtrate that enters the collecting duct is now called **urine**. Urine consists of urea, excess water and salts. Useful substances should not be excreted in the urine.

Urine collects from all the collecting ducts in the **medulla region** and empties into the **pelvic region** of the kidney. Urine passes down the **ureter** and into the bladder. The bladder has muscles that control the release of urine into the urethra and **urination** occurs.

Activity 3: Nephron – Malpighian body

1. Structure and function of Malpighian body.



1.1 Supply labels for A – F. (6)

1.2 What two structures make up the Malpighian body? (2)

1.3 What cell types line the structures D and F? (2)

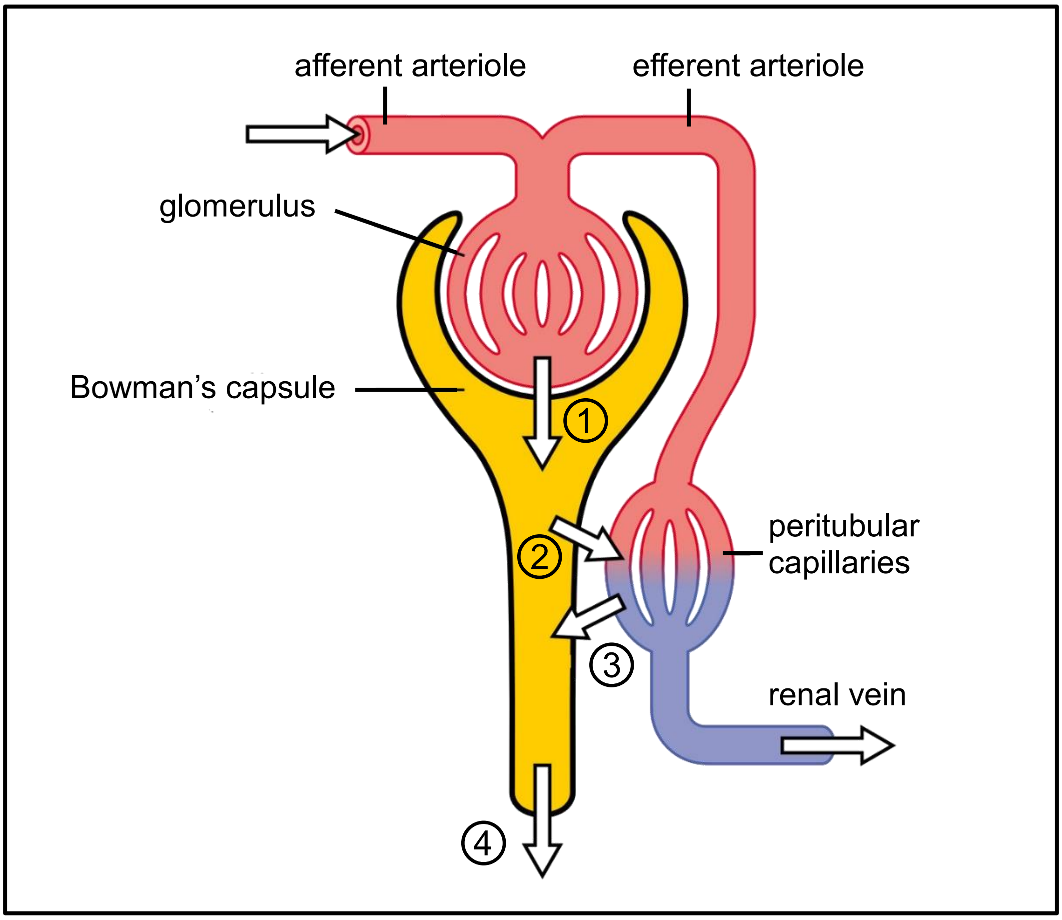
1.4 What difference do you notice between structures A and B? (1)

1.5 C has features that assist in the filtration function of the Malpighian body. Name these 2 features. (2)

1.6 Name four substances found in structure E. (4)

(17)

2. Functions of the nephron:



2.1 Name the processes shown at 1, 2, 3 and 4. (4)

2.2 Mention 3 substances that move back into the blood at process 2. (3)

2.3 Process 3 helps in homeostasis. What does it control? (1)

2.4 What would you expect to be present in urine in a healthy person? (3)

2.5 Explain why a person who regularly smokes marijuana will test positive for the drug with a urine test? (2)

2.6 Suggest two ways in which the nephrons of a desert mammal would differ from human nephrons. (2)

(15)

Homeostatic regulation by the kidneys

The human body has the ability to maintain a stable internal environment – this is homeostasis. It is important that the body's temperature is kept within a narrow range of around 37°C. The pH of the body fluids needs to be regulated and the composition of these fluids need to be kept within certain limits for effective metabolism.

The kidney is involved in 3 homeostatic mechanisms:

- the regulation of **pH** of the blood (considered above)
- the regulation of **water** levels (osmoregulation)
- the regulation of **salt** levels in the blood

Osmoregulation

The homeostatic control of water and salt levels in blood and tissue fluid is known as osmoregulation. ADH is produced by the hypothalamus and secreted from the pituitary gland and helps to limit water loss in the urine and prevent dehydration (see Table 2 and Figure 10).

Table 2: Osmoregulation

Too little water in the blood	Too much water in the blood
Dehydration is when the blood and tissue fluid are short of water	**Overhydration** occurs when the blood and tissue fluids are very dilute.
This can be brought about by excessive exercise, hot temperatures, increased sweating or decreased water intake.	This can be because of cooler temperatures, little exercise with no sweating and an excessive intake of water.
This low level of H_2O is detected by the hypothalamus of the brain.	Water levels are elevated, and this is detected by the hypothalamus.
The pituitary gland releases antidiuretic hormone (ADH)	The pituitary gland releases less ADH.

The hormone is transported in the blood to the kidney. The permeability of the collecting duct and the distal convoluted tubule is increased.	Collecting ducts and distal convoluted tubules in the kidney become less permeable.
More H_2O is absorbed and passed into the blood.	Less H_2O is absorbed into the blood.
The blood becomes more dilute and less, concentrated urine is excreted.	Less water leaves the collecting duct and more, dilute urine is excreted.

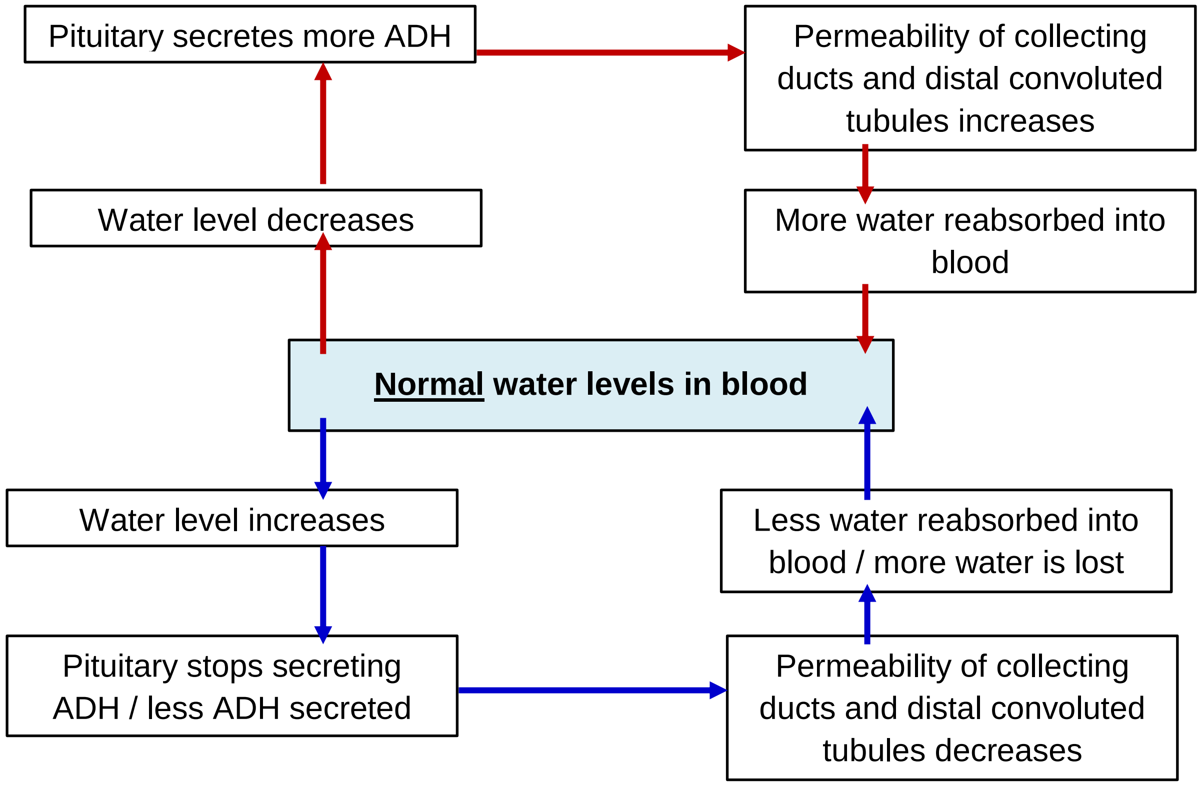


Figure 10: Homeostatic control of water in the body fluids

Alcoholic and caffeine containing drinks act as diuretics (they cause you to lose water by urinating frequently). ADH acts in an opposite way as it helps the body retain water.

Regulation of salt levels in the blood

The blood and tissue fluids are affected by the presence of solutes (dissolved substances). Sodium and potassium are salts that are found in the body fluids. Sodium is important in the body for good nerve and muscle functioning. Constant levels must be maintained (see Table 3 and Figure 11).

Table 3: Homeostatic control of salt concentrations

Low salt levels in blood and tissue fluids make these fluids **hypotonic**	Elevated **salt levels** in the blood / tissue fluids make these fluids **hypertonic**.
Receptor cells in the afferent and efferent arterioles of the glomeruli of the kidney will detect decreased Na^+ levels.	Receptor cells in the afferent and efferent arterioles will detect an increased presence of Na^+.
The adrenal gland in the kidney secretes the hormone aldosterone.	The adrenal gland will stop releasing aldosterone.
Aldosterone stimulates the reabsorption of Na^+ from the filtrate and back into the blood.	Na^+ will not be reabsorbed.
Less sodium is excreted in the urine.	More sodium is excreted in the urine.

The blood and tissue fluid returns to normal and HOMEOSTASIS is maintained. The homeostatic cycles for control of salt levels in the blood are illustrated in Figure 11.

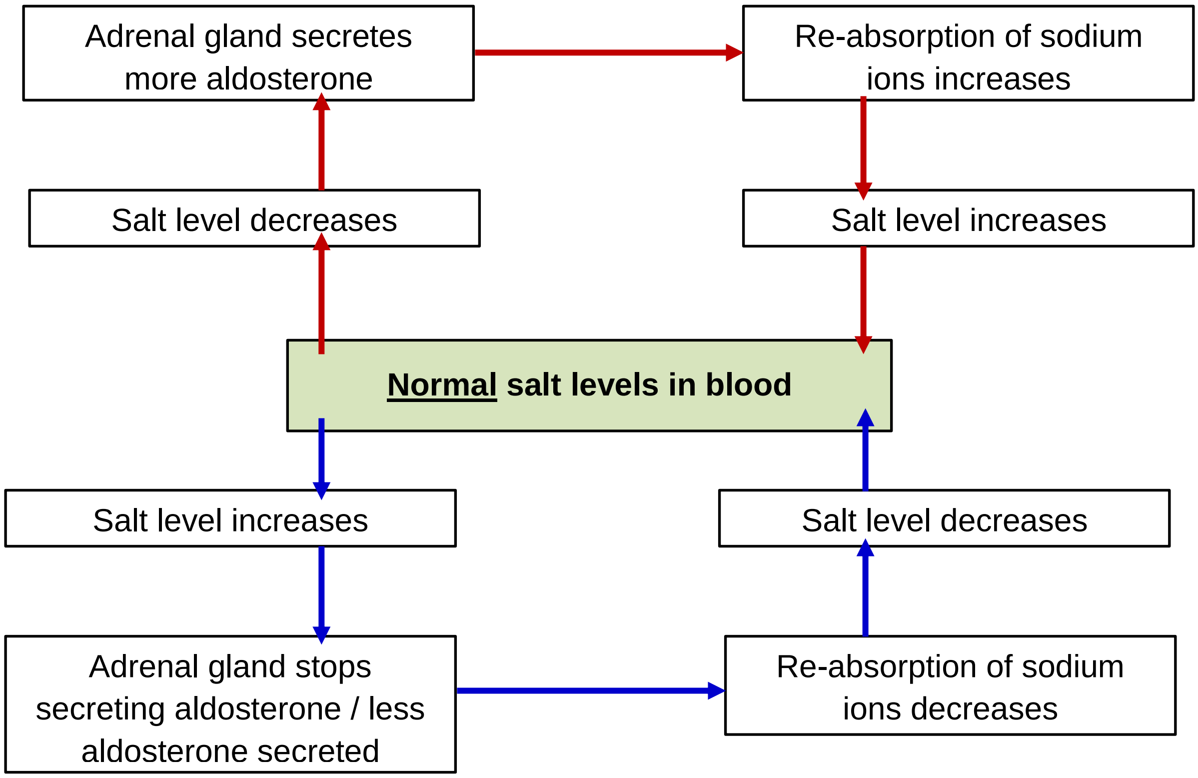


Figure 11: Homeostatic control of salt concentrations

Kidney diseases

Kidney diseases (see Table 4) can be life-threatening and require different treatments. Ineffective kidney function results in an imbalance of salts, water and pH in the blood which may reach toxic levels.

Kidney failure can happen over a period of time due to a chronic condition e.g. diabetes. A sudden injury, kidney infection or severe dehydration can lead to acute kidney failure. Severe cases of kidney failure require dialysis or even a kidney transplant.

Table 4: Diseases affecting the kidneys

kidney stones	Hard calcium granules that form in the pelvic region of the kidney. Caused by a diet high in protein, sugars and coca cola, dehydration and / or inherited conditions. Symptoms include severe back pain and blood in the urine
kidney failure	Caused by the abuse of pain medication and illegal drugs. Long term kidney damage may occur.
bilharzia infection	This disease is common in Africa, South America and Asia. It is caused by a parasitic flatworm**,** *Schistosoma***,** which is found in rivers and dams. The worm larvae which are hosted by snails in the water, attach to the skin of a human. They travel in the blood stream and then release their eggs. These eggs damage the kidneys, ureters and the bladder. The infected person will pass blood in the urine, have a fever and rashes, will be tired and often anaemic. Bilharzia can be prevented by avoiding infected water and treatment to ease the symptoms are available.

Dialysis treatment for chronic and acute kidney failure

Kidney dialysis: https://www.youtube.com/watch?v=lNX65X2iQCA

A dialysis machine is sometimes called an artificial kidney machine. Dialysis (Figure 12) involves a process where a patient’s blood is passed through a filtration system and returned to the body. Certain hospitals in South Africa have dialysis centres and patients have to book a time because of the demand for these machines. Dialysis is an expensive treatment and is scarce in the public health hospitals.

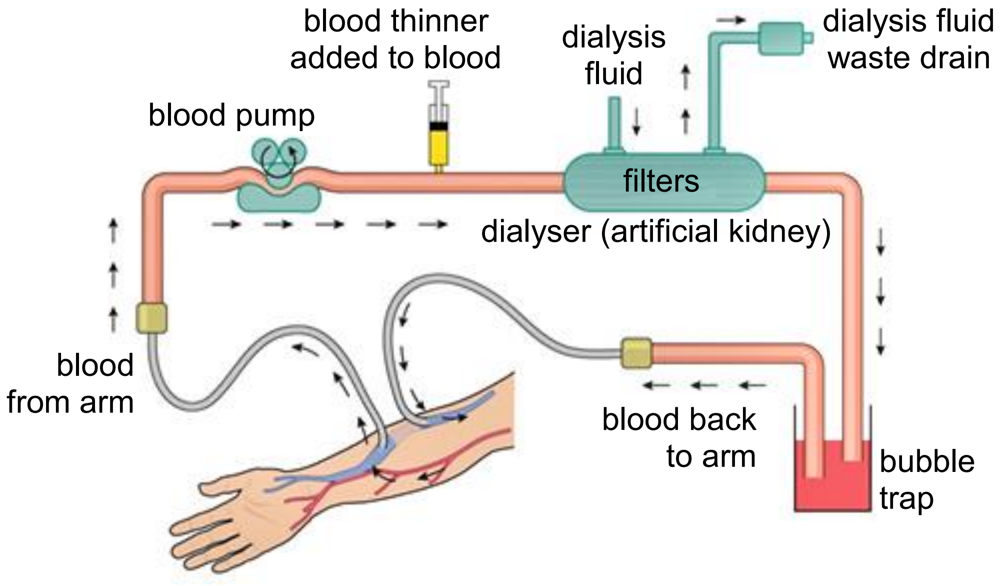


Figure 12: Functioning of a dialysis machine

Dialysis has the following disadvantages:

- Dialysis is time consuming and expensive.
- The patient is often tired after dialysis and cannot work.
- Dialysis cannot remove all the waste in the blood.
- The only long-term solution to kidney failure, is a kidney transplant.

Kidney transplants

A patient with both kidneys seriously damaged could be considered for a kidney transplant. A donor donates one of their kidneys to the patient with kidney failure (the recipient).

A person would be a suitable donor if he or she has the same blood group (A, B, AB or O) as the intended recipient, and if they have a very close tissue match. The ideal donor would be a blood relative of the patient.

The recipient might reject the donated kidney and is given immunosuppressive drugs to reduce the chances of organ rejection. These drugs can have bad side-effects and there is often a shortage of organ donors.

There are legal and ethical aspects of organ donation that need to be considered by donors and recipients in South Africa.

Excretion in humans: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A- D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Which of the following is the correct sequence of activities that occurs during kidney functioning?

A pressure filtration→ excretion → re-absorption
B re-absorption → pressure filtration → excretion
C excretion → pressure filtration → re-absorption
D pressure filtration → re-absorption → excretion

1.1.2 Which of the following is part of the circulatory system of blood?

A glomerulus
B convoluted tubules
C Loop of Henle
D Bowman's capsule

1.1.3 Which of the following will cause the kidneys to reabsorb more sodium ions?

A A decrease in blood pressure
B An increase in the volume of blood
C Constriction of the afferent arterioles
D A decrease in the amount of ADH secreted

1.1.4 If a drop in pH of the blood occurs, the kidneys will…

A increase the absorption of urea
B decrease the absorption of sodium ions
C decrease the secretion of hydrogen ions
D increase the re-absorption of bicarbonate ions

1.1.5 Which ONE of the following is a direct cause of kidney damage?

A High cholesterol
B Too little physical exercise
C Drinking hot tea
D High blood pressure

(5 × 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The process of filtering the accumulated waste products of metabolism from the blood of a patient whose kidneys are not functioning properly.
1.2.2 The functional and structural unit of the human kidney.
1.2.3 The control of water content and salt balances in the blood and tissue fluid.
1.2.4 Specialised cells with filtration slits found lining Bowman's capsule.
1.2.5 A network of capillary blood vessels inside Bowman's capsule.
1.2.6 Blood vessel that carries purified deoxygenated blood away from the kidney.
1.2.7 Outer fibrous membrane that protects the kidney against infection.
1.2.8 Tube that transports urine from the bladder to outside the body.
1.2.9 The blood vessel that carries oxygenated blood filled with waste to the kidney.
1.2.10 Part of the kidney where the Malpighian bodies are found.

(10 x 1) = (10)

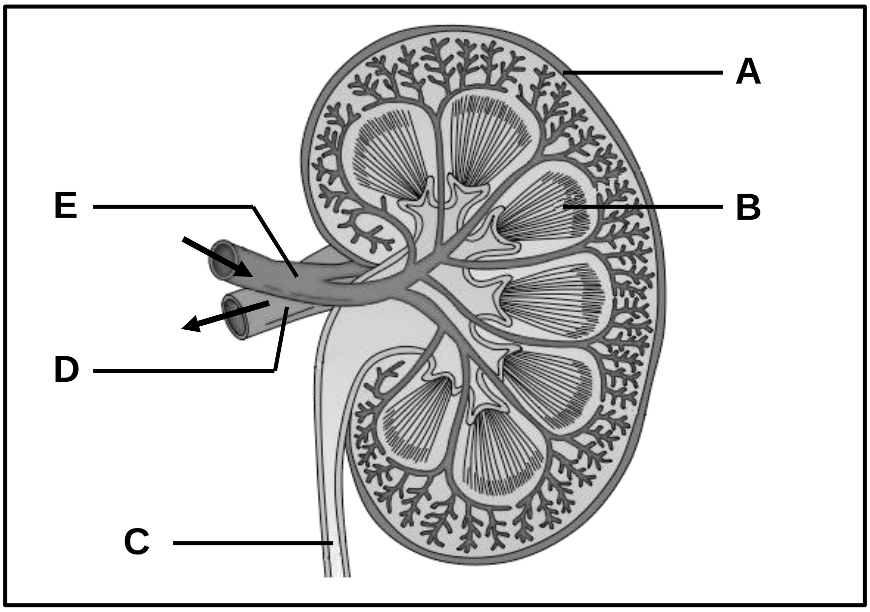
1.3 Indicate whether each of the descriptions in COLUMN I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in COLUMN II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 Blood leaving the kidney contains more of this substance than the blood entering the kidney	A: amino acids B: carbon dioxide
1.3.2 Affected by bilharzia	A: kidneys B: lungs
1.3.3 Osmoregulation	A: ADH B: TSH

1.3.4 Tube that carries urine from the kidney to the bladder.	A: ureter B: urethra
1.3.5 The hormone(s) secreted by the adrenal gland to regulate the salt concentration of the blood.	A: ADH B: aldosterone

(5 × 2) = (10)

1.4 Study the longitudinal section through the human kidney and answer the questions that follow.



1.4.1 Label parts A, B and C. (3)

1.4.2 Which labelled part becomes a site of obstruction to the flow of urine when a pellet or renal stone is dislodged. (1)

1.4.3 Mention two ways in which kidney stones can be prevented. (2)

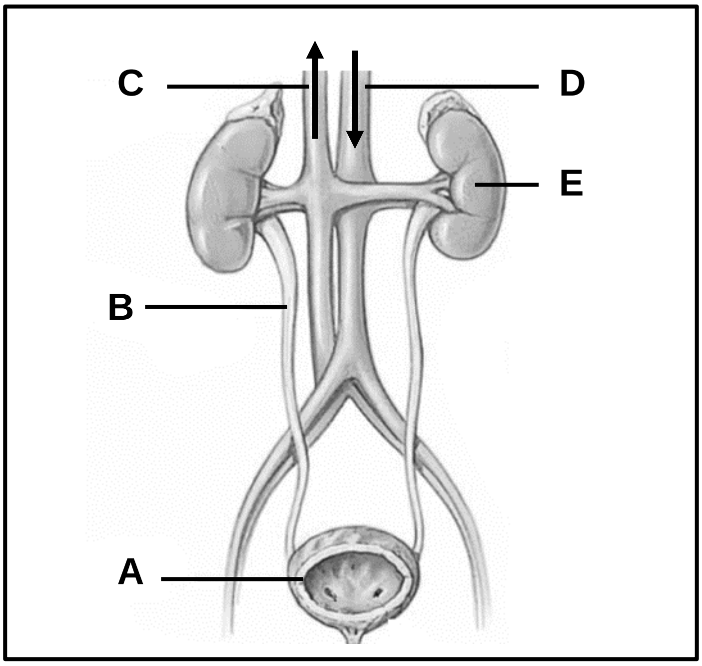
1.4.4 Mention one way in which kidney stones can be treated. (1)

1.4.5 State the name and letter of the blood vessel that contains a higher percentage of waste products. (2)

1.4.6 Which one of the labelled blood vessels has the lowest blood pressure? (1)

(10)

1.5 The diagram below shows the structure of the human urinary system.



1.5.1 Give labels for the following parts:

a) B (1)

b) E (1)

c) A (1)

1.5.2 Mention ONE difference between the composition of the blood in C and D. (2)

1.5.3 Although bilharzia it is not a notifiable disease in South Africa, in 2015 approximately 2 million children were infected with it. More than 200 million people worldwide have bilharzia. There is no vaccine for the disease, but treatment can reduce its impact on the body.

a) Name the parasite that causes bilharzia. (1)

b) The kidneys, ureters and bladder are affected by the parasite. Name 3 symptoms of the disease. (3)

c) What should you avoid doing if you are in an infected area in South Africa? (1)

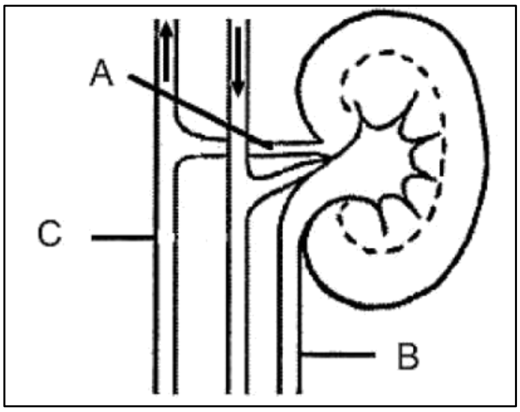
(10)

Section A: [50]

Section B

Question 2

2.1 The accompanying diagram shows part of the excretory system of the human body. Study the diagram and the table below before answering the questions that follow.



2.1.1 Identify the labels marked A, B and C. (3)

The table below shows the composition of fluid in Structure A and Structure B of the diagram.

	Structure A	**Structure B**
Component	**Concentration (%)**	**Concentration (%)**
Urea	3	200
Glucose	10	0
Amino acids	5	0
Salts	72	150
Proteins	800	0

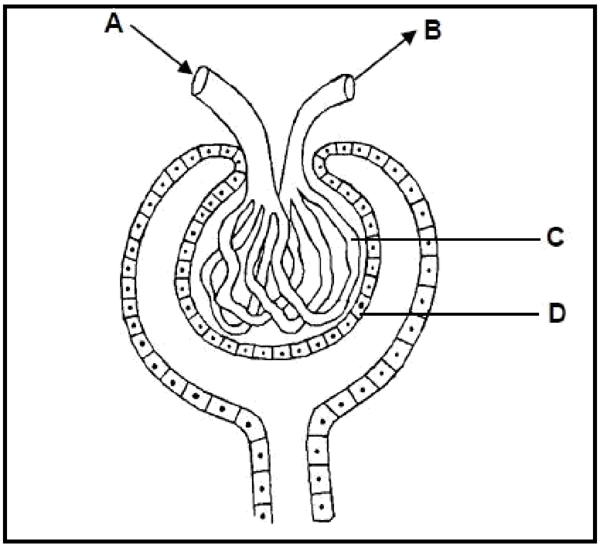
2.1.2 By comparing the contents of structures A and B, what conclusion can be drawn regarding the functions of the kidney? (1)

2.1.3 Would you consider that the person with the medical report shown above suffers from diabetes mellitus? Explain your answer. (4)

2.1.4 Which organic substances in the table are considered to be useful? Give a reason for your answer. (4)

(12)

2.2 Study the diagram below and answer the questions that follow.



2.2.1 In which region of the kidney would you find this structure? (1)

2.2.2 Name the process in urine formation that occurs in this structure. (1)

2.2.3 Identify the part C. (1)

2.2.4 Describe two structural adaptations of part C for the process in question 2.2.3 above. (4)

2.2.5 Part A is wider than part B. What is the importance of this? (2)

2.2.6 Name the hormone secreted when there is a storage of water in A. (1)

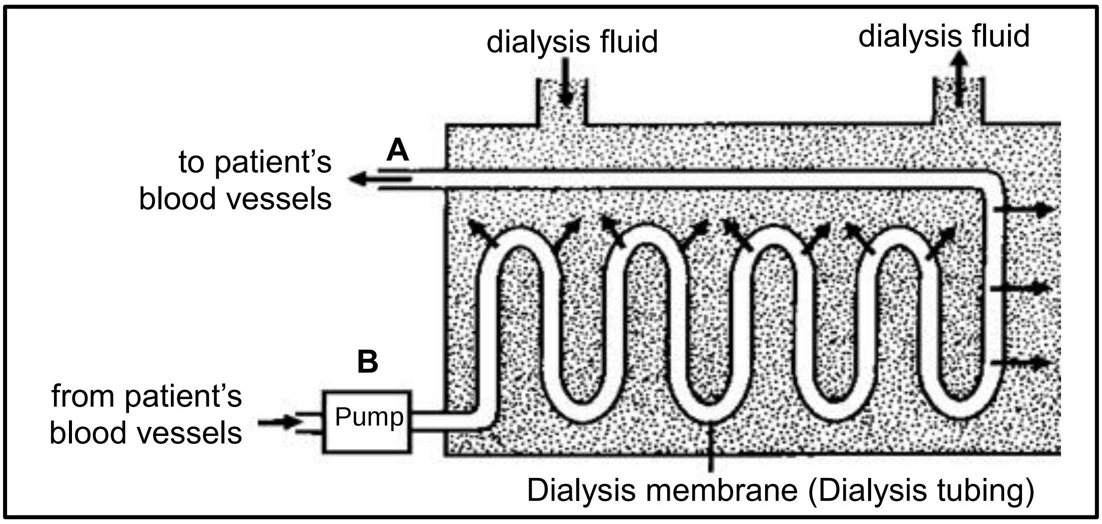
2.2.7 Describe how the hormone named in question 2.2.6 plays its role under such conditions. (3)

(13)

[25]

Question 3

3.1 An extract on renal failure and its treatment is given below (the diagram represents a dialysis machine, used to treat patients with renal failure).



Extract:
Kidneys can become so damaged that they no longer function properly, and we say that the person has renal failure. People with severe renal failure can be treated by dialysis, using a dialysis machine, to purify the blood. Dialysis is the separation of molecules by size, the smaller molecules diffusing through a dialysis tubing (selectively permeable membrane). The process takes between three and six hours and needs to be done two or three times a week.

3.1.1 Describe what *renal failure* is. (2)

3.1.2 Which process is illustrated in the diagram above? (1)

3.1.3 At what point in the diagram (A or B) would you expect the highest concentration of urea? (1)

3.1.4 Describe how blood is purified in the dialysis machine. (2)

3.1.5 Explain why dialysis tubing needs to be selectively permeable. (2)

3.1.6 Renal failure affects the osmoregulatory function of the kidney, so that it no longer excretes water efficiently. Explain the effect of renal failure on the patient's blood pressure. (3)

(11)

3.2 Study the following table that shows the flow rate and concentration of certain substances taken at regions A, B, C and D of the nephron in the human kidney.

Part of nephron	Flow rate (cm^3/min)	Solute concentrations (g/100 cm^3)				
		Proteins	**Glucose**	**Sodium ions**	**Ammonium salts**	**Urea**
A	4	0	0	0,6	0,04	1,80
B	200	0	0,10	0,72	0	0,05
C	4	0	0	0,3	0	0,15
D	2000	7	0,10	0,72	0	0,05

3.2.1 State, with a reason, which of the following parts (A, B, C or D) of the nephron represents the following:

a) afferent arteriole (2)

b) Bowman's capsule (capsular space) (2)

c) Loop of Henle (2)

d) Collecting duct / Duct of Bellini (2)

3.2.2 Explain the difference in the flow rate between B and D. (4)

3.2.3 State two functions of the kidneys, other than pH regulation, that can be supported by the data given. (2)

(14)

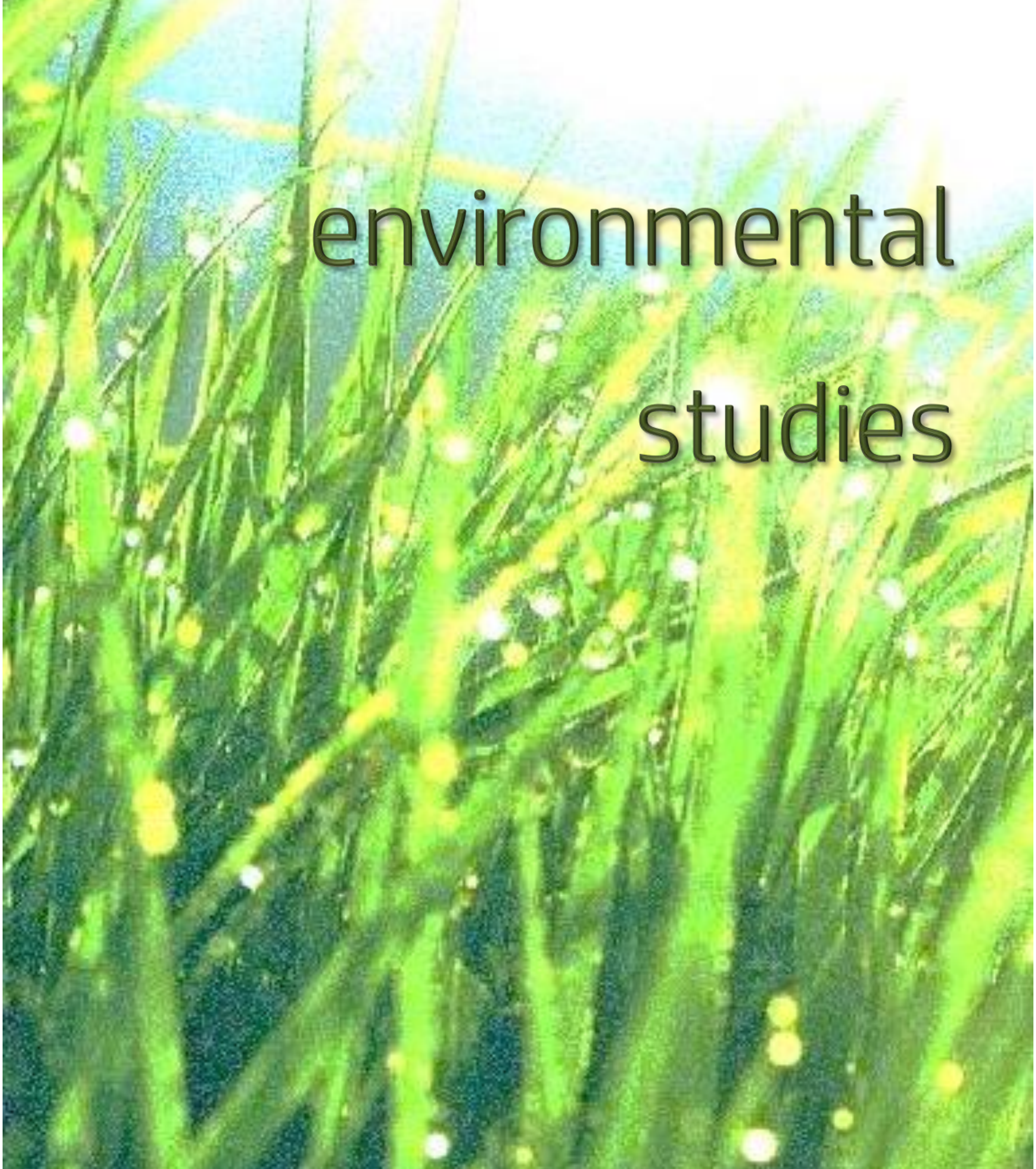
[25]

Section B: [50]

Total marks: [100]

Strand

environmental studies



9: Population ecology

CHAPTER 9: POPULATION ECOLOGY

Introduction

Population ecology is the study of populations in relationship to their **environment** and the **social interactions** amongst each other.

Population ecology includes the study of:

- Population size, factors that influence it, methods used to count populations and the two types of **growth curves** displayed by different organisms
- The types of interactions and **symbioses** found in nature and how organisms specialise to eliminate competition
- How different types of **social organisations** offer protection, enhance hunting, ensure the fittest survive and allow individuals of the same species to specialise into serving unique functions
- **Succession**, looking at how communities develop and in so doing how they alter their abiotic and biotic environments
- Human population growth forms in different **age-gender pyramids**

Key terminology

species	a group of organisms capable of interbreeding, producing fertile offspring
population	a population is a group of the same species that occupies the same habitat at the same time and are able to interbreed
community	Groups of different species populations that interact with each other within a specific habitat
ecosystem	a biological community of interacting organisms and their physical environment
abiotic factors	non – living factors in an ecosystem
biotic factors	living factors of an ecosystem
environment	the sum of all biotic and abiotic factors in an ecosystem
habitat	the environment in which an organism completes its lifecycle (growth, reproduction and eventual death)
niche	the specific area where an organism inhabits
natality	the percentage increase of a population because of the number of births in a given season or year
mortality	mortality refers to the death rate within a population, usually as a percentage of the population

fertility	the number of births per year for all females who can produce offspring (between the ages 15 to 45)
immigration	new members may have migrated for the breeding season and are only temporary or may become permanent members, species dependent
emigration	individuals leaving a population because of migrations at the end of a season and the original population splitting into sub-populations across a large geographical area.
migration	movement from one place to another at certain times of the year or during a particular period of an organism's life cycle
environmental resistance	all factors that are limiting the biotic potential and numerical increase of a population e.g. lack of water, food, space
carrying capacity	the largest number of individuals in a biological species that an ecosystem can support over an indefinite time.
stable population	a population with a zero growth rate, neither growing nor shrinking in size
unstable population	a population whose size exceeds the carrying capacity of an area
density dependent factors	factors that have a direct correlation (relationship) to the size of the population in an area. The greater the size of the population the greater the influence of these factors
density independent factors	factors which exert an influence on a population regardless of its size.
endemic	organisms found only in specific area and nowhere else in the world
indigenous	Organisms found naturally in an area or country
endangered	organisms threatened with extinction (dying out forever)

Population size

Population size is influenced by both abiotic and biotic factors present in the environment.

Factors that influence population size include:

- natality
- mortality
- migration (including immigration and emigration)

Positive and negative population growth

Figures 1 and Table 1 summarise the factors that may cause a positive or negative population growth.

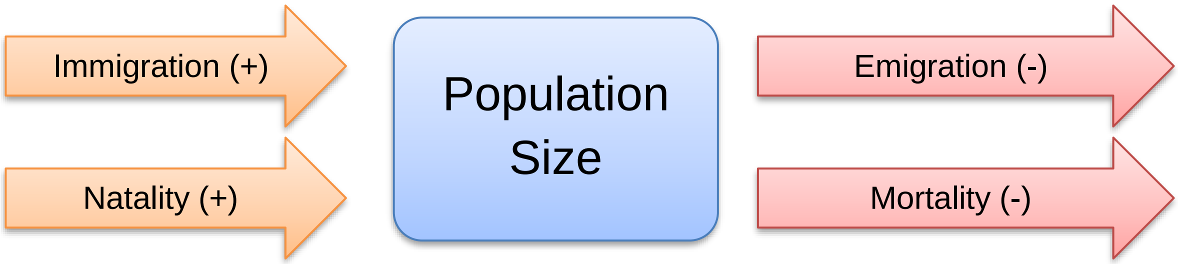


Figure 1: Factors affecting population size

Table 1: Reasons for increasing / decreasing populations

Increasing population	Decreasing population
Population increases because of **Natality** • Birth rate within a population. **Immigration** • Introduces new members into the original population. These members could have entered the population temporarily for the breeding season, or permanently. This is species dependent.	Population decreases because of **Mortality** • Death rate within a population. **Emigration** • Individuals leaving a population because of migrations at the end of a season or the original population splitting into sub-populations across a large geographical area.

The change in the number of individuals in a population can be determined using the following equation:

Population Change = (Number of births + Immigration) – (Deaths + Emigration)

When the balance is positive, population size increases and when negative, population size decreases.

Causes of fluctuations in natural populations

Density dependent and independent factors contribute to fluctuations in population size. These factors increase environmental resistance as indicated by arrows on the graph below (Figure 2). Together, these factors limit population growth.

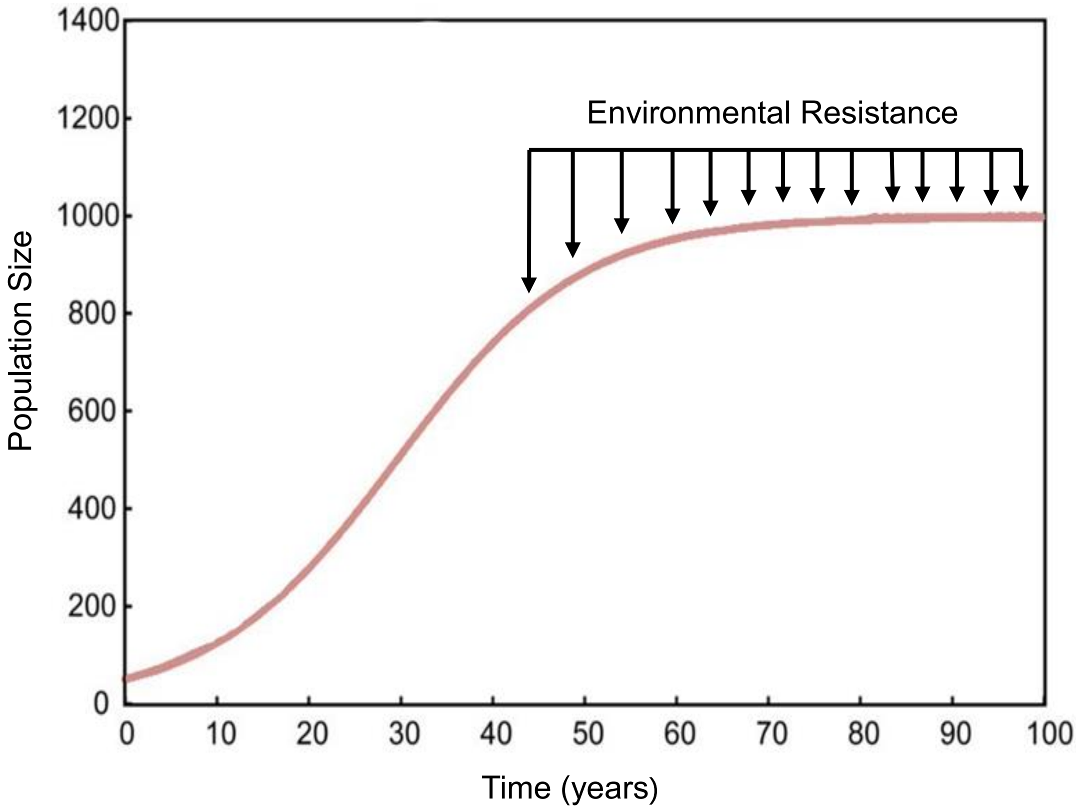


Figure 2: The impact of environmental resistance on population growth

Types of environmental resistance

Environmental resistance includes carrying capacity, density dependent and density independent factors.

- **Carrying capacity**

  Carrying capacity refers to the number of individuals an environment can support in a specific season.

  If populations exceed their environmental carrying capacity, there will not be enough resources to sustain the population and so the population size will fall because of increased environmental resistance.

  Population size may fluctuate in natural populations around the carrying capacity (see Figure 3). This is known as a **stable** population size.

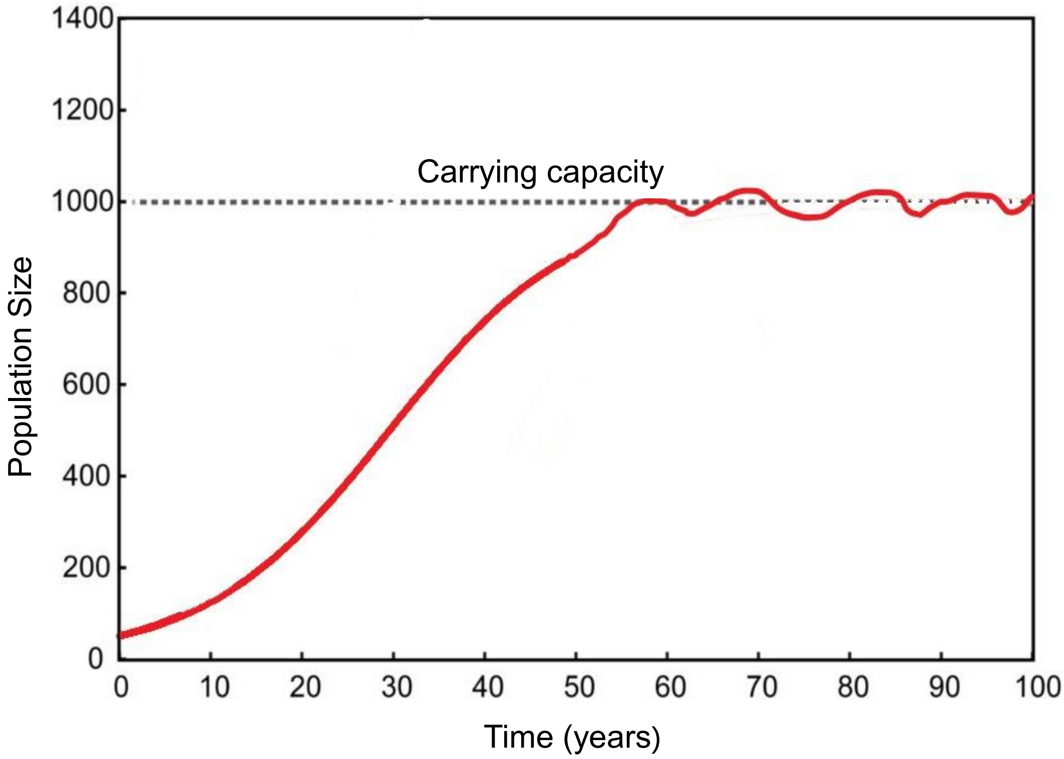


Figure 3: Stable population size fluctuating around carrying capacity

If however the population size exceeds the carrying capacity, resources will be exhausted and the population will rapidly decrease in size. This type of population is called an **unstable** population. It is illustrated in Figure 4 below.

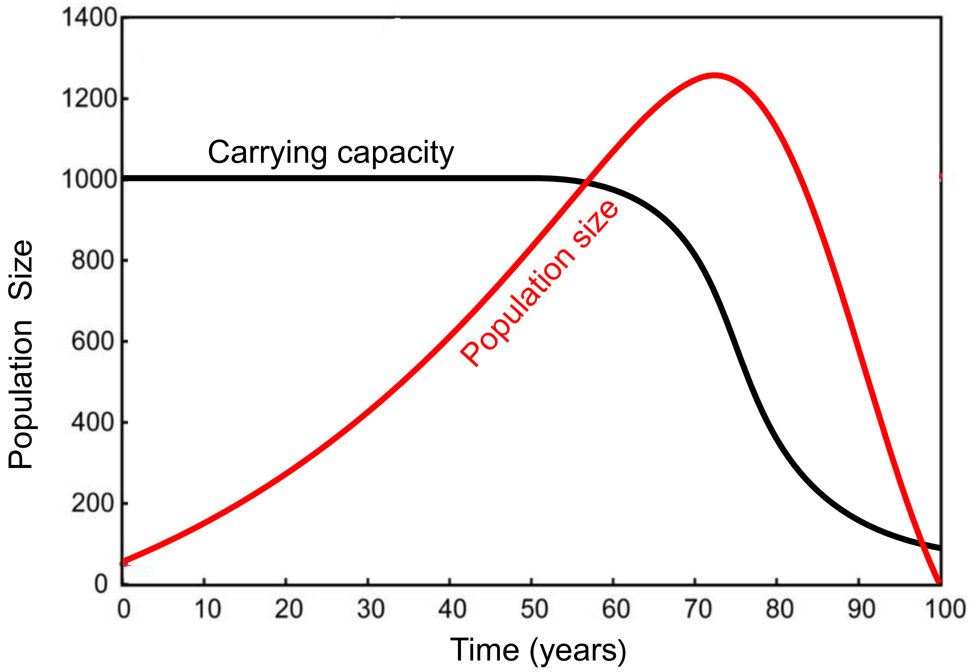


Figure 4: An unstable population – population size exceeds the carry capacity and then crashes

- **Density dependent and density independent factors**

Density dependent factors	**Examples**
• those factors that have a **direct correlation** (relationship) **to the size of the population in an area** • exert a greater influence when a population is large	• territorial behaviour • predation and competition • accumulation of waste • food, space and shelter • parasitism and disease
Density independent factors • factors that will **exert an influence on a population regardless of its size** • are abnormal events in nature and occur randomly	**Examples** (natural disasters) • tsunamis • landslides • volcanic eruptions • veld fires • floods

Activity 1: Populations

1. Distinguish between the terms species, population and community. (6)
2. Explain how the density of a population affects its growth rate. (4)
3. Define the term carrying capacity. (2)
4. Name two environmental conditions which could result in a positive population growth. (2)

(14)

Determining population size

Depending on the type of population, the size of the population can be determined either **directly** or **indirectly**.

Key terminology

closed population	a population where only natality and mortality influence population size; no emigration or immigration
direct counting	techniques that attempt to measure exact population sizes; no estimation are done
census	an official count or survey, especially of a population
indirect counting	techniques which estimate population size; ideal for smaller organisms

mark-recapture	a technique used to indirectly calculate the size of a population by capturing and marking a sample which is then released - a second sample is captured later, and the number of marked organisms counted
quadrats	square frames placed randomly on an area containing the organism; works well for both small sedentary animals and small plants

Direct counting techniques

Direct techniques determine the **actual population sizes**. Direct techniques are suitable for counting larger, slow moving organisms or organisms that are sessile.

Direct counting techniques include:

- **Aerial photography** (Figure 5)

  By taking an aerial photo of a population, the actual number of individual members who make up the population can be determined by counting.

- **Census** (Figure 6)

  A census is a direct method used to determine the actual number of humans in an area or a country.

Figure 5: Aerial photograph taken to determine family group size

Figure 6: Man conducting a census in a community hall

Indirect counting techniques

Indirect counting techniques are used to **estimate population size** where it is difficult to determine the actual number of organisms. Indirect counting techniques are used to estimate the population size of smaller organisms or fast-moving organisms. They include:

Mark and recapture

Mark and recapture is used to estimate animal populations. It involves taking two samples of the population.

- The first sample of organisms is marked and then released. Adequate time must be allowed for the population to mix after the initial marking. This period must not be long enough to allow natality, mortality, immigration and emigration to have an effect.
- The second sample represents the recaptured sample. The number of marked individuals and unmarked organisms must be determined. The following **formula** (Petersen Index) is used to determine the size of the population.

$$\boxed{N = \frac{M \times C}{R}}$$

where:

- **N** represents the total number of individuals estimated in the given population
- **M** represents the number of animals captured and marked in the first sample
- **C** represents the number of individuals captured in the second sample
- **R** represents the number of individuals marked in the second sample

The following **precautions** must be taken to ensure reliable results:

- The sample must be **large enough** to truly represent a population.
- The markings used must **remain** for the entire period of the procedure.
- The markings must be **suitable** for the type of organism and must not harm or interfere with its movements and behaviour.
- The marked organisms should be released into the environment close to the site of capture and be given **enough time** to mix.

- Several secondary samples should be taken, and population sizes calculated. The **average** of each trial should be recorded to improve the reliability of the investigation.

Examples of markings (see Figure 7) include:

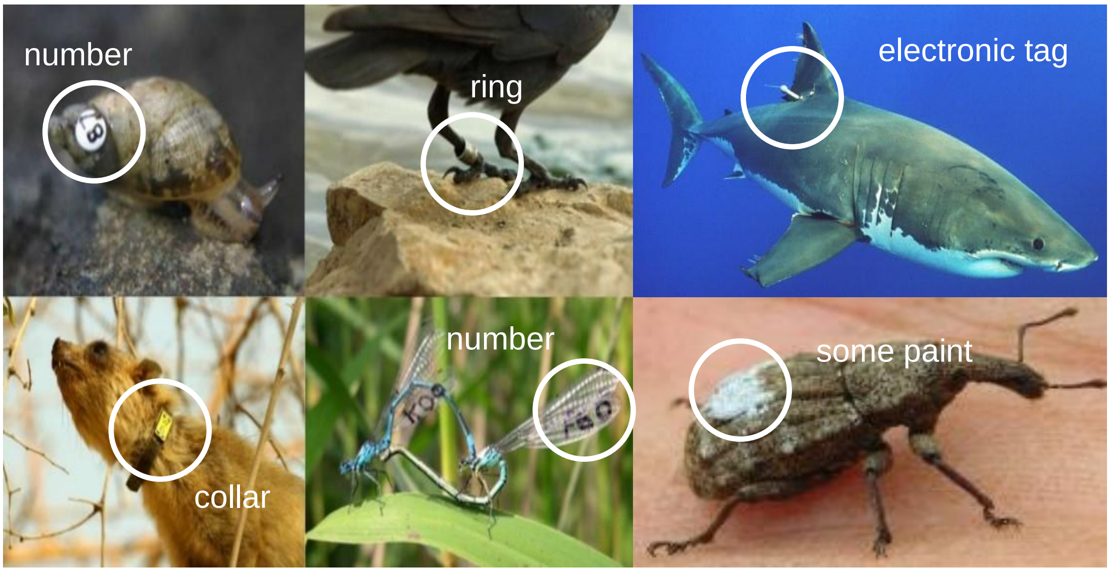


Figure 7: Examples of markings used in the mark and capture technique

Quadrats

Quadrats refer to square frames made of plastic, wood or string that are placed randomly on an area containing the organism (see Figure 8). This technique works well for both small sedentary animals and small plants. Quadrat sizes may range from 1 m^2 (small plants / animals) to 5 m^2 (medium sized shrubs / animals).

Figure 8: A simple plastic quadrat

$$\text{Population size} = \frac{\text{average number of individuals per quadrat} \times \text{surface area of land}}{\text{quadrat surface area}}$$

Precautions to ensure reliable results:

- **Several quadrat throws** (samples) should be made to determine the average number of individuals per quadrant.
- Quadrat samples must be done **randomly** throughout the total area.
- The process should be **repeated** several times and the average number of organisms per quadrat calculated.

Activity 2: Determining population size

1. Phumzi and Rebecca want to determine the mussel population size in the rock pools at their local beach (see Figure 9 below). Mussels are sessile marine invertebrates that attach themselves to rocks. The rock pools have a total surface area of 32 m^2.

Figure 9: Mussels growing in a rock pool

a) Phumzi and Rebecca both agree that the quadrat method would work best. Explain why you would agree with them and not choose to use the mark and recapture method. (3)

b) The quadrat that they will be using is 2,5 m^2 and they choose to throw the quadrat six times at random at different locations along the 32 m^2 rock pool. The results are recorded in the table below. Using these results, calculate the population size of the mussels. (4)

Throw no.	Number of mussels in quadrat
1	25
2	13
3	31
4	19
5	22
6	26
Total	
Population size	

c) How has (i) validity and (ii) reliability been assured? (2)

2. Describe any four precautions that must be considered when working with the mark and recapture method. (4)

(13)

Population growth forms

Populations have characteristic patterns of growth. When population sizes are plotted over time, two different growth patterns can be found in nature. They are referred to as **geometric (**or **a J-shaped growth curve)** and **logistic (**or **S-shaped growth curve)** growth.

Key terminology

growth curves	graphs that plot population size against time
geometric growth	a doubling after every reproductive event, i.e. exhibit exponential growth; graph has a **J-shape**
logistic growth	the type of population growth that starts with a few individuals and many resources – growth rate and consumption then increases. As resources are used up, growth rate levels off, resulting in an **S-shaped** graph
lag phase	first phase in a population growth curve where growth is slow; individuals may be acclimatizing to environment; few individuals that are sexually mature and able to reproduce

exponential growth phase	second phase in a growth curve; individuals have acclimatized, many reproducing individuals exist; in favourable conditions can produce many offspring
decelerating growth phase	third phase in a growth curve; environmental resistance leads to a decrease in the number of individuals; initially, natality rate is higher than the mortality rate but later the mortality rate is equal to the natality rate and eventually exceeds it
equilibrium phase	forth phase in a growth curve; carrying capacity is reached and factors limit size of population; carrying capacity is stable and able to maintain the population at a set value
death / extinction phase	fifth phase in population curve; without management of resource usage, and changes to abiotic and biotic factors in their environment, the population may not be able to sustain itself and enter a population crash phase

Geometric growth curve

Geometric growth is characteristic of many micro-organisms e.g. bacteria and protists. These species are able to reproduce quickly and double their numbers after every reproductive division in favourable conditions. Eventually their resources become limited and/or waste products accumulate and adversely affect the population. This causes death or an extinction event. Three distinct phases can be seen in geometric growth curves (Figure 10):

- **Lag phase** – population number inceases slowly because:
    - individuals may still be acclimatising to their environment
    - they need time to find mates
    - most of the population is sexually immature
- **Geometric (or accelerated) growth phase –** individuals have acclimatised, many reproducing individuals exist and in favourable conditions produce many offspring. The birth rate is higher than the death rate. There is very little environmental resistance.
- **Extinction or death phase** – resources become limited, i.e. food, space, etc., and the population is no longer able to reproduce as effectively. The mortality rate becomes greater than the natality rate. The population decreases rapidly.

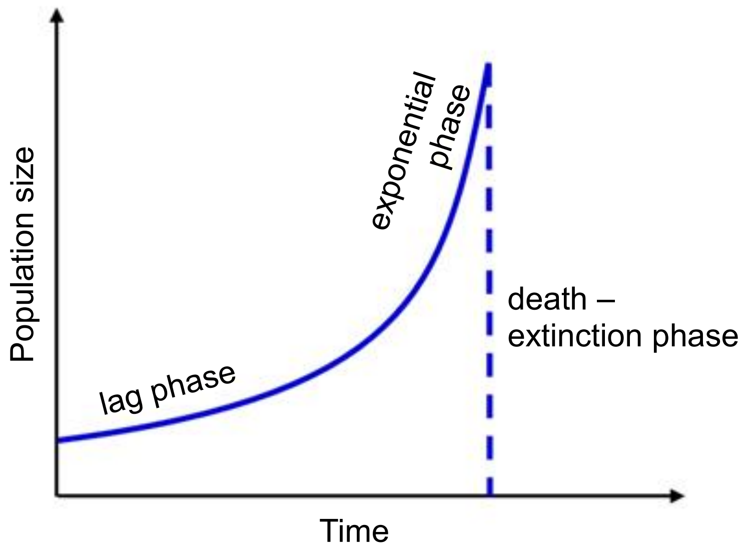


Figure 10: Geometric growth in a population

Logistic growth form

Logistic S-shaped growth (Figure 11) is normally found in higher-order organisms (e.g. mammals) which typically reproduce slower. Populations tend not to exceed the carrying capacity and, if they do, they show higher levels of resilience to environmental resistance.

An S-shaped graph forms typically consists of five phases.

- **Lag phase:** As in the geometric growth curve, the population numbers increase slowly.
- **Exponential or accelerating growth phase**: The population can reach higher natality levels because of more sexually mature individuals procreating and environmental resistance being low (because of enough food, space and shelter).
- **Decelerating growth phase**: Natality rate is still higher than the mortality rate, however, the mortality rate is gaining momentum because of higher levels of environmental resistance and old age.
- **Equilibrium / stationary phase**: Carrying capacity of the environment has been reached. One or more limiting factors are exerting a toll on the population. The carrying capacity is somewhat stable and able to maintain the population at a set value.
- **Death / extinction phase** (not shown on graph): Some populations cannot regulate their resource usage and/or changes to abiotic and biotic factors in their environment and are then unable to sustain themselves.

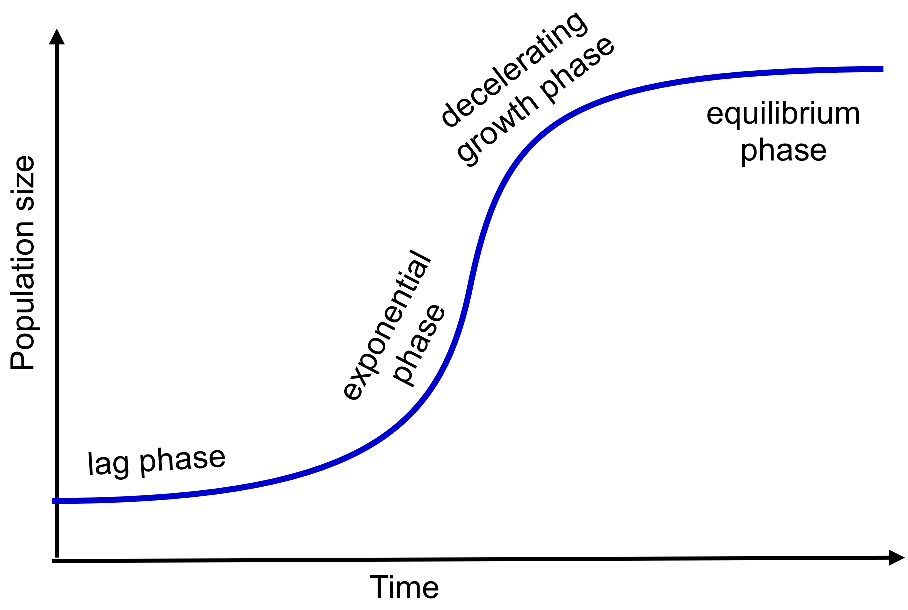
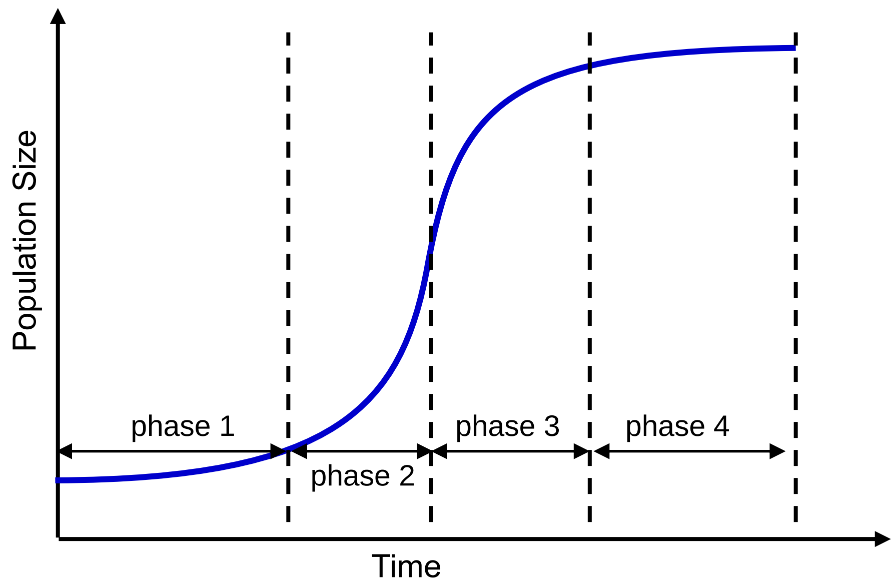


Figure 11: Logistic growth curve

Activity 3: Growth forms

1. Tabulate two major differences between logistic and geometric growth forms. Include an example of a species representing each growth form. (6)
2. Identify the growth form in the following graph. (1)



3. Identify the phases 1 to 4 in the above graph. (4)

(11)

Interactions in the environment

Species interact with each other in a variety of ways. These include:

- predation
- competition
- symbiotic relationships

Predation

A **predator** (Figure 12) is an organism that actively **hunts**, **kills** and **consumes** its prey to meet its energy needs.

Key terminology

predation	the act of preying on another animal
predator	heterotrophic organisms (usually animals) that hunt, kill and eat other organisms (or animals)
predator – prey curve	a curve that describes the dynamics of biological systems in which two species interact

Figure 12: A spotted hyena claiming a share of the kill

Predators play an important role in regulating the number of other species. The relationship between the number of predators and their prey, can be represented by a predator-prey graph (Figure 13).

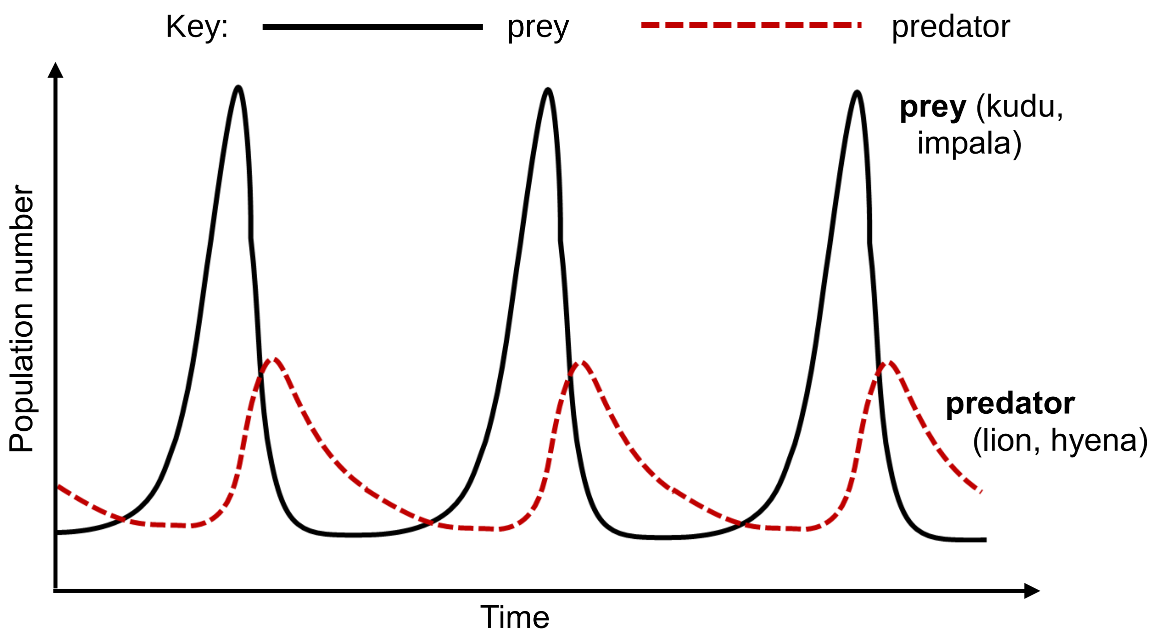


Figure 13: Predator – prey graph

Interpreting a predator-prey graph

- The number of prey increases first
  - An environment with food, space and a lack of predators will allow the prey population to increase exponentially.
- The number of predators only rises after the prey numbers have increase or are high. There is a delayed reaction to the rise in prey.
  - Predators are still in the initial lag phase. There are few sexually mature individuals reproducing, and gestation periods are quite long.
  - If new to an environment, predators might also need to acclimatise first.
  - There is competition for prey
- **Prey numbers** starts to **decrease**.
  - Due to higher environmental resistance (lack of food, water, space, etc. and increased predation levels).
- **Predator numbers** start to **decrease** once prey numbers are low or are busy decreasing rapidly.
  - As prey decreases, food becomes a limiting factor for the predator. Increased competition between predators for food causes higher mortality rates amongst predators.
  - Predators may also emigrate out of the area to where more food may be found.

- Stationary (stable) phases are extremely short, and fluctuations of predator and prey numbers tend to be high.
    - Environmental resistance increases on prey populations as predators have access to a large supply of prey. Prey numbers decrease as predator numbers increase. When predator numbers grow too large and there is not enough prey anymore, their numbers decrease rapidly.

Competition

Competition is the interaction between individuals over scare resources.

Key terminology

competition	social interaction between organisms fighting for dominance over the same limited resources (food, living space)
interspecific competition	competition between two or more different species
intraspecific competition	competition within members of the same species
competitive exclusion	process whereby species can exist independently and survive; when placed in the same environment, one species will out compete the other and cause its extinction / death

- When individuals of the **same** species compete, it is called **intra**specific competition.
- When individuals of **different** species compete, it is **inter**specific competition (Figure 14).

Figure 14: An African elephant chasing a buffalo from the watering hole is an example of interspecific competition

Competitive exclusion

The **competitive exclusion** principle states that when two species competing for the same resources, one species will out-compete the other. An example of competitive exclusion is illustrated in Figure 15.

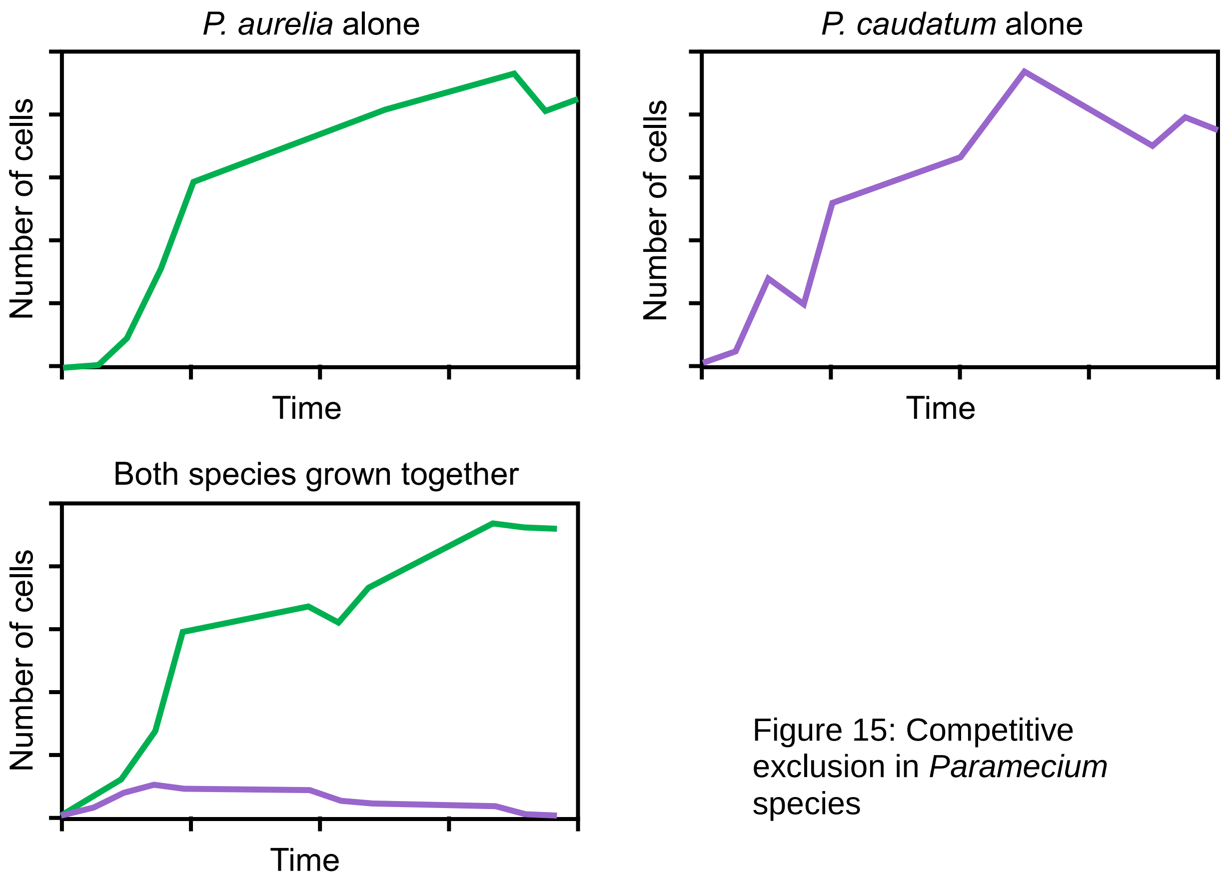


Figure 15: Competitive exclusion in *Paramecium* species

When *Paramecium aurelia* and *Paramecium caudatum* are kept in separate containers, their numbers increase rapidly. If the two species are put into the same container P. caudatum out-competes P. aurelia and the numbers of P. aurelia decease rapidly.

Resource partitioning

Resource partitioning refers to the sharing of resources so that different species can co-exist in the same area.

Key terminology

resource partitioning	a specialisation that limits interspecific competition; through resource partitioning, different carnivores, herbivores and even plant species can co-exist and survive in the same environment since each occupies a different ecological niche

Examples of resource partitioning include:

- **Herbivores grazing in the same area –** taller animals such as giraffes feed on the leaves at the top of trees while larger buck feed from the middle and smaller buck from the lower branches (Figure 16).

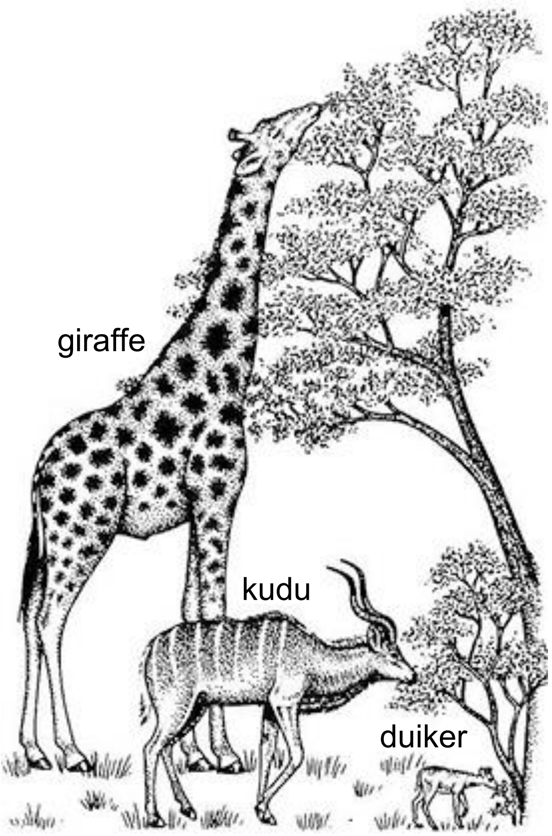


Figure 16: Resource partitioning on the savannah

- **Partitioning of light in a forest (stratification) –** Plants grow to a certain height depending on their light requirements. Plants which require less light grow in the shade of taller plants (Figure 17).

Figure 17: Forest stratification showing four distinct layers

Symbiotic relationships

Symbiosis is a close, long-term biological relationship between individuals of two or more species. There are 3 types of symbiotic relationships:

- mutualism
- commensalism
- parasitism

Key terminology

symbiotic relationship(s)	close physical association between two different organisms; includes mutualism, commensalism and parasitism
mutualism	species that partake in this relationship benefit equally
commensalism	symbiotic relationship where one organism benefits without harming or affecting the other organism
parasitism	symbiotic relationship in which one organism benefits from the relationship (parasite) while causing harm to their host
obligatory parasitism	parasite which cannot complete its life cycle without exploiting the bodies of suitable host(s)

Mutualism

Mutualism is an example of a symbiotic relationship between two different species in which **both species benefit**.

Examples of mutualism found in South Africa

- **Buffalo and oxpeckers** (Figure 18). The oxpecker feeds on ticks and the buffalo benefits by having the ticks removed.

Figure 18: Oxpecker eating ticks off a buffalo

Figure 19: Sunbird drinking nectar from an Erica species

- **Sunbirds and Ericas** – Sunbirds (Figure 19) drink the sugar rich nectar of indigenous Erica flowers. Pollen sticks to the feathers of the birds and is carried to other flowers thus ensuring cross-pollination.

Commensalism

In a commensalistic relationship, **one species benefits** while the **other neither benefits nor is it negatively** affected from the shared interaction.

Example

- **Whales and barnacles** share a commensalistic relationship (Figure 20).

  Barnacles attached to whales filter water for food while the whale moves through the ocean. The whale is not harmed by the barnacles.

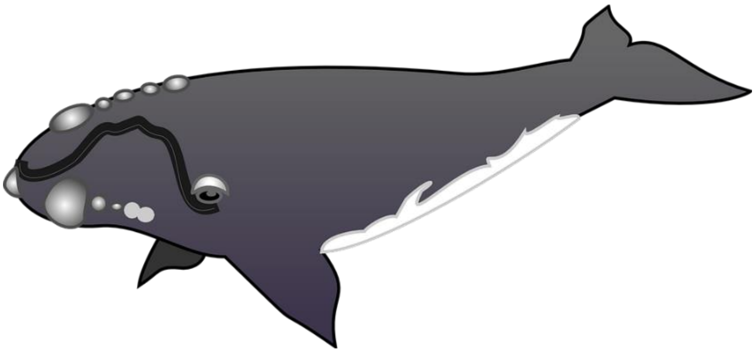


Figure 20: Barnacles on a grey whale

- **Egrets** share a commensalistic relationship with many herbivorous species (Figure 21). Egrets are insectivorous birds who walk with cattle, rhinos and giraffes among other herbivorous species. While the herbivores do not gain anything from the egret, the egret benefits by catching the insects more easily that have been disrupted by the movement of the herbivore through the vegetation.

Figure 21: An egret and bovid species

Parasitism

In parasitic relationships, one species (the parasite) benefits while the other species (the host) is harmed.

Parasites can be either

- **endoparasites:** those that parasitise the host internally e.g. tapeworms; or
- **ectoparasites:** those that parasitize the host externally e.g. leeches and ticks (Figure 22).

Ticks are common examples of ectoparasites as they consume the blood of their host externally. Parasites are almost always host specific (they only parasitise certain host bodies).

Figure 22: Ticks as an example of ectoparasites

Dodder (Figure 23), an obligate parasite. It has no chlorophyll so it is completely dependent on other plants (hosts) for both food and water.

Figure 23: A dodder species parasitizing an herbaceous bush

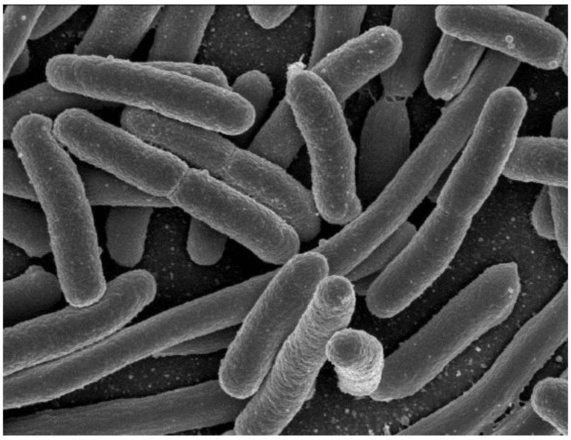
Activity 4: Symbiotic relationships

Identify the types of symbiotic relationships depicted in A – D below. (4)

A – mosquito

B – Bird's nest in a tree

C – lichen



D – E.coli in the gut

Social Organisation

Social organisation increases the chances of survival through the shared efforts of individuals benefiting the members of the population.

Key terminology

social organisation	interactions that increase the chances of survival through shared efforts of individuals benefiting the members of the population
herding behaviour	individuals in a group which act collectively without centralized direction
pack hunting	typically associated with cooperative coordinated, purposeful movements in the catching and killing of prey

Examples of social organisation include **herding**, **packs**, **dominance** and the **division of tasks**.

Herding as a protective strategy

Safety exists in numbers. Many herbivorous species such as wildebeest (Figure 24), buffalo and zebra live in large herds. In herding there are many eyes available to watch for predators. Young are protected by keeping them in the middle of the herd.

Figure 24: Wildebeest travel in large migratory herds

Packs as a hunting strategy

As a hunting strategy, packs allow groups of a population to produce highly co-ordinated, purposeful movements in the catching and killing of prey. Packs also allow for smaller-to-medium sized carnivores to take down larger, more dangerous prey.

Figure 25: The African wild dogs is a highly social animal that lives in packs and takes mutual care of its young, sick and old

Dominance as a protective and reproductive strategy

In most groups of animals, certain individuals are naturally stronger. These individuals may compete amongst each other until one member of the group becomes the dominant male or female called the 'alpha member'.

This establishes a hierarchy and to an extent reduces intraspecific competition within the group. Depending on the species of animal, groups can be led by alpha females (where males are submissive) or by alpha males (where females are submissive).

Through dominance, reproductive quality is ensured. The offspring produced from strong parents are more likely to inherit their parents' traits and continue the existence of the species.

Figure 26: Meerkats in a mob are led by a dominant mating pair

Division of tasks (castes)

A division of tasks means that each individual of a population has a specific role to fulfil to which they devote all their time and energy. In insect populations, especially colonial (bees or wasps) or sociable burrowing insects (termites and ants) at least 3 different castes exist (Figure 27):

- **Reproductive** caste: normally only one queen with a handful of male drones who reproduce with the queen.
- **Soldier** caste: consisting of larger more robust figured individuals able to defend the nest or colony or attack.
- **Worker** caste: members who forage for food and/or build the colony or nest and often tend to the queen.

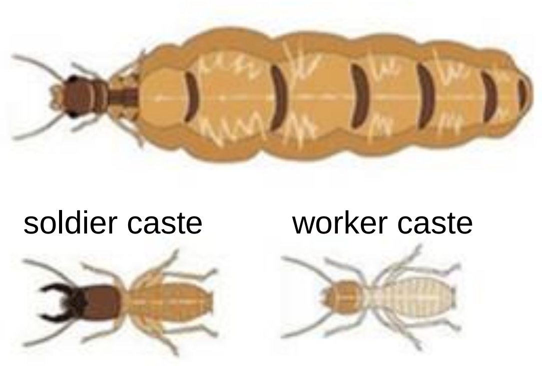


Figure 27: Termite castes

All castes are interdependent and cannot survive on their own. As a collective, they are able to ensure the survival of the species.

Community change over time (Succession)

Succession refers to the slow changes that occur over time in a new ecosystem until a climax community is reached. In nature, we study two types of succession, namely primary and secondary.

Key terminology

primary succession	process of **initial colonization** (primary), then the natural gradual changes in plant / animal species that live in an area
pioneer species	hardy organisms to **first** grow in a new or disturbed area and help break down rock and build soil.
secondary succession	process of **regrowth** or development after a previously existing habitat has been disturbed or damaged.
climax community	the **final, stable** community after succession

Primary and secondary succession in ecosystems

Primary succession (Figure 28) refers to all the biotic changes to a community in a new habitat, i.e. in a barren landscape devoid of any soil or biotic influence, such as:

- when a new island rises out of the ocean because of volcanic activity
- when receding glaciers expose a large mountain surface

The first organisms to move into a newly exposed area are called **pioneer species**.

- Pioneer species include **lichens**. By attaching themselves to the rocky outcrop, they begin the very slow process of weathering the rock down. Gradually, over a long period of time, a thin layer of soil forms.
- Certain pioneer species also secrete acid-like substances into the surrounding rock that further assists in its break-down.

Once enough soil is present, **grass species** can enter the habitat and further break down rocky outcrops to build up the soil layer.

As time progresses, small to medium **herbaceous shrubs and ferns** can settle and replace the pioneer species by outcompeting them.

In time, those plants will be replaced by **softwood** and by **hardwood tree species**. Each previous community makes the environment more suitable for the next.

A **climax community** includes plant and animal species that are consistently stable in their environment.

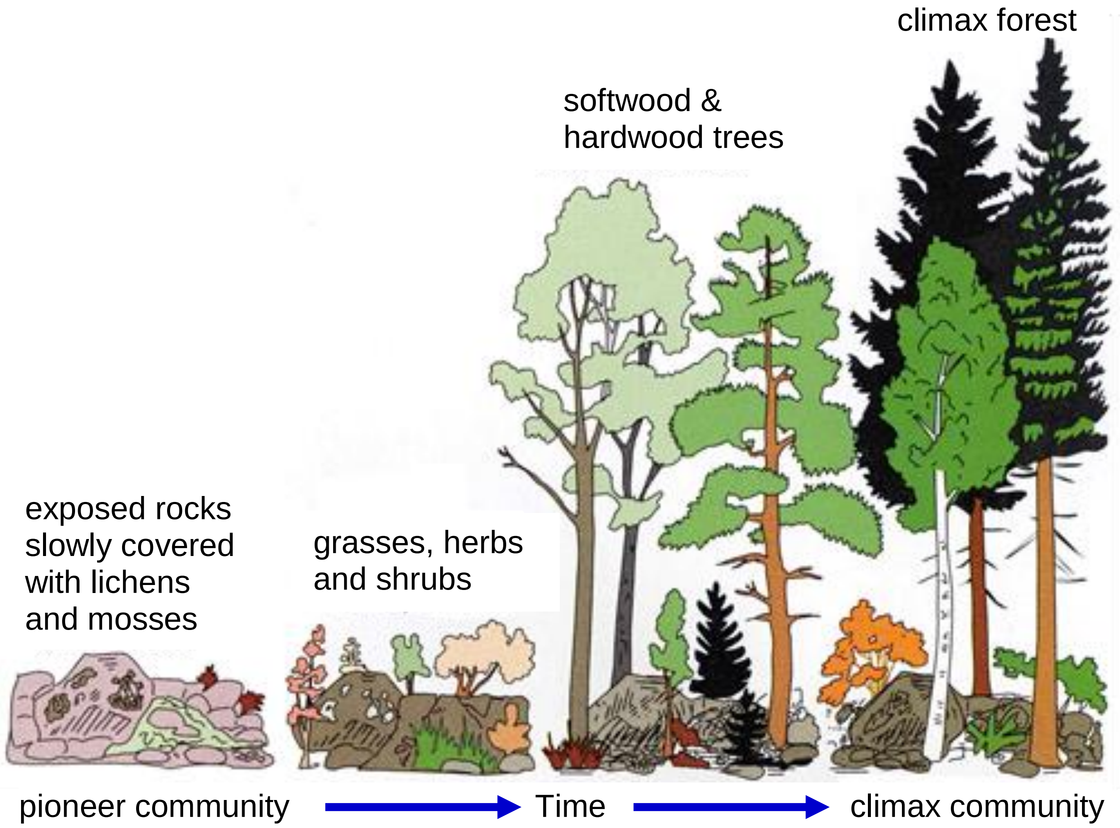


Figure 28: Succession in the formation of a climax forest community

Secondary succession (Figure 29) occurs when land that was previously used for agricultural purposes, becomes abandoned, or a fire has swept through an area destroying all vegetation.

In these communities, succession takes place faster as a thick soil layer is usually already present. Pioneer species (such as grasses) are quickly outcompeted by later more competitive occupants and climax species (i.e. hardwoods and fauna).

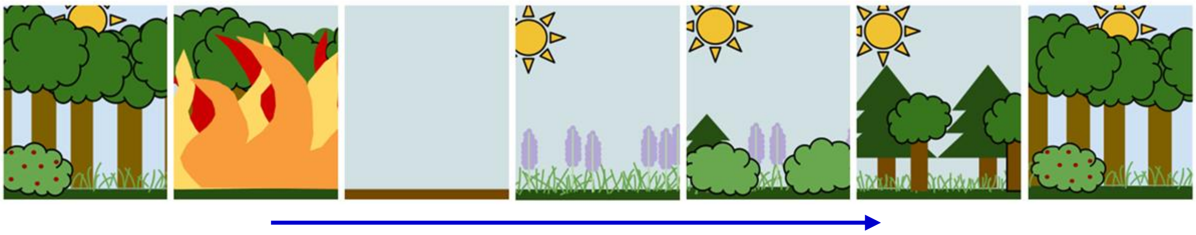


Figure 29: Vegetation is destroyed by fire. Over time new grasses and shrubs grow, finally to be replaced by lush forest as there was originally

Human population

Modern humans evolved 200 000 years ago. The population size then, was probably less than several hundred. Today, the human population stands at 7,66 billion.

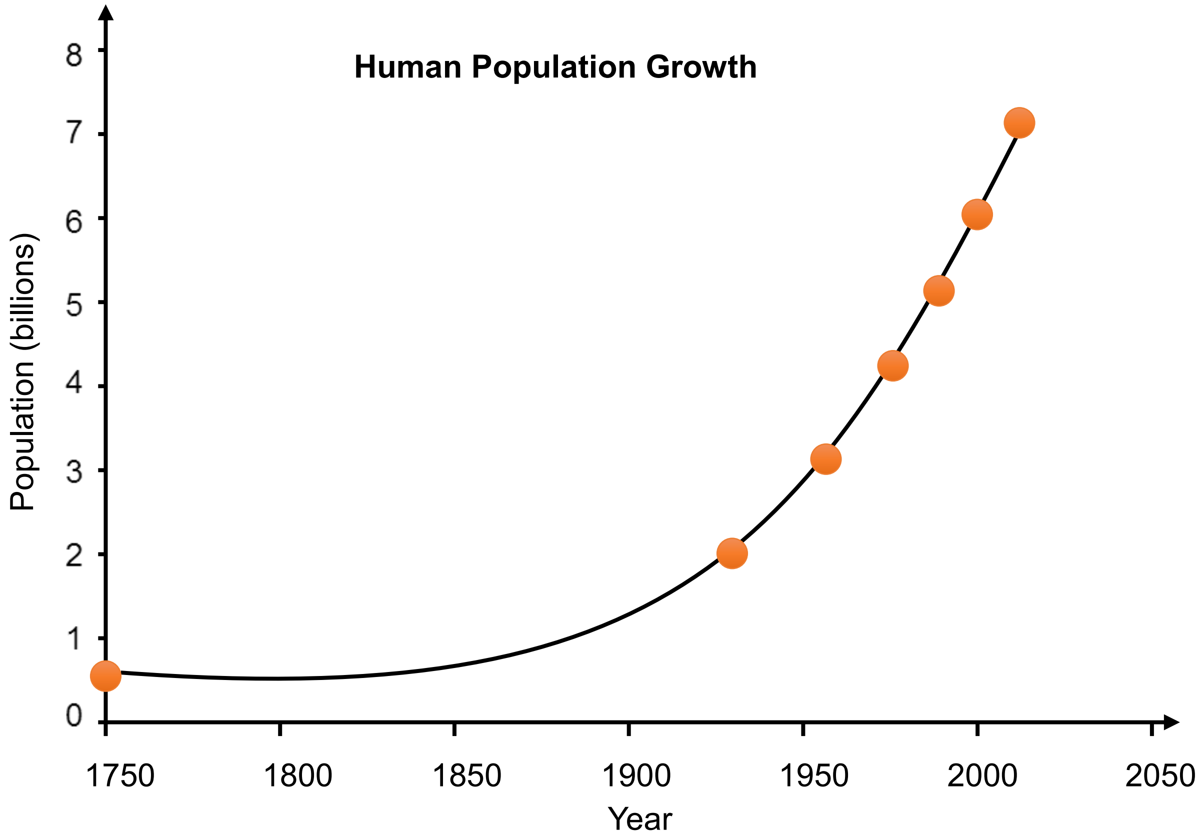


Figure 30: The human population has grown exponentially over the last 200 years

Human population growth: https://youtu.be/PUwmA3Q0_OE

Reasons for exponential growth

- **Agricultural improvements**

  Through agricultural improvements, man has been able to increase and secure food availability.

- **Medicinal improvements**.

  Our medical technology has improved drastically in the space of a few hundred years. We can counter the effects of pathogenic diseases and their subsequent spread

- **Technological improvements**

  Technology has made our daily lives easier and more convenient. Carrying capacity was further increased.

Through constantly increasing our carrying capacity and decreasing our environmental resistance, our population growth rate has exploded.

Age-gender population pyramids

Data regarding a population can be gathered through conducting a census and then ordered according to the number of individuals of a certain age category and of a certain gender. The results are then presented as a population pyramid.

Key terminology

Age-gender pyramids	also called an age-sex pyramid where a demographic graph depicts the age and gender of a population per age group

Three types of population pyramids can be observed according to whether or not the population size is growing or declining, namely:

- expanding or growing population pyramid
- stable population pyramid
- declining population pyramid

Expanding population growth pyramid

- more youth than elderly
- both natality and mortality rates are high
- few individuals reach old age - not much medical and social welfare assistance
- life expectancy, education levels, general standard of living are all quite low
- characteristic of developing countries / third world countries / many African countries

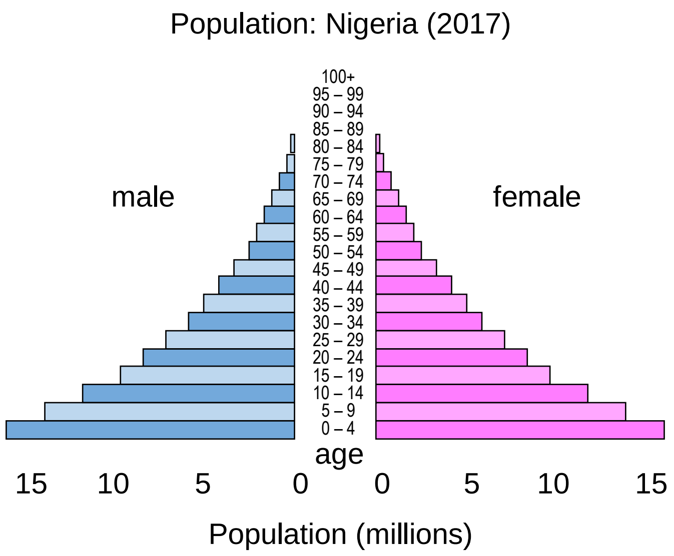


Figure 31: Positive growth of Nigeria's population in 2017

Stable population growth pyramid

- number of pre-reproductive individuals approximately the same as the number of reproductive individuals
- natality rates are low
- many individuals reach older ages because of medical and social welfare services
- life expectancy, education levels and general standard of living are all relatively high
- characteristic of certain developed countries, e.g. USA and China

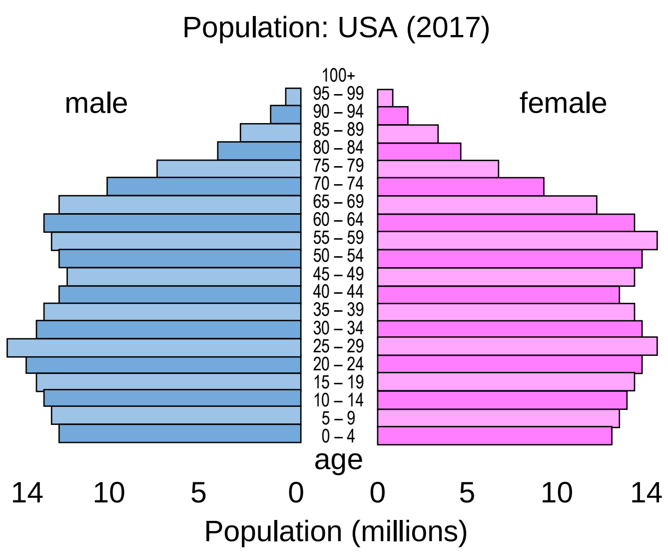


Figure 32: Stable growth of the USA's population in 2017

Negative or declining growth pyramid

- pre-reproductive groups are smaller than reproductive group
- natality and mortality rates are low
- many individuals reach older ages because of medical assistance and strong social welfare
- life expectancy, education levels and general standard of living are relatively high
- characteristic of developed countries, e.g. UK, Japan, Denmark and Italy

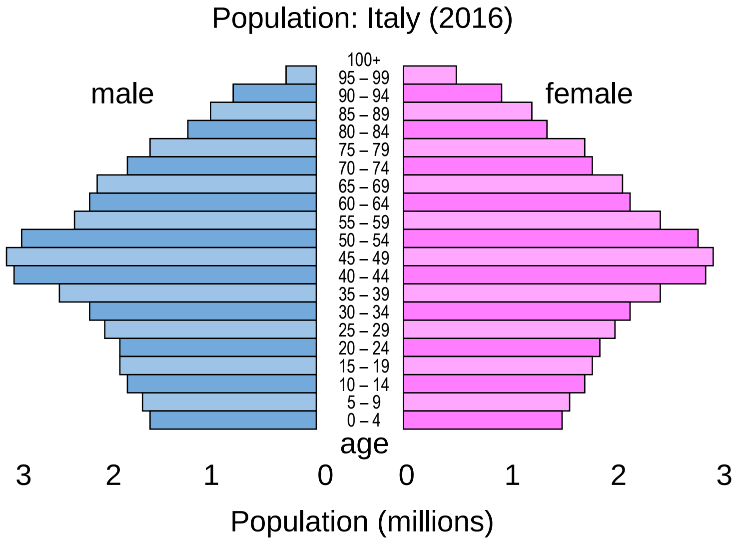


Figure 33: Negative growth of Italy's population in 2016

Apart from the above, human populations are also regulated by the prevailing global environment at the time, e.g. wars, famines, economic recessions, incurable super-bugs that are easily transmitted through international travel.

Governments can also regulate their population sizes through legislation. Some countries choose a more direct method to regulate their population whereas other would want to decrease it through legislation and policy.

The South African population

The South African population, like the global population, has shown a steady increase and is projected to increase further in the future. Table 2 summarises SA's population in 10-year intervals, and Figure 34 is a graphic representation of the population growth.

Table 2: SA population and projections (in millions)

1960	1970	1980	1990	2000	2010	2020	2050
17,4 m	22 m	27,6 m	35,2 m	44 m	50 m	58,7 m	65,5 m

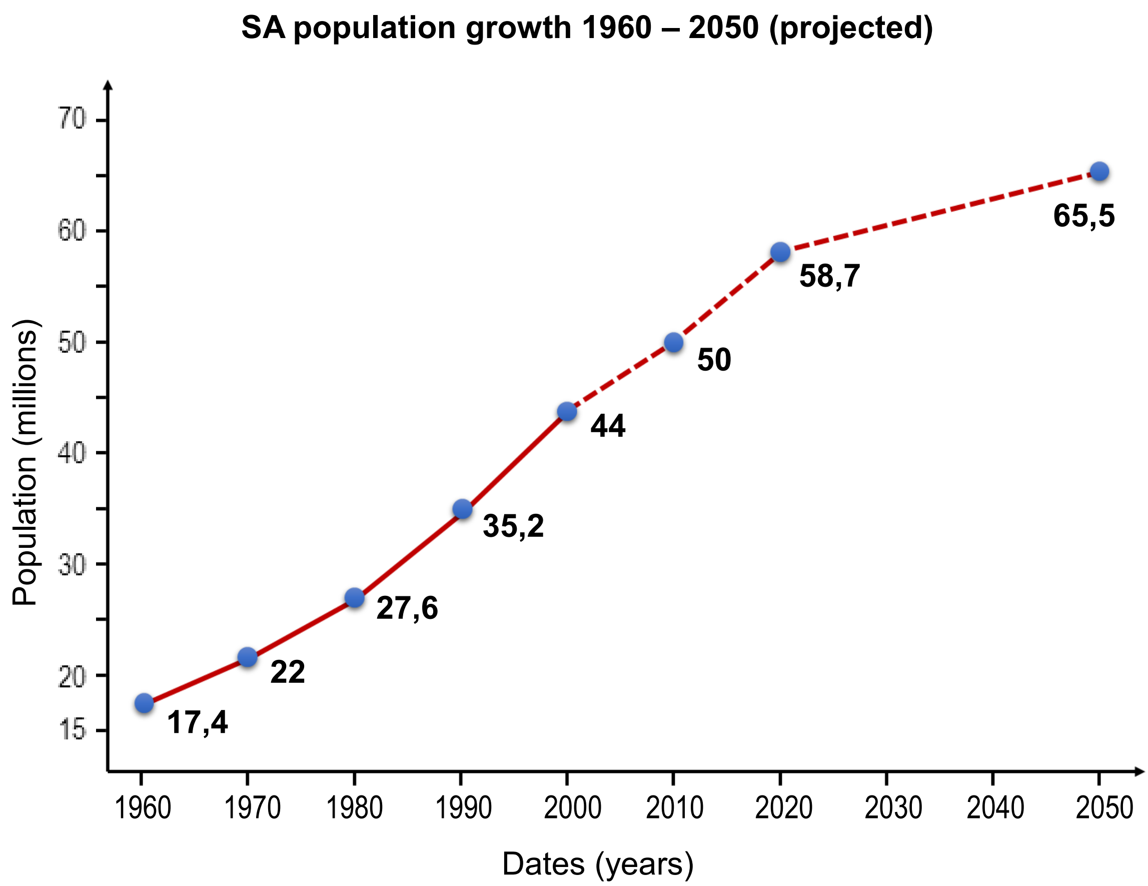


Figure 34: Graph of South African population
from 1960 to 2018, and projected to 2050

Projections beyond 2018

The South African population grew steadily over the last 58 years (1960 – 2018) by about 40 million people.

This growth rate is expected to slow down significantly in the next 30 years, adding only a further 8 million.

- The fecundity rate (birth rate) has already shown a large decrease
    - in 1955, the average SA female bore 6,05 children in her lifetime
    - in 2018, the birth rate had decreased to 2,52 children

Life expectancy

The life expectancy of the average South African was 49 years in 1960 but reached 60 years in 2016. This is however still significantly lower than the global average of 70,5 years.

Possible reasons for the longer life expectancy globally

- better health and sanitation
- social welfare improvements
- increased primary health care services

Figure 35 below gives the population pyramid for the South African population in 2016.

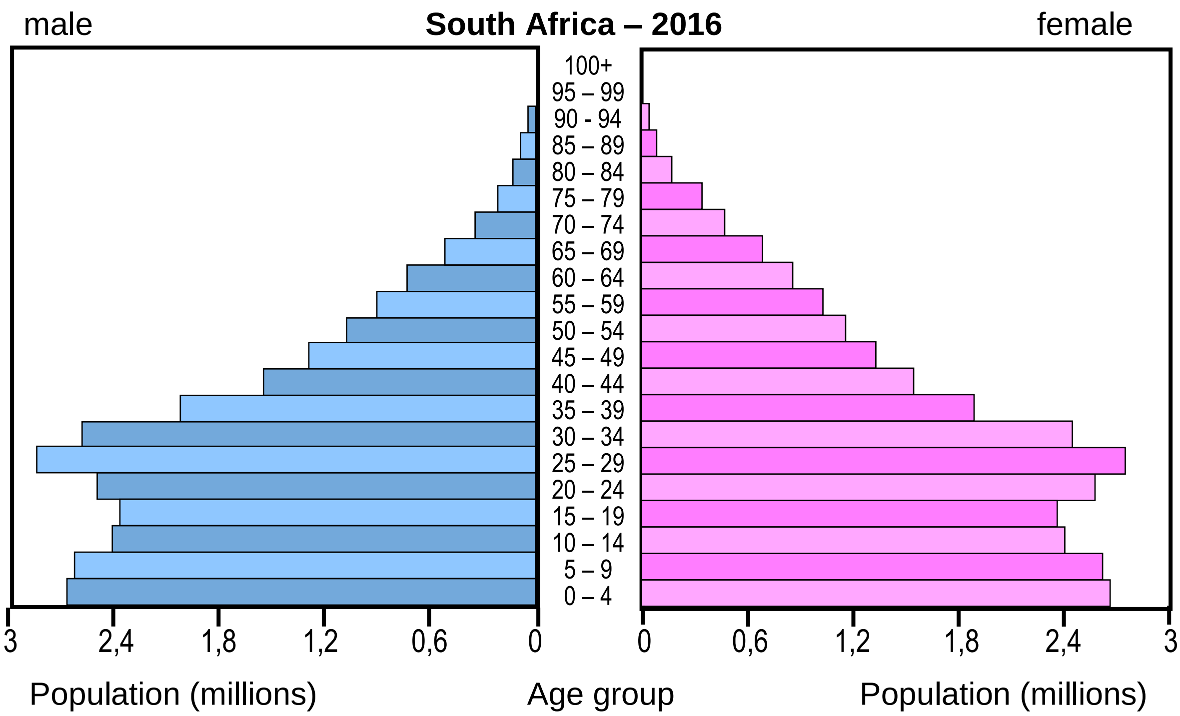


Figure 35: South African population (2016)

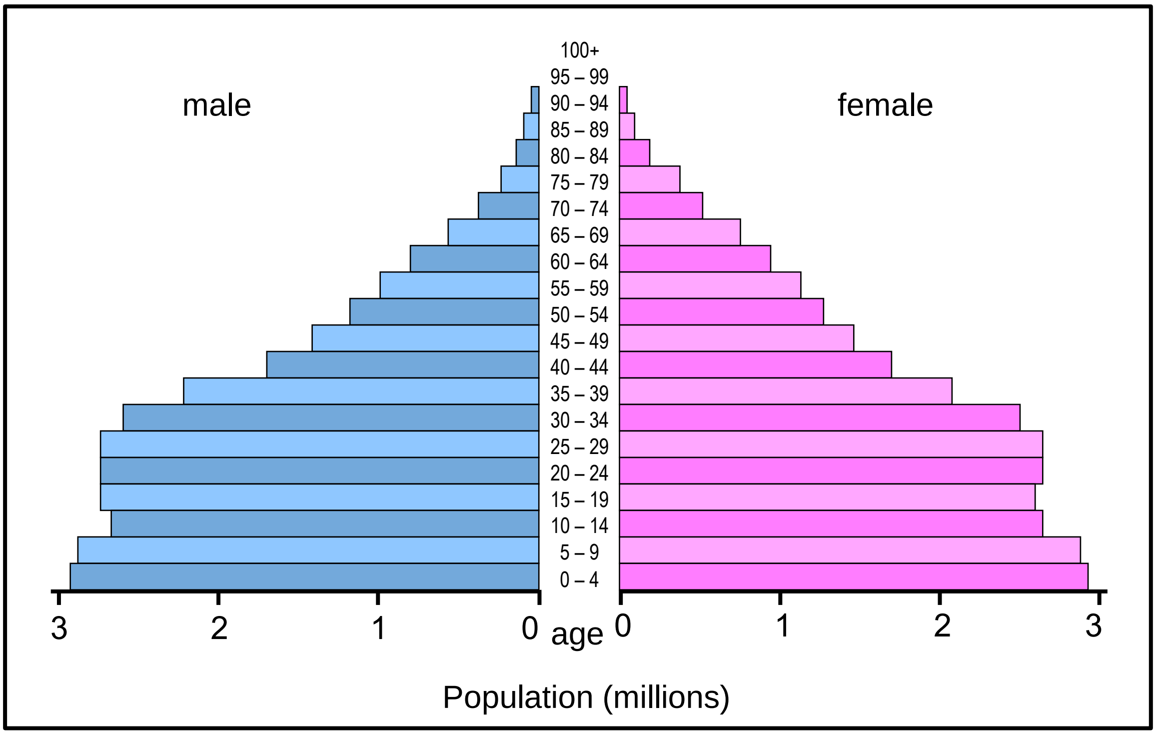
What does all this mean for the future of South Africa?

Statistical data acquired from population estimates should help policy makers, government and society think about South Africa's future. Our population's size is growing. People are growing older and the world of business is becoming more complex and sophisticated daily. Proper planning needs to take place. City planning and civil societal planning on how many schools, hospitals, industrial development zones are needed, needs to take place.

South African population (2013): https://youtube/ZeW8kbG0wG8

Activity 5: Population pyramids

Study the follow population pyramid before answering the questions that follow.



1. Which age-gender population growth curve is displayed in the above population pyramid? (1)
2. Give three reasons for your answer in question 1. (3)
3. What type of country is this population pyramid representative of? List any two characteristics of such a country. (3)

(7)

Population ecology: End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the answer and write only the letter (A to D) next to the question number (1.1.1 to 1.1.5) in your ANSWER BOOK, for example 1.1.6 D.

1.1.1 Which of the following will cause a decrease in the size of a population?

(i) emigration
(ii) immigration
(iii) natality
(iv) predation

A (i) and (iii)

B (ii) and (iv)

C (i) and (iv)

D (iii) and (iv)

1.1.2 The net increase of a population can be determined by ...

A adding births and deaths and subtracting emigrations and immigrations.

B adding births and emigrations and subtracting deaths and immigrations

C adding births and immigrations and subtracting deaths and emigrations

D adding deaths and immigrations and subtracting births and emigrations.

1.1.3 The following limitations on population size are all considered density dependent factors, except for…

A Predation

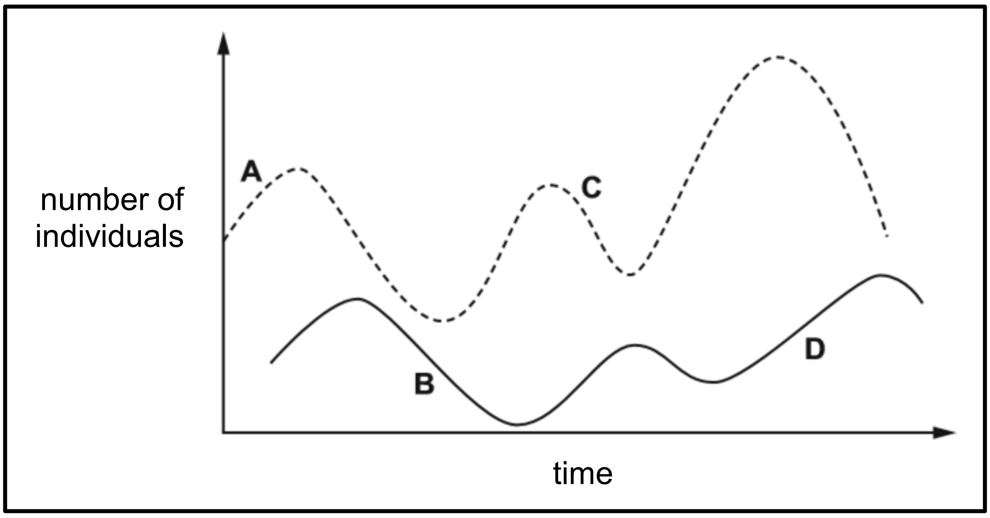
B Competition

C Wild fires

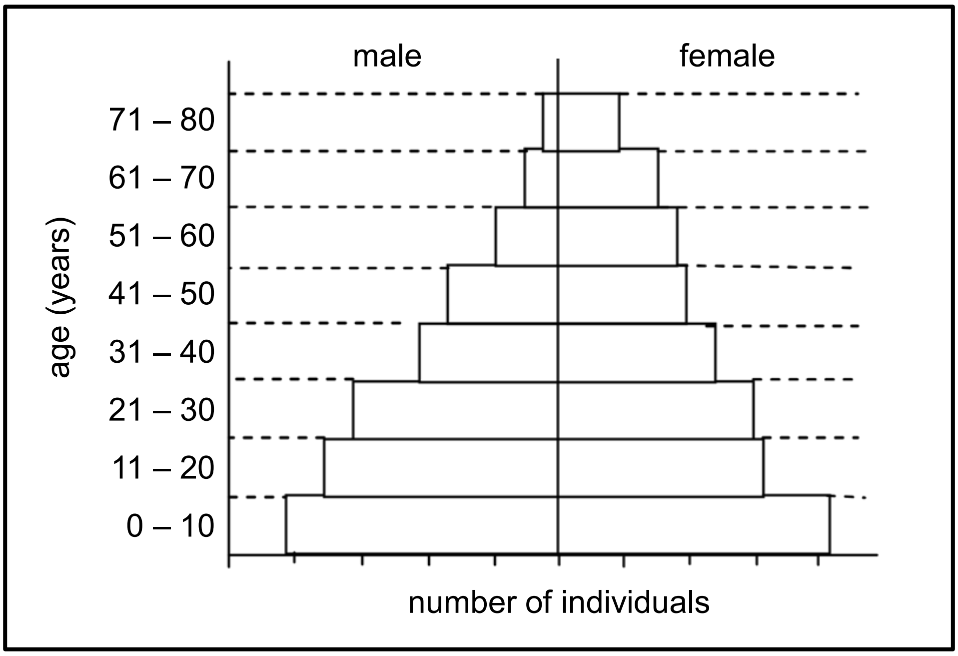
D Spread of disease

1.1.4 The graph shows the changes in the populations of predator and prey over a period of time.

Which point on the graph shows a decrease in predator population?



1.1.5 Study the population pyramid below:



Which of the following is a correct interpretation of the population above?

A Rapidly growing population; characteristic of a developing country

B Declining population; characteristic of a developing country

C Stable population; characteristic of a developed country

D Declining population; characteristic of a developed country

(5 × 2) = (10)

1.2 Give the correct **biological term** for each of the following descriptions. Write only the term next to the question number (1.2.1 to 1.2.9).

1.2.1 The relationship between two species that live in close contact with each other for part or all of their lives

1.2.2 A community made up of living organisms and non-living components such as air, water, and mineral soil

1.2.3 The phase during population growth where animals adapt to their new environment

1.2.4 The maximum number of organisms of a particular kind that can be supported by resources in the environment

1.2.5 The movement of individuals of a population out of a habitat

1.2.6 A pattern of animal behaviour of an organism or a group of similar organisms in defending an area for such purposes as mating, nesting, roosting, or feeding

1.2.7 A common term for factors that limit population size

1.2.8 The total count of all individuals in a population

1.2.9 Development of a community over time where species in one stage are replaced by other species

1.2.10 A square frame used to determine population size over an area.

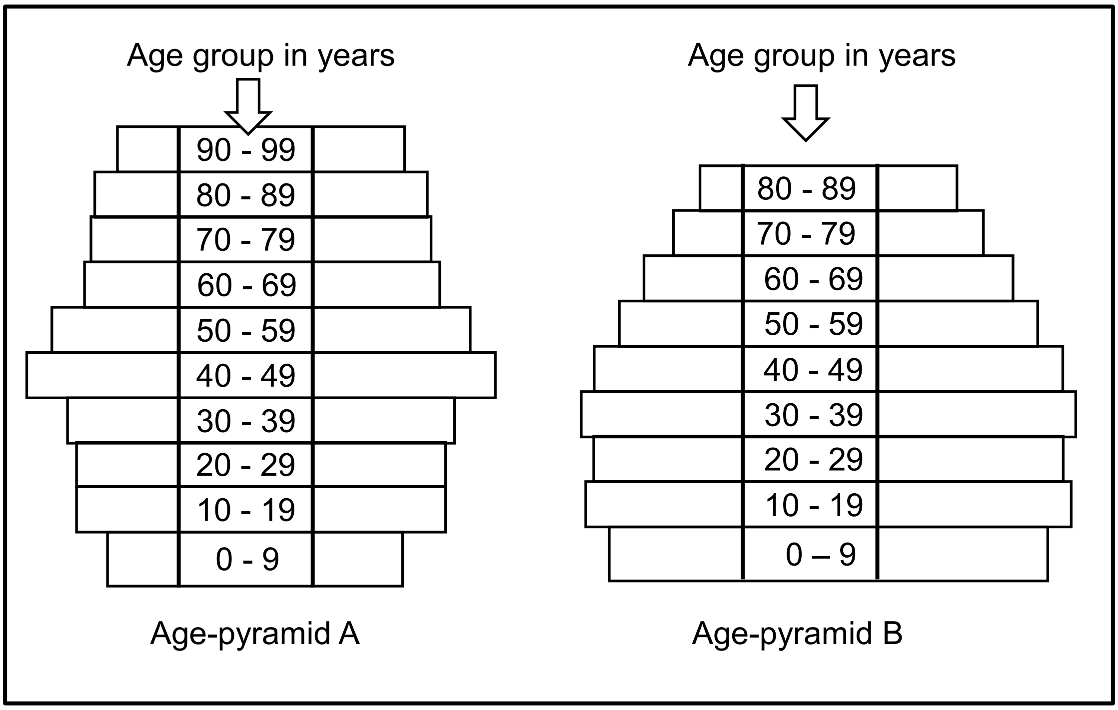
(10 × 1) = (10)

1.3 Indicate whether each of the statements in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B**, or **none** next to the question number (1.3.1 to 1.3.5).

	Column I	Column II
1.3.1	Kittens competing for their mother's milk	A: interspecific competition B: intraspecific competition
1.3.2	A pine forest is burnt to the ground over a 10 km^2 area when lightning strikes a tree. In spring, a few seedlings begin to sprout.	A: primary succession B: secondary succession
1.3.3	One of the species benefits and the other is unaffected	A: commensalism B: mutualism
1.3.4	Organisms have overlapping niches and compete for the same resources but they coexist because they use the resources slightly differently	A: resource partitioning. B: temporal partitioning
1.3.5	Example of social organization that increases the chances of survival	A: division of labour in bees B: a herd of zebras

(5 × 2) = (10)

1.4 Study the age-gender pyramids below representing a developing country and a developed country. Both pyramids have been drawn to the same scale.



1.4.1 Which pyramid represents the population distribution of a developed country? (1)

1.4.2 Give two reasons for your choice in question 1.4.1. (2)

1.4.3 Which group (male or female) has the larger percentage reaching old age in Pyramid B? (1)

1.4.4 Which two age groups has exactly the same percentage of male and female population in Pyramid A? (2)

1.4.5 Give four reasons why it is important for a country to know the age and gender structure of its population. (4)

(10)

1.5 Read the article below on elephant culling.

TOO HUNGRY, TOO DESTRUCTIVE, TOO MANY: SOUTH AFRICA TO BEGIN ELEPHANT CULL

An elephant herd at the Kruger National Park has 20 000 elephants, 5 000 more than is sustainable. Ecologists say the animals' huge appetites and fondness for 'habitat re-engineering' – reducing forests to flatland by uprooting trees and trampling plants – is the main problem.

Culling of the excess elephants is seen as an advantage in that it generates revenue for the communities from the sale of ivory and other elephant products. It will also provide meat to the local communities. Alternatives to culling include contraception and relocation of entire elephant families. The removal of fences between the Kruger National Park and parks in neighbouring Mozambique will eventually help with migration into less congested areas.

The 1998 figure of 8 000 elephant increased to 20 000 in 2008 and it is expected to reach 34 000 by 2020.

1.5.1 Give the main reason mentioned above in support of the culling of elephants. (1)

1.5.2 Name three alternatives to culling proposed above. (3)

1.5.3 Predict the likely elephant population number by 2036 if the population is allowed to keep growing at the same rate? (2)

1.5.4 Determine the carrying capacity, for elephants, in the Kruger National Park. (2)

1.5.5 Suggest how the community can benefit from the culling of elephants. (2)

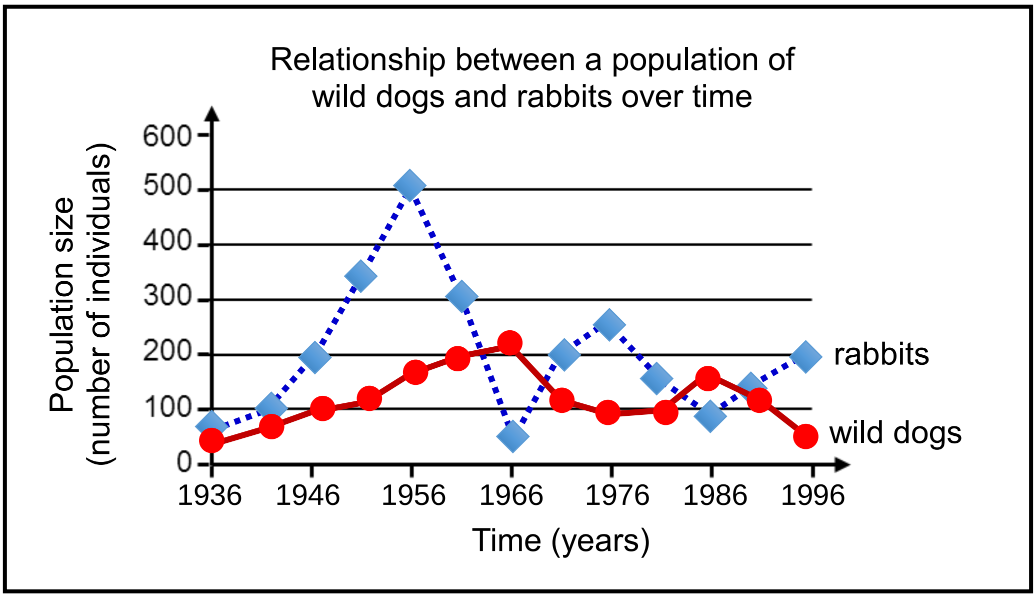
(10)

Section A: [50]

Section B

Question 2

2.1 Study the graph below and answer the questions that follow.



2.1.1 Which population-regulating factor is illustrated by this graph? (1)

2.1.2 Is this regulating factor named in question 2.2.1 a density dependent or a density-independent factor? Give a reason for your answer. (2)

2.1.3 How many of the following were there in 1966?

(a) Rabbits (1)

(b) Wild dogs (1)

2.1.4 What is the maximum number of rabbits that have ever survived in this environment? (1)

2.1.5 Will the rabbit population increase or decrease when there is a small number of wild dogs? Explain your answer. (2)

(8)

2.2 In an experiment, yeast cells were grown in a glucose solution in a test tube and kept at a temperature of 30 °C. Every two hours, a drop was taken from the mixture and examined under a microscope. The number of cells per unit area was counted. The results of the experiment are shown in the table.

Time	**Number of yeast cells (per unit area)**
0	10
2	30
4	70
6	175
8	350
10	515
12	595
14	640
16	655
18	660

2.2.1 Draw a line graph to illustrate these results. (6)

2.2.2 On your graph, indicate the various phases. (3)

2.2.3 Identify the growth form indicated by the graph (1)

2.2.4 During which time period did the greatest increase in the number of yeast cells occur? (2)

2.2.5 After six hours, there are 175 yeast cells per unit area. How long does it take to double this number? (1)

2.2.6 Give two reasons why the growth rate of the population might have slowed down? (2)

(15)

2.3 A population of mice in a field of mealies was studied for one week. The population parameters (per thousand mice) were calculated for that week. Six months later the investigation was repeated. The results are recorded in a table.

Population parameter (per 1000)	First survey	Second survey
Birth rate	110	270
Immigration	10	30
Death rate	145	200
Emigration	10	70

The rate of change of a population can be calculated by the following formula:

Rate of change = (birth rate + immigration rate)
– (death rate + emigration rate)

2.3.1 Calculate the rate of change for the first survey. (4)

2.3.2 What was happening to the size of the population in the first survey? Give a reason for your answer. (2)

2.3.3 Calculate the rate of change for the second survey. (4)

2.3.4 What was happening to the size of the population in the second survey? (1)

2.3.5 The difference in the rate of change between the two investigations is a result of which possible factors? (2)

2.3.6 Distinguish between the concepts: population size and population density. (4)

(17)

Section B: [40]

Total marks: [90]

10: Human impact on the environment

The atmosphere and climate change

Composition of the atmosphere

Sources of CO_2 and CH_4 emissions

- Carbon dioxide emissions
- Methane emissions
- Other potent greenhouse gases
  - Nitrous oxide
  - Ozone
  - CFC's

The greenhouse effect and its importance for life on Earth

- The natural greenhouse effect
- The enhanced greenhouse effect

The effects of global warming

Deforestation and its influence on the CO_2 concentration in the atmosphere

- Reasons for deforestation
- Effects of deforestation

Carbon footprint: ways of reducing our 'carbon footprint'

- Human activities increase CO_2 emissions daily
- Carbon footprint calculator
- Reduction strategies
- Ozone depletion
- Causes of ozone depletion
- Consequences of ozone depletion
- Strategies to decrease ozone depletion

Activity 1: Greenhouse effect

Water availability and water quality

Water availability

Factors affecting water availability in SA

- Construction of dams
- Destruction of natural wetlands
- Exotic / alien plantations
- Water wastage
- Cost of water
- Poor farming practices
- Droughts and floods
- Boreholes deplete aquifers

Water quality

Concept of water quality

Factors reducing water quality

- Eutrophication and algae blooms
- Domestic, industrial, and agricultural pollution
  - Agricultural contamination
  - Industrial effluent
- Effect of mining on the quality of water
- Thermal pollution
- Alien invasive plants

Role of water purification in improving quality of water

- Water purification

Role of water recycling in improving the quality of water

Activity 2: Water availability

Food security

CHAPTER 10: HUMAN IMPACT ON THE ENVIRONMENT

Introduction

Humans depend on the environment for survival but our activities are causing severe problems in the natural environment. Our rapidly increasing population and technological growth are out of balance. Human needs are becoming greater than the natural resources available to us and we produce more waste than our ecosystems can cope with. Our environmental equilibrium is disturbed. The quality of life on Earth is threatened (Figure 1).

Figure 1: Humans are fewer than 0.01% of all life on earth
but have caused the extinction of an estimated 83% of all mammals

In this chapter we examine:

- The atmosphere and climate change
- Water availability
- Water quality
- Food security
- Loss of biodiversity
- Solid waste disposal

The atmosphere and climate change

- **Climate** refers to the average weather conditions (temperature, rainfall and air pressure) of a large area over a long period of time.
- **Climate change** refers to any change or disturbance to an established climate pattern. This has happened in the past and is occurring now.

Key terminology

greenhouse gases (GHGS)	gases which trap heat in the atmosphere: the two main GHGS are carbon dioxide and methane
emissions	released gases which are usually harmful to the environment
the greenhouse effect	warming of the surface of the earth by greenhouse gases trapping heat in the atmosphere
the natural greenhouse effect	when greenhouse gases are in balance they regulate earth's temperature and enable life on earth
the enhanced greenhouse effect	when excessive greenhouse gases are emitted they trap too much heat in the atmosphere
global warming	the rise in earth's average temperature as a result of the enhanced greenhouse effect
carbon sink	any natural system (soil, water or plant) which absorbs and stores carbon dioxide (CO_2)
carbon footprint	the amount of carbon dioxide released into the air because of individual or group energy needs
ozone depletion	reduction in the concentration of ozone in the ozone layer in the stratosphere (upper atmosphere)
deforestation	the destruction of natural forests through human activities
desertification	the process by which fertile land becomes desert

Composition of the atmosphere

Earth's atmosphere is a critical mixture of gases (Figure 2) which sustain life, with

- 78% nitrogen (N_2)
- 21% oxygen (O_2)
- 1% – all remaining gases, mainly carbon dioxide (CO_2) and other small (trace) amounts

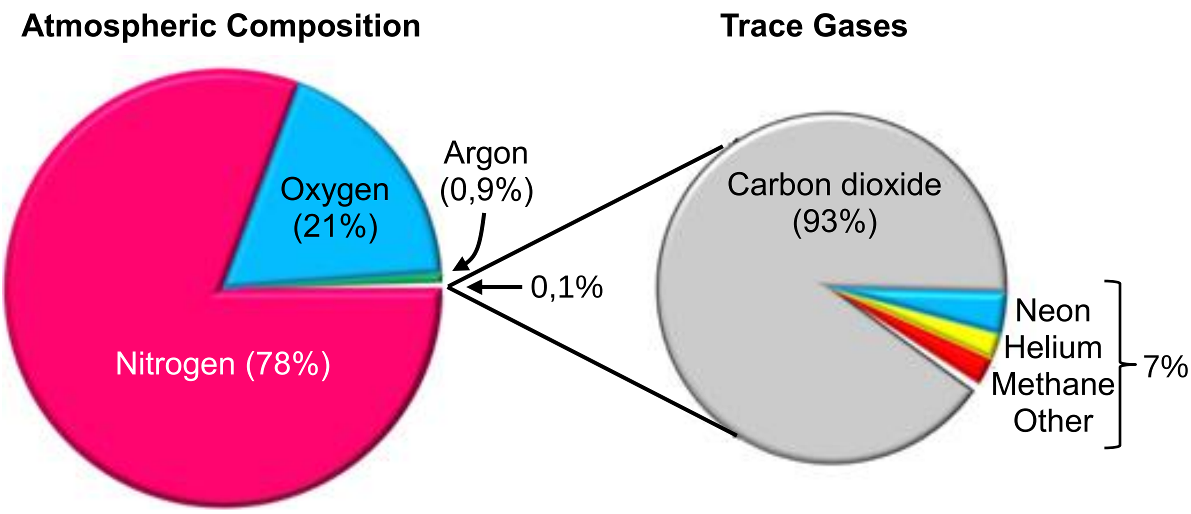


Figure 2: Composition of the atmosphere

Sources of CO_2 and CH_4 emissions – greenhouse gases

Carbon dioxide (CO_2) emissions

Carbon dioxide (CO_2) emissions are produced by:

- **cellular respiration** when CO_2 is exhaled
- **decomposition** of dead plants and animals
- the **burning of fossil fuels** as an energy source for electricity or transport
- **chemical reactions** in the cement industry and the production of fertilisers
- **veld fires** and **domestic wood burning,** which release CO_2 into the atmosphere and lead to rampant deforestation as well (Figures 3 and 4)

Figure 3: Coal fires releasing CO_2

Figure 4: Forest fires / deforestation

Methane (CH_4) emissions

Methane is the second largest contributor to the enhanced greenhouse effect, and as the planet warms up so its contribution increases even faster.

Human activities are responsible for over 60% of total methane in the atmosphere.

CH_4 emissions are produced by:

- **natural anaerobic decomposition** of organic materials, e.g. in wetlands
- **melting ice** in polar regions and permafrost releasing trapped CH_4 bubbles (Figure 5)

Figure 5: Methane bubbles trapped in ice and being released from the ocean floor

- **seawater** - decomposing marine organisms release methane bubbles. As the ocean temperature rises, more methane is released.
- **intensive agriculture**:
  - decomposing dung and compost for fertilising
  - gas being released by ruminants (animals with two stomachs – mostly cattle)
- **industrial / mining** processes:
  - refining of fossil fuels (crude oil and gas)
  - drilling / fracking (Figure 6 below) for natural gas trapped in the sediments

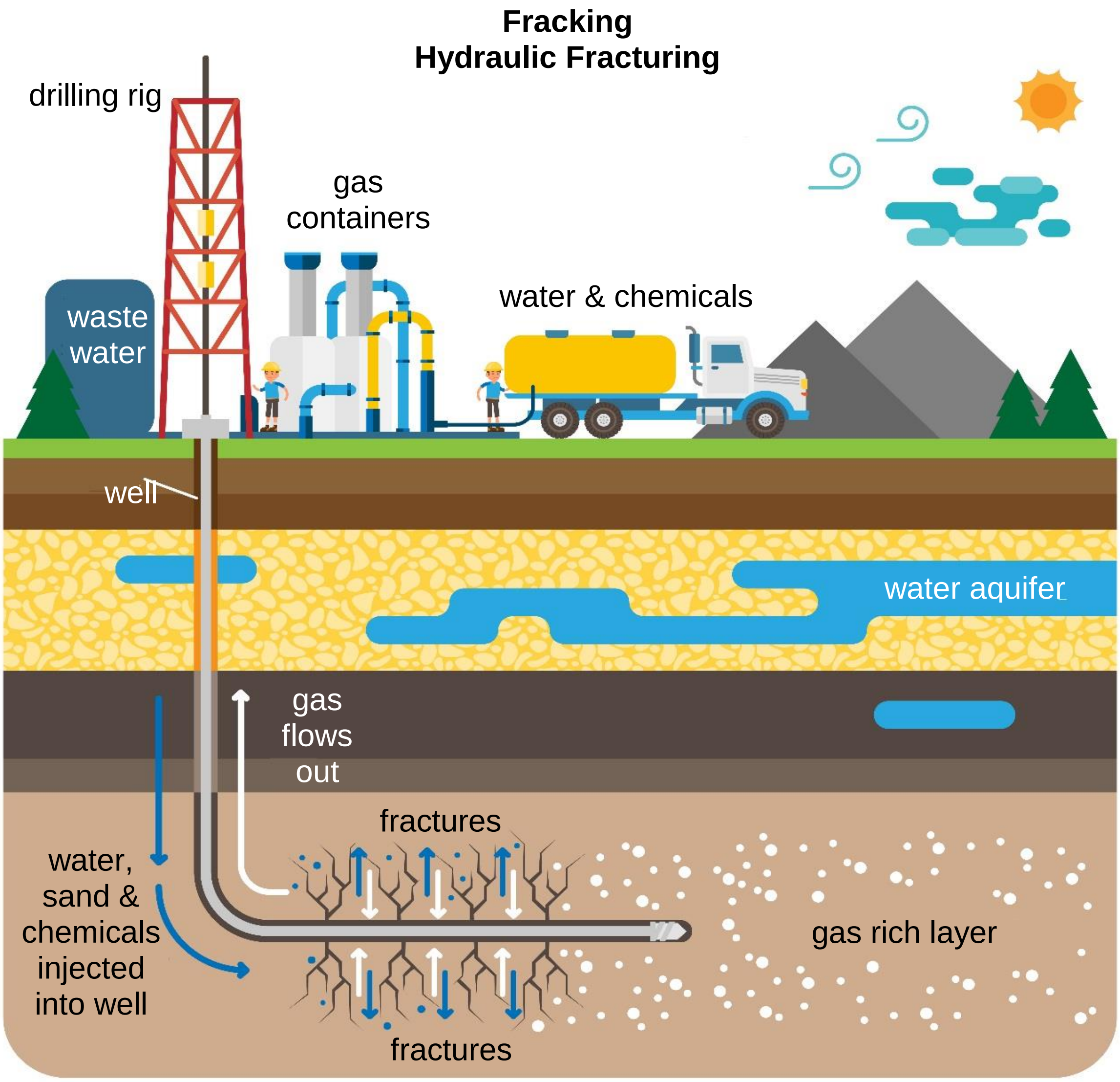


Figure 6: Fracking operation – releasing methane / contaminating underground water

- **Landfill sites** and waste water (**sewage**) treatment

Figure 7: Solid waste disposal and water treatment plant

- **termite populations** feeding on dead trees as a result of logging release large quantities of CH_4

Other potent greenhouse gases

Water vapour is the largest volume of greenhouse gas warming the planet naturally.

Nitrous oxide, ozone and CFCs (*chlorofluorocarbon)* all contribute to global warming as greenhouse gas pollutants.

- **Nitrous oxide (N_2O)**

  N_2O is released by:

  - burning wood and fossil fuels
  - biological processes which break down organic matter in the soil and sea
  - nitrogen fertilisers used for commercial farming

- **Ozone (O_3)**

  An ozone molecule consists of three oxygen atoms bonded together and is either helpful or harmful depending on where it occurs in the atmosphere.

  - The ozone produced by vehicle emissions that accumulates close to the Earth is a pollutant and a harmful greenhouse gas. These ozone emissions should be eliminated.

  - Ozone can however also be helpful, especially in the upper atmosphere (15 – 50 km above the Earth's surface). Here the ozone serves to protect life on Earth by absorbing up to 99% of the sun's ultraviolet radiation.

- **CFC's**

  CFC's (chlorofluorocarbons) are found in aerosol sprays, solvents, fridges and foams used for fast food packaging.

The greenhouse effect and its importance for life on Earth

- **How a greenhouse works**

  A greenhouse (Figure 8) is built with transparent walls (either glass or plastic). Heat from the sun warms the space inside. Although some heat is radiated out through the transparent walls, the trapped heat keeps the inside warm enough that plants can grow inside in all weather.

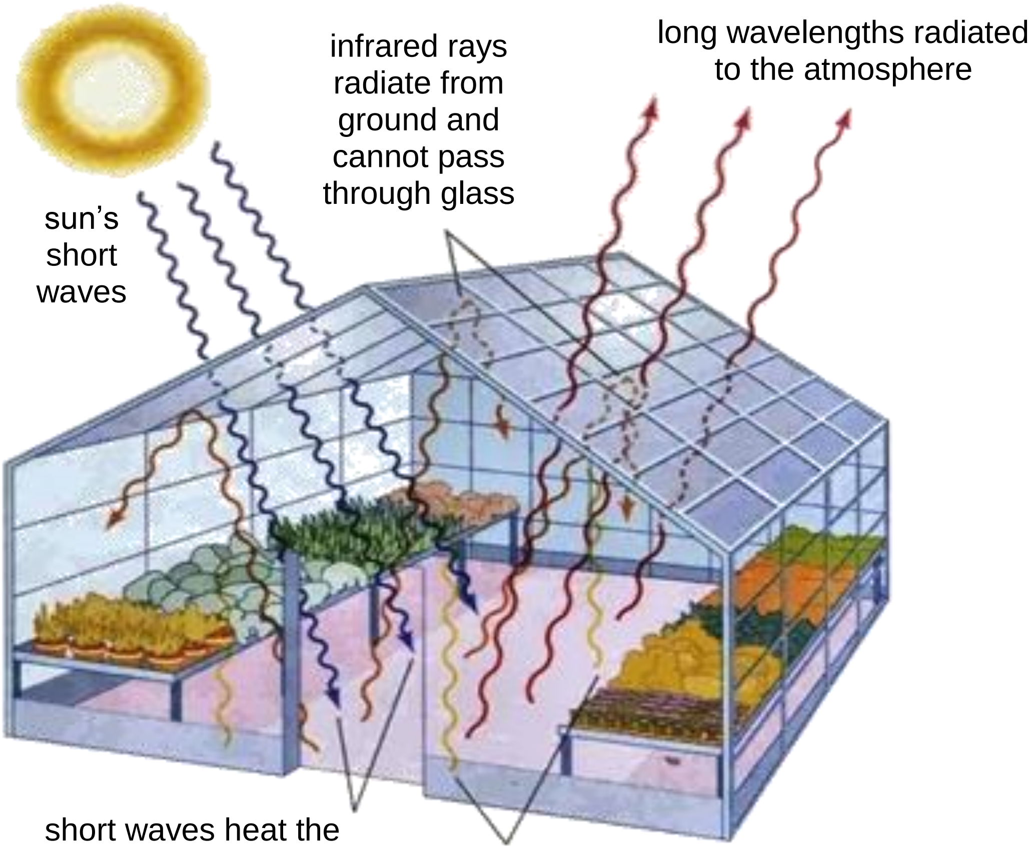
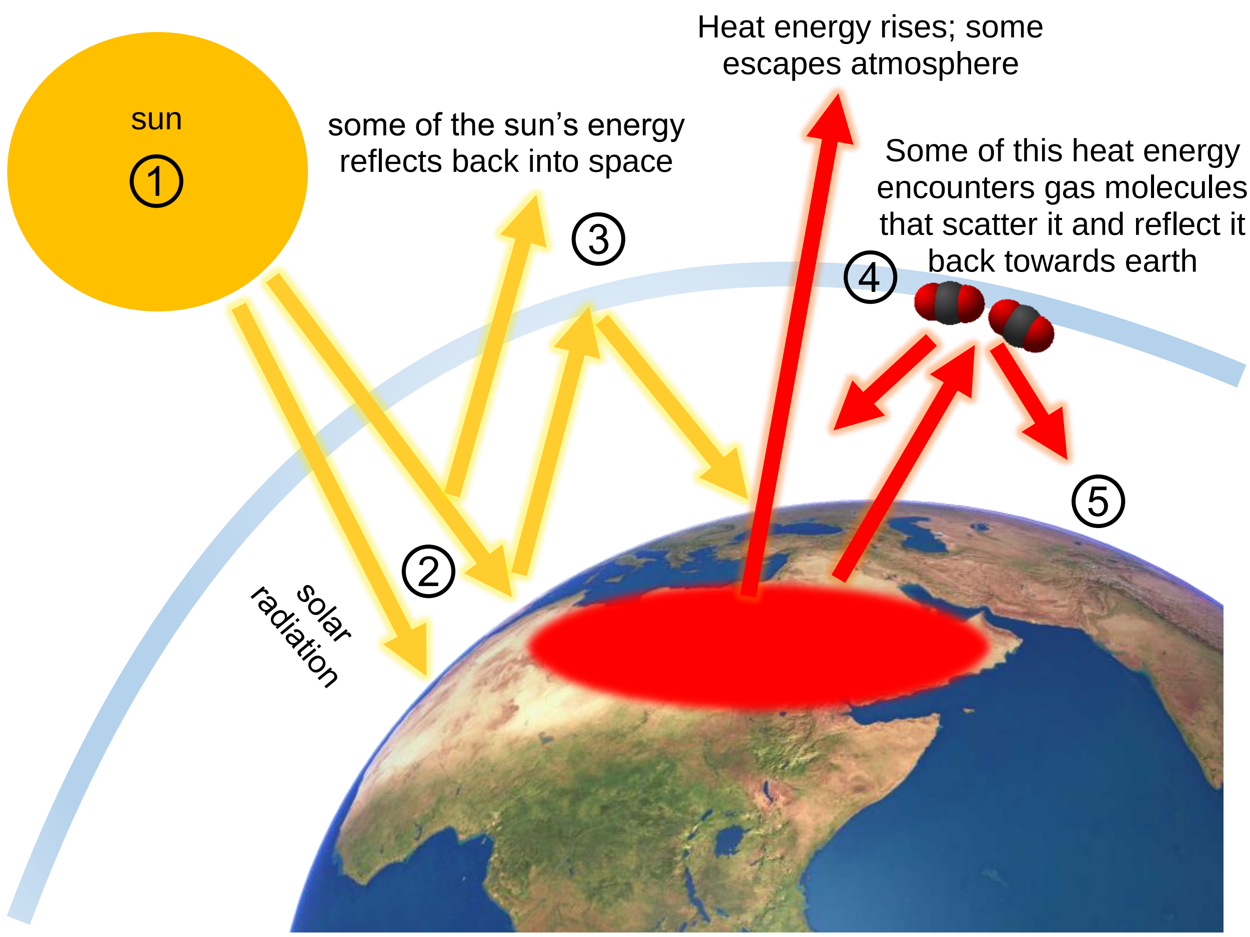


Figure 8: A greenhouse, with transparent walls, allowing heat in, and some heat out.

The natural greenhouse effect

The greenhouse effect refers to the natural warming of the earth (see Figure 9 on the next page) by heat trapped by the greenhouse gases such as water vapour, carbon dioxide (CO_2) and methane (CH_4). These gases act as an insulating blanket in Earth's atmosphere keeping temperatures evenly warm at a range that supports life on Earth. If there were no greenhouse gases, the atmosphere would have a temperature of -18˚C. This temperature would be unable to sustain life.



some of sun's energy is absorbed by earth's surface and converted into heat energy

Figure 9: The natural greenhouse effect

Figure 9 illustrates the following:

1. the Sun emits radiation towards the Earth – some of this radiation reflects off the atmosphere back into space
2. some radiation goes through the atmosphere and warms Earth's surface
3. Earth's surface releases radiation back into the atmosphere - some of this radiation escapes back into space
4. most of the reflected radiation is absorbed and trapped by greenhouse gases in the atmosphere, warming the Earth
5. trapped radiation is reflected back to Earth as well, warming and insulating the surface even more

The enhanced greenhouse effect

An increase in the concentration of greenhouse gases due to human activities, leads to an **enhanced greenhouse effect**. This results in a significant rise in the average temperature of the earth's surface over a period of time and has many negative effects. The enhanced greenhouse effect is responsible for **global warming.**

The effects of global warming

- Sharply rising temperatures result in increasing numbers of **heat waves** alternating with extreme weather conditions such as **powerful storms**.
- **Rising sea levels** cause coastal flooding. Many coastal cities will vanish.
- **Rainfall patterns** are changing – once dry areas are getting volumes of rain, and areas that had plentiful rain are slowly turned into desert areas.
- **Droughts periods are increasing** leading to more frequent fires, soil erosion and desertification.
- **Food production is decreasing**. Crops die as they cannot adapt to the changing seasons. Food insecurity increases.
    - **Warmer sea water kills corals** in shallower parts of the oceans. Corals are carbon and methane 'sinks' so this adds to the enhanced greenhouse effect. (The word 'sink' is used meaning holding tank or reservoir)
- **Seawater is becoming too acidic.** Increasing CO_2 in seawater forms carbonic acid which weakens marine animal exoskeletons as well as corals.
- **Desertification** (Figure 10) – fertile land becoming a desert. 33% of land is becoming desert, putting a billion people at risk of famine. 90% of South Africa is classified as desert or semi-desert.

Figure 10: Desertification

- **Economic, political and social conflicts will increase** as natural resources are limited due to climate change. Climate refugees are migrating from war-torn, developing countries suffering the consequences of climate change.

- **Melting polar ice caps** and glaciers (see Figure 11 below) result in:
    - **polar species unable to adapt become extinct**: e.g. polar bears and Arctic foxes in the Arctic Regions and Emperor penguins in Antarctica
    - **global temperatures rise further** as ice reflects solar radiation and does not hold heat as liquid water does
    - **methane trapped in ice is released** – this adds to the warming which in turn melts more ice
- **Melting permafrost** in Arctic regions is releasing tons of CO_2 and methane into the atmosphere

Figure 11: Ice caps / glaziers melting

In general, global warming is responsible for desertification, drought and floods (extreme weather conditions).

Deforestation and its influence on the CO_2 concentration in the atmosphere

Deforestation (see Figure 12) is the large-scale destruction of indigenous forests by humans felling and burning trees and bush to clear space for other purposes. This is a major contributor to the enhanced greenhouse effect and is estimated to contribute 20% of the total global greenhouse gas emissions.

Figure 12: Deforestation – the destruction of vast area of indigenous forest

Reasons for deforestation

- **Land clearance** – for farming and urban development
- **Commercial logging** – of indigenous timber to supply world market demands
- **Removal of commercial plantations** of non-indigenous, fast-growing trees – to supply timber for building and for making paper
- **Mining** – vegetation cleared / burnt to enable large scale mining operations
- **Fuel** – trees cut down to supply firewood / charcoal for those without gas or electricity
- **Traditional medicines** – indigenous trees stripped of their bark and roots to meet the increasing demands for traditional medicines
- **Forest fires** – deliberate or accidental – destroy vast areas of natural vegetation
- **Acid rain** – weakens trees by damaging their leaves, limiting nutrients uptake, or poisoning them

Effects of deforestation

- **Increase in carbon dioxide** (CO_2) in the atmosphere
    - Forests act as **natural carbon sinks** (Figure 13) – they absorb CO_2 during photosynthesis, and when they die and decompose, CO_2 becomes part of the humus in the soil, enabling new plants to grow. This is the natural **carbon cycle** which balances CO_2 in the atmosphere.
    - If forests are cut down the CO_2 **remains in the atmosphere** contributing to global warming instead of being part of the carbon cycle.

- The manufacturing of wood / paper products releases more CO_2.
- Burning of felled trees releases the CO_2 that was trapped in the trees

Figure 13: Rainforests of the Congo Basin – Africa's largest carbon sink

- **Increase in methane** (CH_4) in the atmosphere
  - livestock (goats, sheep, cows) in cleared areas produce CH_4
  - termite populations feed on dead trees releasing large quantities of CH_4

- **Other effects of deforestation include:**
  - **Soil degradation** from nitrogen loss, exposure to wind and water erosion
  - **More frequent flooding / mudslides** as reduced vegetation cannot absorb heavy rainfall (Figure 14)
  - **Desertification and extinction of species** occur more rapidly. It is estimated that 50,000 species disappear annually

Figure 14: A once fertile forest reduced to desert

Carbon footprint: ways of reducing our 'carbon footprint'

The term **'carbon footprint'** (Figure 15) refers to the total amount of CO_2 emitted by an individual or group in one year.

A **heavy carbon footprint** – a large quantity of CO_2 released

A **light carbon footprint** – a small quantity of CO_2 released

Figure 15: Heavy and light carbon footprints

Human activities increase CO_2 emissions daily

- **directly** through the use of fossil fuels, or
- **indirectly** by using products and services processed with fossil fuel energy.

Reducing our carbon footprint
is the most important long-term step
we can take to ensure
our future on this planet
There are many ways we can do this.

Carbon foot print calculator

Use this South African carbon calculator to find out how many trees you should plant to offset (provide balance for) your CO_2 emissions, for example, if you fly from Gauteng to Durban.
http://www.trees.co.za/carboncalculator/index3.php#carbon_results

Strategies to reduce the carbon footprint (Figure 16)

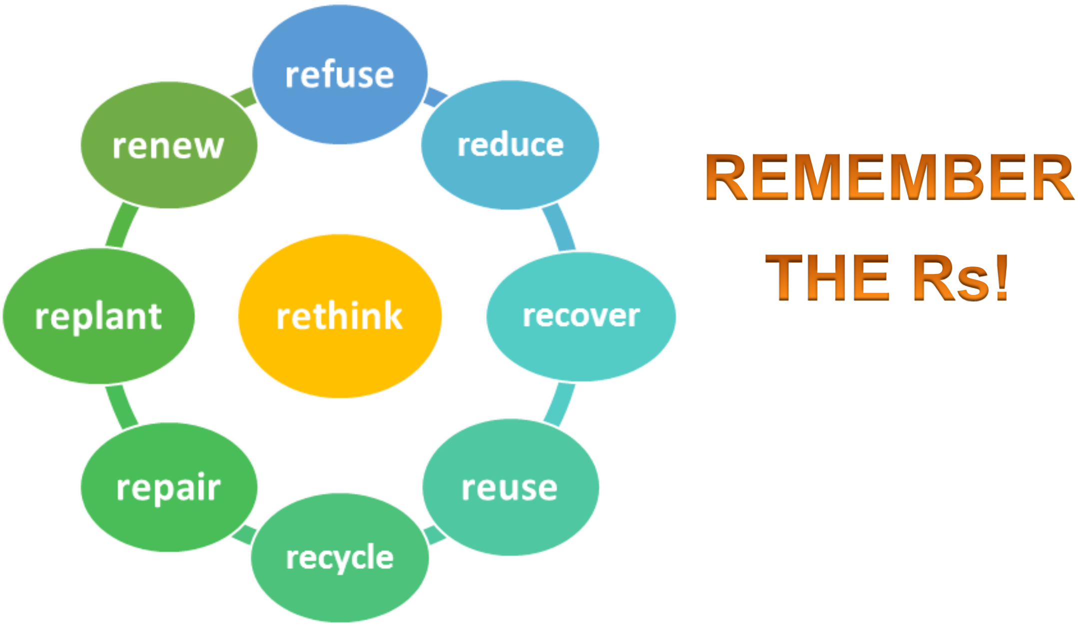


Figure 16: Remember the Rs!

Rethink everything you use in terms of your carbon footprint

Refuse to waste; do not use or buy disposable items, e.g. straws, cutlery, nappies,

Reduce burning wood, gas and coal; using appliances, shopping; transport use.

Reuse products whenever possible, e.g. water bottles, mugs, shopping bags

Recover and **replace** items and materials with recycled, donated or upcycled

Recycle paper, plastics, glass, metal and electronic items by separating waste.

Repair clothing, furniture, appliances to decrease market demands.

Replant indigenous vegetation as carbon sinks in densely populated areas

Renew ways of producing energy and making items. Be creative and inventive.

Possible examples of reducing our carbon footprint:

Figure 17: Energy saving bulbs

Figure 18: Spekboom

- Replace old light bulbs with energy saving bulbs.
- Plant indigenous spekboom. These plants remove a 100 times more carbon from the atmosphere than pine trees.

Ozone depletion

As stated above, ozone in the stratosphere forms a protective layer that absorbs 97 – 99% of the sun's high frequency and dangerous ultraviolet radiation that is potentially damaging to life on Earth.

In the 1970s, scientists noticed that a 'hole' was forming in the ozone layer above the South pole. The ozone was thinning, and even disappearing at times over the polar regions, allowing the sun's harmful UV radiation to penetrate the atmosphere.

Scientists referred to this phenomenon as **ozone depletion** (Figure 19). The 'hole' in the ozone layer was larger than the continent of Antarctica (Figure 20).

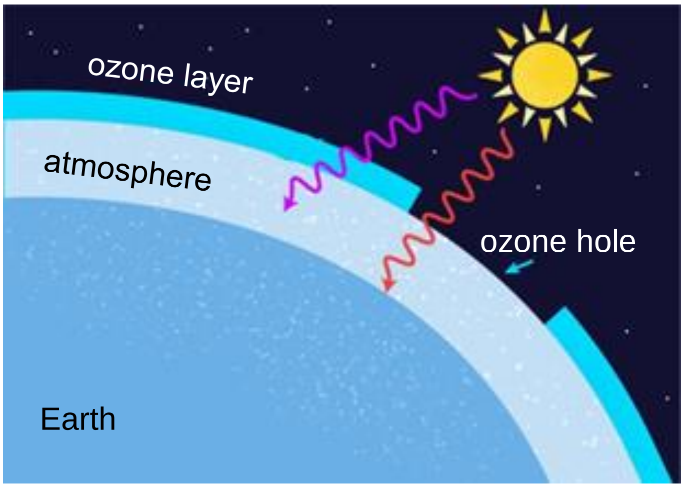


Figure 19: Ozone depletion

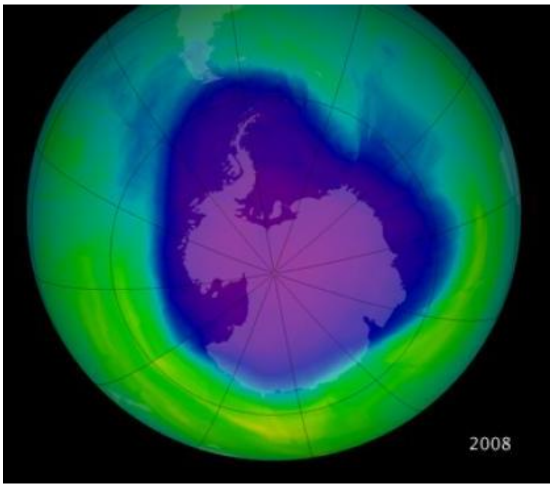


Figure 20: 2008 NASA image of

the ozone hole over Antarctica

Causes of ozone depletion

Ozone depletion is caused by various chemicals and pollutants which react with ozone. Examples include:

- **CFCs (chlorofluorocarbons) and** HCFCs (hydrofluorocarbons) used in older refrigerators, air-conditioners and spray cans/aerosols – release chlorine which destroys ozone molecules
- **Bromine** from pesticides and fire extinguishers
- **Carbon tetrachloride,** a solvent used in dry cleaning and paints

Consequences of ozone depletion

If the ozone layer is thinner or destroyed, more harmful ultraviolet (UV) radiation reaches the Earth's surface causing:

- **Human damage**: increased UV exposure weakens our immune system, leading to skin cancer (Figure 21), sun burn, and skin ageing. It also causes cataracts and damages chromosomes.

Figure 21: Skin cancer characterized by raised, rough skin.

- **Agricultural damage**: UV radiation interferes with photosynthesis in plant growth. As a result greenhouse CO_2 levels rise as plants no longer absorb CO_2. Food security is threatened as plant growth slows down drastically.
- **Marine damage**: excessive UV radiation damages marine life.
- **Material damage**: excessive UV radiation breaks down wood, plastics, rubber, textiles and other construction materials.

Strategies to decrease ozone depletion

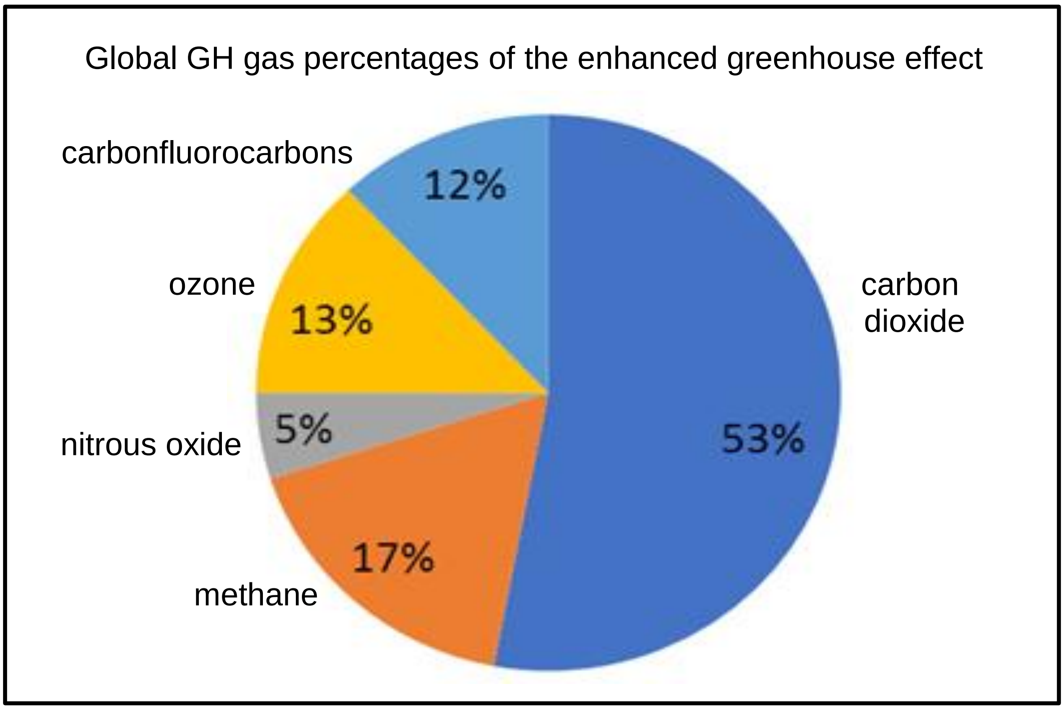
The Montreal Protocol

In 1987 in Montreal, Canada, 30 nations signed a global treaty to reduce and eventually stop production of ozone destroying substances such as CFCs and others.

The Montreal Protocol is a success story, and ozone depletion has been stopped, but has not yet been reversed. We need to continue our care by developing ozone friendly products, maintaining laws preventing ozone depletion, monitoring skin cancers and increase public awareness.

Activity 1: The greenhouse effect

Study the pie chart and fill in the missing information on the table below. (6)



Greenhouse Gas	**Sources of emissions**	**%**
Carbon dioxide	respiration, fires, fossil fuel burning, decomposition	53
Methane (name 3 more)	gas leaks	17
Nitrous oxide	fertilisers, organic decomposition, fires, deforestation	.....
....	industrial processes, chemical reactions to sunlight	.....
Carbonfluorocarbons	refrigerants, aerosols, cleaning solvents	12

Water availability

Clean fresh water is essential for the survival of all living species on Earth. Water is a renewable resource, but the availability depends on climate conditions.

It is estimated that by 2050 almost 2 billion people won't have access to clean, safe water supplies. This is an urgent problem for governments across the world.

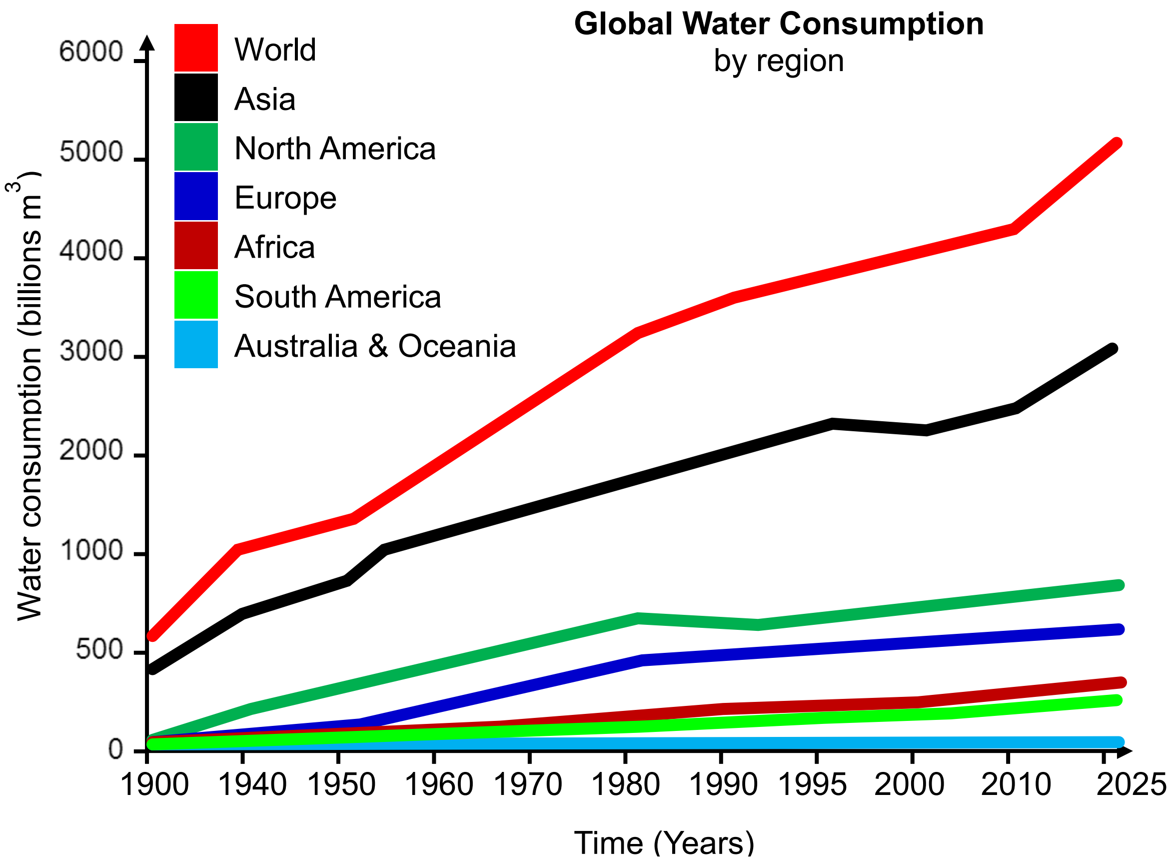


Figure 22: Global water consumption from 1900 to 2025

Key terminology

hydroelectricity	electricity generated by the power of water
wetland	ecosystem saturated permanently or seasonally with water
aquifer	underground layer of water-bearing, sponge-like rock
irrigation	supply of water to land or crops to help growth
eutrophication	excessive nutrients in a waterbody causing excessive growth of algae or aquatic plants
sewage	liquid waste: water and excrement (urine and faeces) in sewers
sewers	drains and pipes

sewerage system	sewers carrying sewage to a sewerage plant or place of water treatment
sanitation system	a hygienic or waterborne sewerage system
contamination	pollution or poisoning
thermal (pollution)	heat pollution (in this case from hot water)
AMD	acid mine drainage
purification	cleaning by removing contaminants
reclamation	returning something to a previous, better condition

Factors affecting water availability in South Africa

Access to sufficient water is a basic human right in the Constitution of South Africa. This has improved access for some, but service delivery is a challenge for most people of our country. The following are major factors affecting water availability:

The construction of dams

A dam is a man-made barrier usually built across a river or catchment area for the following reasons:

- water supply for domestic and industrial use
- water supply for agricultural and food production
- flood control catchment areas
- generating hydro-electricity (Figure 23)

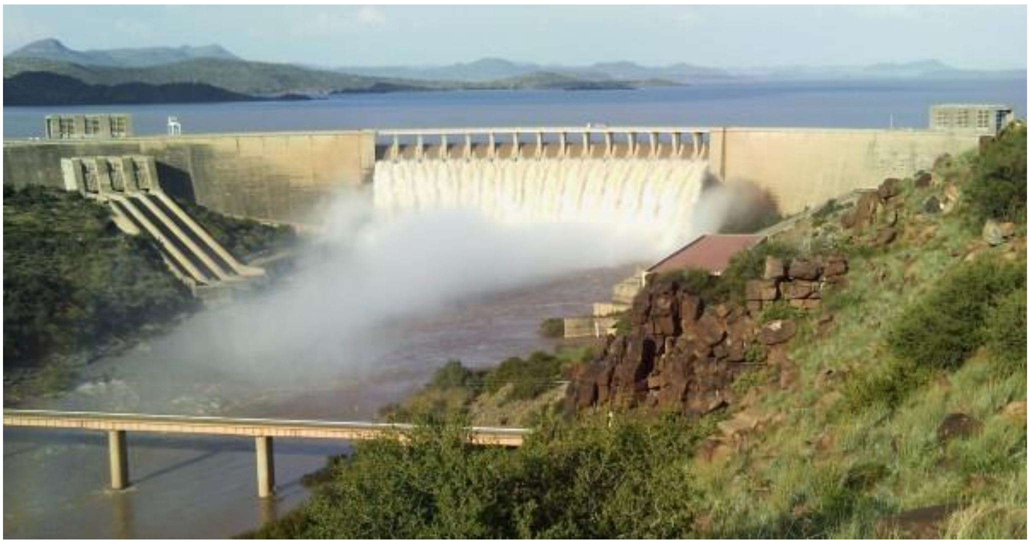


Figure 23: SA's largest dam, the Gariep, overflowing in 2011 and generating hydroelectricity

The negative impacts of dams include:

- loss of habitats below the dam – making less water available
- changes in the natural flow of water
- reduced water quality
- increased sedimentation
- prevention of the natural migration of fish

The destruction of natural wetlands

Wetlands are important ecosystems (Figure 24):

- Wetlands act as sponges, storing rainwater and releasing it slowly in dry seasons. This prevents flooding and any soil erosion that would result from the quick run-off of flood waters.
- Wetlands are habitats for diverse species of animals, plants and aquatic plants which act as filters, cleaning water that flows through them.

Figure 24: iSimangaliso Wetland Park in KwaZulu Natal provides a valuable research site for environmental scientists to explore impacts on water and quality.

Wetlands are damaged by human activities:

- Wetlands are drained to build roads, factories and housing in urban areas and as by irrigation for agriculture.
- Damming wetlands destroys their ability to filter and release water naturally.
- Wetlands are polluted by mining, industrial and domestic waste and litter.

Exotic / alien plantations deplete the water table

Many alien plants (not from SA – wattles, gums, pines, etc.) are grown in South Africa to supply timber (Figure 25 & 26) wood pulp for paper. These are all fast-growing, water-hungry plants which deplete the groundwater and reduce biodiversity.

Figure 25: Pine plantations for the paper industry

Figure 26: Black wattle – an invasive alien

Water wastage

- Water is wasted in homes, on farms, in industry and on mines through carelessness, poor management and inefficiency. 40% of our cities' water supplies are lost to leaking pipes (Figure 27, 28).
- Crisis events, such as droughts or veld fires, increase the demand for water and therefore increase the risk of wastage.

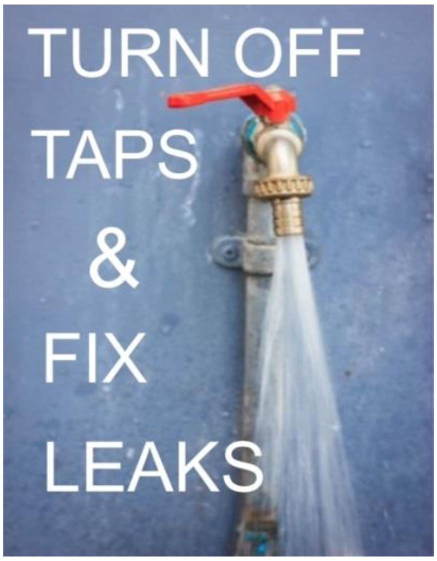


Figure 27: Stop wasting water!

Figure 28: Collecting water from a communal street tap in Soweto, Johannesburg. Worn taps result in leaks and water wastage.

The cost of water

- 'Water for all' as a human right was introduced in South Africa in 2006: 6 kL (kilolitres) per month is free for a family of five. Because the building and maintenance of dams, water treatment and supply is expensive, municipalities charge for extra usage – the greater the volume used, the greater the charge.
- Urban areas are supplied by dams situated in distant rural areas which also increases costs.

Poor farming practices

- Monoculture (planting of a single crop) uses a lot of water. Open ditch irrigation and overhead sprinkling systems lose water to evaporation.
- Overgrazing, vegetation destruction, burning and deforestation all cause erosion which leads to water loss through increasing run off.
- Incorrect ploughing up and down slopes (instead of contour ploughing) also causes more runoff (water wastage), which in turn causes more erosion.

Figure 29: Contour ploughed fields in the Western Cape prevent excess run off

Droughts and floods

Rainfall is variable from year to year and most of our country is arid.

- During droughts availability of water decreases. Increasing temperatures lead to high rates of evaporation from open sources such as dams and lakes. The water used from dams during these times is not easily replaced.
- Natural vegetation allows water to soak into the soil. If vegetation is removed, or the land is too arid, then there is nothing to hold excess water during floods – the soil is further eroded and the extra water is lost.

Figure 30: Aerial image of barren earth exposed over the nearly empty Theewaterskloof dam during severe drought in the Western Cape in 2018

Boreholes deplete aquifers

- Boreholes need to be monitored to prevent too much water being taken from aquifers.
- Mining in Gauteng and North West Province and fracking in the Karoo drain and pollute the aquifers, decreasing availability.

Water quality in South Africa

What do we mean by the concept of water quality?

Water must be clean and treated so that it is safe to drink. Diseases such as cholera, typhoid and dysentery are waterborne (carried by water) and cause diarrhoea which can lead to dehydration and death.

Water is used for various purposes: domestic, industrial, agricultural and mining. These various activities all affect the quality of the water.

Factors reducing water quality

The factors responsible for reducing water quality include:

- Eutrophication and algal bloom

- Domestic, agricultural and industrial pollution
- Mining
- Thermal pollution
- Introduction of alien plants

Eutrophication and algae blooms

- Eutrophication occurs when high levels of nutrients from fertilisers and sewage-polluting water bodies encourage the rapid growth of algae.
- Nitrates and phosphates from fertilisers, sewage and detergents are rich food for algae which then reproduce very quickly. This is called an **algal** (or algae) **bloom** and shows as a thick layer of green scum (Figure 31) on the water.
- The algae block out light needed by aquatic organisms for photosynthesis, so these organisms die. Anaerobic bacteria use up all the oxygen in the water to decompose the dead organisms. The result is that all other organisms (including fish) which are dependent on the oxygen, die as well (Figure 32).

Figure 31: Eutrophication produces this thick green pond scum

Figure 32: Algae bloom leads to oxygen depletion and the death of aquatic species

Domestic, industrial and agricultural use

- Detergents, pesticides, fertilisers, sewage (Figure 33) all negatively affect water quality
- Domestic waste must be disposed of through controlled sewerage systems in urban areas to be treated / purified at sewerage plants.
- Untreated waste can spread diseases or lead to eutrophication

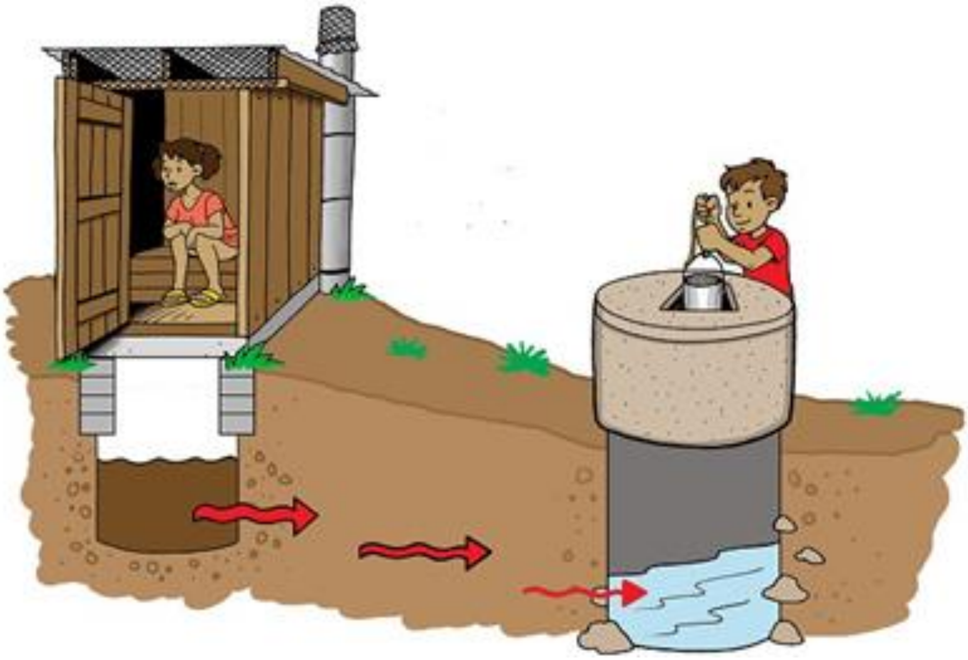


Figure 33: Open pit latrines contaminate groundwater: *E. coli* bacteria from human faeces make it un-safe to drink ground water or river water without purification treatment.

Agricultural contamination

- Large commercial farms use huge quantities of fertilisers, hormones and pesticides to speed up plant growth, kill insects and other pests (Figure 34).
- Irrigation and rainwater washes a lot of these chemicals into wetlands, dams and rivers, and some filter into the groundwater.

Figure 34: A farmer spraying pesticides in a rice paddy field

Industrial effluent (liquid waste) (Figure 35)

Waterborne waste from industrial processing that is pumped into rivers or wetlands causes various types of pollution depending on the industry:

- **Toxic chemical pollution** from paints, glues and solvents, heavy metals such as mercury and lead causes poisoning.
- **Increasing salinity** (saltiness) of wastewater containing common salts used in or produced by industries kills sensitive organisms.
- **Oil and petrol spills** from industries and underground storage tanks pollute and poison surrounding water systems.

Figure 35: Polluted water (waste water or effluent) discharging into a river and wetland

The effects of mining on the quality of water

A lot of waste water is generated by all sectors of mining. Most of this is pumped into drainage ponds and dams (Figures 36 and 37). It is then treated and recycled by responsible mining companies.

Figure 36: AMD inside an abandoned gold mine.

Figure 37: AMD on the surface outside an old mine

Most of the water used in mining goes to waste and pollutes the quality of water bodies in the following ways:

- **Thermal pollution:** Mines also discharge large amounts of hot water which kills plant and animal life.
- **Chemical contamination:** The poison cyanide is used in goldmining and contaminates surface and ground water bodies near mines.
- **Metal contamination**: Mine waste water contains traces of poisonous arsenic, mercury, lead and zinc which affect nearby water bodies. Radio-active elements such as uranium are also dangerous contaminants.
- **Acid mine drainage (AMD):** Ground water dissolves sulfide minerals out of the rock in mines forming sulfuric acid. This contaminates ground water and surface water bodies around disused mines for years, impacting human and animal health negatively and resulting in a loss of biodiversity and desertification.

Thermal pollution

Thermal pollution is the result of warm or extremely hot waste water from industrial processing being pumped out into nearby waterbodies (Figure 38).

- Hot water kills many temperature sensitive organisms.
- Hot water has a lower oxygen content which also kills oxygen-dependent, aquatic organisms.
- The increased temperatures contribute to favourable conditions for algal bloom and eutrophication.

Figure 38: In winter it is easy to see how hot water from the cooling towers of a power station melts an ice covered river

Alien invasive plants

Alien invasive plants – they are alien since not indigenous to an area, and invasive because they flourish and out-compete indigenous species for space and resources.

- Aquatic aliens invade water bodies containing excessive nutrients from sewage and agricultural waste. There are many of these in South Africa but the worst is **the water hyacinth** *(Eichornia crassipes)* (Figure 39)
- Water hyacinth reproduce quickly to form a dense mat over the surface of water bodies such as rivers, dams and lakes. They choke irrigation canals, pipes and pumps controlling water flow.
- The dense covering or carpet of water hyacinths blocks sunlight penetrating water bodies, causes eutrophication and kills all aquatic life. This severely decreases water quality and increases the risk of waterborne diseases.

Figure 39: Water hyacinth float on water, and form a dense carpet

Role of water purification in improving quality of water

The poor quality of water is more of a problem than the lack of water supply.

Figure 40: Boil water before drinking to kill any disease causing pathogens

If we continue to pollute our available water:

- we will damage ecosystems which are our primary sources of fresh water.
- there will be less water for all human activities, from drinking water to industrial water use.
- water will cost more to treat and recycle, and everyone will have to pay.
- there will be an increase in waterborne diseases.

Water purification

Water purification is expensive but necessary to ensure clean fresh drinking water for human consumption.

- Water is treated and purified on a large scale at water treatment and sewerage plants.

Fig 41. Aerial view of storage tanks in sewerage plant

- Water may be purified at home using filters. The water should be boiled to make it safe for drinking.

Figure 42: Make a simple homemade water filter using a discarded 2 L bottle

- Use a 2 L bottle with a lid
- Cut the bottom off the bottle and fill it with layers of filtering materials in the order shown in Figure 42.
- Invert it over a glass container and pour dirty water in the open end.
- Remove the lid. Clean water will drip through the filter.
- The filtered water must be boiled or chlorine tablets can be added.

Recycling water improves the quality (and availability) of water

Recycling used water is a necessary source of water, particularly in arid areas or in times of drought.

- Power stations, mines and industry should all recycle their water waste.
- Domestic households can use their greywater for growing plants.
- Cities and towns should reclaim water at sewerage works and purify it for domestic use

Activity 2: Water availability

Western Cape water consumption data was calculated to be the following in 2018:

Consumers	Water consumption in Mm^3
City of Cape Town	360
Agricultural sector	180
Other municipalities (Overberg, Boland, West Coast and Swartland)	40

1. Identify …
   a) the independent variable (1)
   b) the dependent variable (1)
2. Can this data be used to accurately predict the water consumption for the year 2019? Give a reason for your answer. (2)
3. Draw a pie chart (with labels) to show the data in the table expressed in percentages. Show workings in table format, round to whole numbers. (6)
4. Can one predict future water consumption for the Western Cape? Give a reason for your answer. (2)
5. Research waterless composting toilets and determine whether they should be installed as an alternative to septic tanks, pit latrines or bucket toilets. (4)

   Here is a video link to a one type of waterless composting toilet.

   https://www.youtube.com/watch?v=4LrUc0C7vW0

(16)

Food security

According to the World Health Organisation (1996), "**food security** exists when all people, at all times, have physical and economic access to sufficient, safe, nutritious food that meets their dietary needs and food preferences for an active, healthy life."

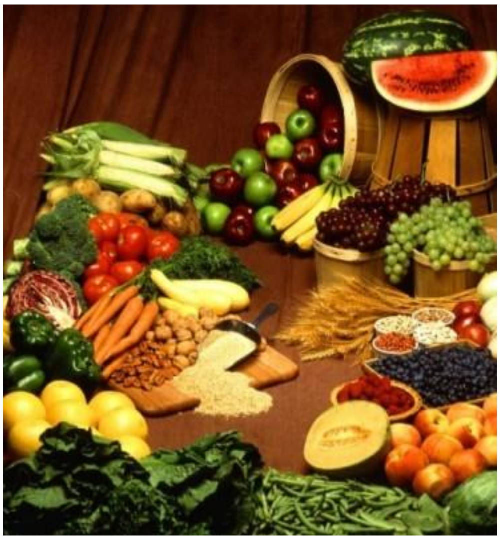


Figure 43: Healthy, nutritious fruits, grains and vegetables are often too expensive for the poor to access, even though there is a surplus to be had.

Food <u>insecurity</u> is where there is evidence of malnutrition and starvation. This is often a result of socio-political conditions such as wars, refugee migrations, diseases and epidemics.

Key terminology

food security	the guarantee that nutritious food will be available to all people at all times and in sufficient quantities
exponential growth	where size increases at a greater and greater rate
famine	severe shortage of food that causes starvation
monoculture	farming a single crop or breed over a large area
pesticide	insect or rodent killer or poisons
herbicide	weed / plant killer
fertiliser	food for plants
gene pool	all the different genes in a breeding population
genetic engineering	altering the genes of organisms
subsistence farming	farming traditionally to feed themselves to survive
commercial farming	farming with machinery to sell products for profit

Factors that influence food security

Food security is influenced by:

- human exponential population growth
- drought and floods (climate change)
- alien plants and the reduction of agricultural land
- the loss of wild varieties
- wastage
- genetically engineered foods
- poor farming practices such as:
    - monoculture
    - overgrazing and the loss of topsoil
    - the use of fertilizers
    - the use of pesticides

Human exponential population growth

For thousands of years, human population growth increased very slowly and it wasn't until the early 1800s that the world's human population reached an estimated 1 billion people (see Figure 44). The estimate for 2020 is 9 billion people on the planet. This puts enormous strain on food resources.

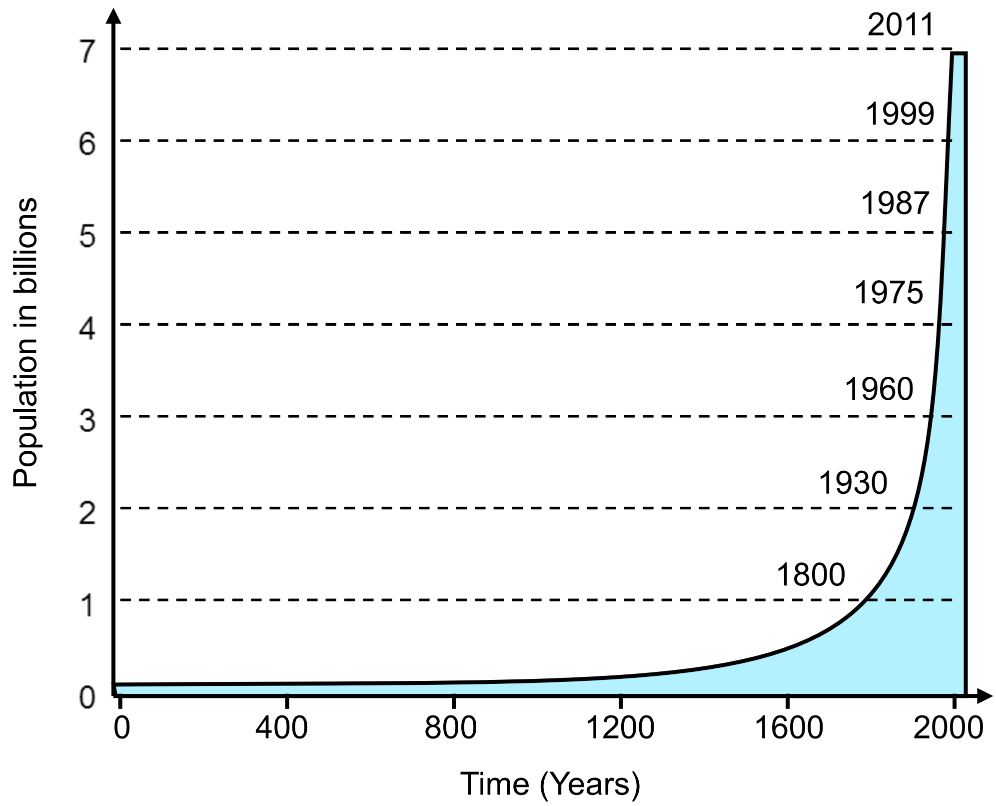


Figure 44: The exponential growth of the human population

Droughts and floods (climate change)

Climate change and extreme weather conditions are caused by global warming:

- Increasing droughts are a threat to crops and reduce food security and result in famine. After diseases, famine is the second largest cause of deaths worldwide.
- Floods are becoming more frequent because of changes in rainfall patterns and the increasing incidents of extreme conditions such as hurricanes. Floods put enormous pressure on food production, and the ability of humans to recover agricultural land after flooding. Floods also increase the spread of diseases.

Alien invasive plants and the reduction of agricultural land

Alien invasive plants reduce food security because:

- Aliens use much more water than indigenous plants and lower the water table for boreholes. This reduces the supply of water for irrigation of food plants.
- Aliens such as gum, pine and wattle trees contain volatile oils which burn faster than indigenous species resulting in veld fires (see Figure 45).

Figure 45: Alien invasive pine trees are highly flammable: they contain resins, retain lots of dry needles on dry, low-hanging branches, and shed dead needles into dense carpets of dry mulch

- The bark, stems and leaves of some alien invasive plants change the soil pH which then cannot support agricultural production.

- Some alien plants that invade pastures and grasslands, are inedible or toxic. This negatively affects livestock attempting to eat them.
- Weeds outcompete planted crops, which affects food production, as they are labour-intensive to remove and control with pesticides (Figure 46)

Figure 46: The Alien Invasive Species Removal programme trains people to identify and remove alien species

Loss of wild varieties impacts biodiversity and the gene pool

Most modern food crops and meat supplies come from plants and animals that have been selectively bred or domesticated from wild varieties. Over centuries humans have improved nutrient values and food yields by selectively breeding some varieties of plants or animals over others. Wild varieties, however are often more resistant to pests & diseases and can be used to breed resistant genes into domesticated crops.

Figure 47: Wild varieties of maize – they are more genetically diverse, but with lower yields than modern selectively bred maize.

The gene pool refers to the wide varieties of genetic characteristics which are passed on through reproduction:

- A large gene pool means great genetic diversity, with strong and healthy breeding stock. (Wild varieties)
- A small gene pool means low genetic diversity, and more susceptibility to problems, therefore weaker stock. (Often a result of selective breeding)
- Ongoing destruction of habitats is resulting in mass extinction of species and shrinking of the gene pools across all dependent food species.

Food wastage

Food security is more threatened by wastage than any shortage: it is estimated that a third of global food production (1.3 billion tons) is wasted worldwide every year!

Wastage occurs at every step of the food chain: from growing, harvesting and processing, to retailing (selling) and consumption (buying and eating).

Wastage differs in developing countries from developed countries:

In **developing countries**, 40% of food is lost during food production and transportation (Figure 48) because subsistence farmers:

- mostly farm in poor-quality soil or in areas that are unsuited to agriculture
- lack adequate storage and cooling facilities
- are unable to protect crops and livestock from the effects of extreme weather conditions, pest infestations and diseases in animals
- cannot afford expensive long-distance transportation for produce and struggle with bad roads and limited access to railways

Figure 48: Subsistence farming and its problems

In **developed countries**, food is wasted at all stages of food supply. The total food waste of developed countries is estimated to be 222 million tons per year. This is almost the entire food production of sub-Saharan Africa.

Wastage in developed countries occurs because of:

- harvesting with machinery, which harvests ripe and unripe crops together. As a result unripe crops are wasted.
- laws which require disease infected stocks to be completely destroyed
- surpluses occurring from commercial farming being discarded because the selling price is not high enough
- supermarkets marking foods with ‘sell-by’ and ‘eat-by’ dates. Foods past these dates are dumped even though still perfectly edible

Genetically engineered foods

Genetically modified (GM) foods can improve food security because:

- they are modified to be pest and disease resistant – which reduces the cost of pesticides
- they are modified to provide extra nutrients and greater yields
- they can be altered to tolerate drought conditions and salty soils which means they can be grown in areas that were previously unsuitable

Poor farming practices

Famine is also a result of poor farming practices. The effects of climate change is making the situation worse.

The future of food: https://www.youtube.com/watch?v=SbMUUPJFy40

Poor farming practices include:

- **Monoculture** – this refers to the growing of high-yielding crops of plants, of a **single species** (Figure 49), in large areas for many consecutive years e.g. maize, wheat, carrots, fruit trees etc.

Figure 49: Irrigating a monoculture field – huge amounts of pesticides and fertilisers are needed to farm monocultures

The negative effects of monoculture include:

- exponential growth of pests attracted by the concentration of food
- loss of topsoil once the crop is harvested
- loss of biodiversity
- increased application of fertilizers and pesticides
- periods during which there is no food for bees

- **Overgrazing and loss of topsoil**

  Overgrazing occurs when too many animals graze an area for prolonged periods. The plant cover which protects and binds the soil is removed. Topsoil is vital for agriculture. It is rich in humus (organic matter) as well as inorganic nutrients (minerals) and organisms, e.g. earthworms that aerate and enrich the soil with their excreta.

  In South Africa, almost 70% of agricultural land is used for grazing because it is not fertile enough, or is too dry, to support crop planting.

  The effects of overgrazing include:

  - loss of topsoil and erosion because the plants have been removed (Figure 50)
  - increased growth of unpalatable species – grazers selectively remove the palatable species
  - topsoil is washed in dams and rivers causing silting

Figure 50: Eroded topsoil caused by overgrazing, drought and floods in farmlands near Cradock in the Eastern Cape province of South Africa

- **The use of fertilisers**
  - Artificial fertilisers are industrially manufactured and contain nitrates, phosphates and potassium to increase crop yields and quality and reduce growing time.
  - They are expensive and drive up the cost of food production thereby lowering food security.
- **The use of pesticides**
  - Currently, over a third of our global food crops are lost to pests. Farmers use large quantities of chemical pesticides to control them. Examples of pests are:
    - microorganisms, which cause diseases such as rust and blight
    - insects such as aphids, beetles, caterpillars and locusts
    - rodents such as rabbits, rats and mice
  - Chemical pesticides are toxic to the environment and useful species are affected as well as the pests they target.
  - Concentrations of toxins accumulate (build up) in the food chain: e.g. an owl that eats poisoned rats and mice will accumulate more poison than the amount consumed by just one of its prey (Figure 51). This is called **bio-accumulation** of poisons.
  - When heavy rains fall, pesticides are washed from sprayed crops, as well as poisoned soil, into surface water bodies, which affects fish and

other aquatic organisms. Birds that prey on these die as well. This also reduces food supplies for humans.

Figure 51: Poisons are unbelievably destructive to wildlife and our shared environment. Raptors that eat rodents die by secondary poisoning.

Activity 3: Food security

Read the following and then answer the questions below.

The multinational companies controlling agricultural economics:

- impoverish farmers who are forced to buy seed, pesticides, fertilisers and even farming equipment from them at high costs.
- do not allow independent research, in order to protect their profits.
- control most GMO seed rights with patents. Farmers who traditionally saved their seed for replanting or exchanging with other farmers are no longer allowed to do so. The control and ownership of seeds - in the case of GM maize, GM soya and GM cotton in South Africa - passes entirely to multinational corporations that hold the patents, such as Monsanto (German and American) and Syngenta (American and Chinese). This undermines farmers' rights, and places control outside the country.
- the costs of genetic modification increases food prices which negatively impacts food security.
- Most South Africans are unaware that some of their staple foods are genetically modified.

Redacted from: March Against Syngenta: Monsanto's Swiss Twin Unmasked by MultiWatch, Schwabe AG, 2016

Figure 52: European farmers and public protest against Monsanto and Syngenta controlling food seeds

1. Describe what is meant by the following terms: (4)
   a) Genetically modified organism (GMO)
   b) food security
2. Name three genetically modified crops grown in South Africa. (3)
3. Discuss three ways in which genetically modified seed companies negatively impact on impoverished farmers. (3)
4. The extract above describes only the negative impacts of genetically modified crops. Describe how food security is positively affected by genetic modification of crops. (3)
5. How do GM seeds affect the gene pool and biodiversity? (2)

(15)

Loss of biodiversity

Introduction

Biodiversity refers to the variety of all living organisms on Earth. Loss of biodiversity is the most damaging impact humans have on the environment.

Biodiversity is important because it maintains the provision of …

- good quality fresh water and air quality
- climate stabilisation
- healthy quality soil formation
- pollination and natural seed dispersal
- natural fuel and food from the environment
- natural pest control with predators
- healthcare from medicinal plants and microbes
- ecotourism and recreation in nature

Key terminology

extinction	when a species has completely died out
maintain	provide for, or enable, life to keep stable and existing
diversity	a wide range of different things
biodiversity	the variety of all living organisms on Earth
biome	large community of plants and animals occupying a region with distinct climate conditions, e.g. grassland, desert, tundra..
predators	organisms that capture and feed off other organisms (prey)
habitat	place where organisms live, including all living and nonliving factors or conditions of the surrounding environment.
urbanisation	the increasing development of towns and cities
migration	long-distance movement of organisms, often seasonal
sustainable	enabling or maintaining growth without depleting resources
invasion	rapidly spreading and taking over an area

Factors that reduce biodiversity

The following factors contribute to reducing biodiversity:

- Habitat destruction through:
    - farming methods
    - golf estates
    - mining
    - urbanization
    - deforestation
    - loss of wetlands and grasslands
- Poaching (e.g. rhino horn, ivory, ‘bush meat’)
- Alien plant invasions

Habitat destruction

Habitat destruction occurs through:

- **Farming methods (overgrazing and monoculture)**

  Overstocking livestock and overgrazing pastures (Figure 64) for too long in one area results in:
    - soil contamination from excessive dung and urine
    - soil erosion
    - makes way for alien plants to take over
    - reduces the diversity of vegetation leading to land degradation and
    - desertification

  Growing large quantities of these single type crops (monoculture) year after year leads to:
    - loss of indigenous species and biodiversity
    - specific insects overbreeding and feeding on these crops
    - environmental pollution is caused by pesticides and fertilisers
    - poisoning and eutrophication of nearby water supplies

Figure 53: Overgrazing – stripping the land of ground covering vegetation

- **Golf estates**

  Luxury golf estate developments (Figure 54) are increasing in South Africa. Most golf estates are built in ecologically sensitive areas with high natural biodiversity which is destroyed by:

  - construction of building high density housing on the estates; indigenous bush and trees are cleared and dependent animal and bird life affected
  - the same pollution impacts as for urban town-housing, with the same negative effects on birds, predators and water bodies
  - private gardens on the estate increasing the threat of alien invasive species
  - golf fairways that represent monoculture on a huge scale, e.g. alien kikuyu grass, requiring pesticides, fertilisers and huge amounts of water

Figure 54: Luxury golf estate

- **Mining**

  Both surface (open-cast) mining and underground mining destroys habitats and negatively affects biodiversity in many ways:

  - Open-cast (surface) mines (Figure 55) take up more space and generate noise and dust pollution

Figure 55: Open cast mining destroys biodiversity of large areas of land

  - When vegetation and topsoil are removed for surface mining, animal and plant habitats are destroyed
  - All mines produce tons of gas emissions, solid waste, liquid effluent (waste or sewage) and some result in acid mine drainage. These poison underground water supplies and seep into river systems
  - Huge mining trucks destroy vegetation and compact soil reducing the drainage ability. Generally mining exposes topsoil to erosion and degradation

- **Urbanisation** (Figure 56)

  As the population increases and cities grow, more indigenous vegetation is cleared to build more industries, road networks and high density housing.

  This negatively impacts biodiversity by increasing:

  - all types of pollution - air, land, water, noise and light
  - physical barriers to animal migration and reproduction patterns
  - rainwater run off causing flooding
  - bioaccumulation of poisons
  - the growth of alien vegetation

Figure 56: Urban sprawl

The urban sprawl of informal settlements and high density, low cost housing alters the landscape permanently; more open areas are needed to redevelop biodiversity.

- **Deforestation**

  Deforestation is the large-scale removal of indigenous trees. Forests cover less than 1% of South Africa's land area (Figure 57) but account for a large part of our biodiversity. The destruction of woodlands and indigenous forested areas for the purposes of timber, agriculture, fuel supplies and other human activities leads to:

  - the destruction of habitats for insects, especially pollinators such as bees, and amphibians, e.g. frogs. Other larger dependent species are in turn affected
  - the loss of many medicinal and food plant species

Figure 57: How little of South Africa is forested – seen from space

- **Loss of wetlands and grasslands**

Wetlands

Wetlands (Figure 58) are the habitats of a rich biodiversity of plants of animals. South Africa being arid has few wetland areas. Any pollution or removal of wetlands for development threatens:

  - the biodiversity of soils and vegetation (including useful and medicinal plants) associated with wetlands
  - the capacity for freshwater purification and storage, erosion and flood control
  - the habitats of fish and other aquatic animals
  - tourism, recreation, wildlife and bird conservation

Figure 58: Grasslands and wetlands of the inland Okavango Delta are rich in diverse species of plants and animals

Grasslands

As natural grazing areas, grasslands support a rich biodiversity of wild animals and bird species. If these habitats are removed, eroded or polluted we will lose:

- several endangered and threatened species which survive on grass seeds, worms and insects that populate the grasslands, e.g. South Africa's national bird, the blue crane, which lives in the grasslands (Figure 59)
- many useful and medicinal plants
- ecotourism opportunities such as hiking trails
- flood control and water filtering capacities of grasslands

Figure 59: Nesting blue crane (SA national bird) at home in grasslands

Poaching

Poaching is the illegal hunting or collecting of species (animal or plant) either for food or money. Relentless removal of any species negatively affects all other species that interact with and depend on them for survival. This results in loss of biodiversity.

Culling is the careful and legal control of animal numbers to protect biodiversity..

In South Africa, abalone, rhino and elephants are examples of animals that are poached – often only for a small body part:

- **Abalone (**‘perlemoen’ in Afrikaans – Figure 60)

  This sea snail, is a great delicacy in Asia and has a high market value. Abalone take 7 years to mature before they can reproduce, and as a result of overharvesting they are a declining population. Illegal poaching and trading in abalone affects marine biodiversity.

Figure 60: ‘Shucked’ abalone removed from their shells

- **Rhino**

  Rhinos are illegally killed for their horns (Figure 61) that consist of keratin, the same substance that makes up hair, nails or claws, in all mammals.

  Asian buyers are willing to pay large sums for the horn which they believe has healing and sexual properties. On average 3 rhinos are poached every day in South Africa. They will be extinct in the wild before 2030.

Figure 61: A rhino with its magnificent horn, before it is cut off to discourage poachers from killing it.

- **Elephants**

  Elephants are poached for their tusks for the ivory trade in ornaments and jewellery, particularly for Asian markets. Elephants have a great impact on biodiversity which is damaged by poaching:

Figure 62: Elephant clearing trees, creating grasslands

Figure 63: Elephant digging for water in dry riverbed

- **Bushmeat**

  Traditionally African hunters depended on bushmeat for food. As hunting equipment upgraded to automatic weapons, and roads were built into wild areas to enable the logging trade, hunters could kill and export more game for commercial gain. Protected animals such as gorillas and chimpanzees are endangered and the biodiversity of their habitats is threatened. The animals are being killed faster than natural populations can replace them.

Alien plant invasions

Alien plants outcompete natural vegetation. They spread quickly and become the dominant vegetation, leading to a loss of biodiversity.

Factors that reduce the loss of biodiversity

Loss of biodiversity can be reduced by controlling alien invaders and the sustainable use of the environment.

Figure 64: Even two monocultures grown side by side can improve biodiversity

Control of alien plant invasions

Alien plants are removed:

- mechanically
  - by hand or machine to chop down plants
  - this is effective but expensive and time consuming.
- chemically
  - by spraying or injecting plants with herbicides
  - this is also expensive and risky as it can pollute land or water, killing many other species of plants and animals
- biologically
  - by introducing natural enemies of the alien invaders as control agents: e.g. wasps that form galls on Port Jackson willows (Figure 65) or fungi that form galls preventing black wattle from reproducing
  - this the easier and more affordable option but may also be risky if the natural enemies multiply unchecked and attack indigenous species

Figure 65: Fungal gall on black wattle

Sustainable use of the environment

Sustainable use means managing and using resources so that future generations will still be able to use those resources.

- Traditional healers can be encouraged to grow medicinal plants
- Rural unemployed people – especially women – can be taught to harvest wild plants responsibly

Figure 66: Sangomas remove strips of bark for medicinal purposes – tribal chiefs imposed strict rules which prevented plants from being damaged by bark stripping

Useful indigenous plants impact biodiversity

Some useful indigenous plants that have economic value are at risk of overexploitation unless they are carefully managed and harvesting is legislated:

- **Fynbos**

  Nearly 2000 fynbos plants are threatened with extinction.

  - increasing wild fires are destroying the biodiversity of fynbos
  - worldwide demand for fynbos wildflower species (especially proteas) is also putting these plants' habitats under pressure

- **Rooibos** (Figure 67 and 68)

  Rooibos tea is celebrated for its antioxidant and medicinal properties including protection again cancer, strengthening bones, relieving stress and colic.

  - Global demand for rooibos tea means that more land is needed for growing the bushes. Rooibos plantations are now encroaching on wild fynbos lands and impacting on the biodiversity of those species.
  - Farmers need to manage the plantations carefully to ensure that indigenous fauna and flora can live in corridors in between the plantations, so as not to destroy the rich biodiversity of the fynbos.

Figure 67: Rooibos growing

Figure 68: Processing of rooibos tealeaves

- **Devil's claw** *(Harpagophytum procumbens)*

  Devil's claw is the hooked shaped fruit (Figures 69) which grows in the arid sandy parts of southern Africa. Tons are exported yearly as a treatment for back pain, fever and arthritis

  - The current demand on wild Devil's claw is unsustainable as the plant has to grow for four years before it can be harvested.
  - It is listed as a protected plant and may not be harvested in the wild unless the harvester has a permit and training in sustainable harvesting.
  - Devil's claw plants are now being cultivated for trade on a large commercial scale in an attempt to protect the species.

Figure 69: Khoisan man with devil's claw fruit

Figure 70: African potato plant with yellow flower

Figure 71: *Hoodia gordonii* with yellow flowers

- **African potato** *(Hypoxis hemerocallidea)*

  African potato is a perennial, grassland plant with long narrow leaves and yellow star shaped flowers (Figure 70). It is used for treating TB, HIV, diabetes, rheumatoid arthritis, cancers and urinary tract infections

  - In many areas, harvesting the corns has led to a massive reduction of this wild plant population and destruction of its habitats. As the popularity and fame of the African potato increases, so the government will have to develop more sustainable ways of managing and harvesting it.
  - Some indigenous and medicinal plant nurseries are growing and trading with African potato plants already.

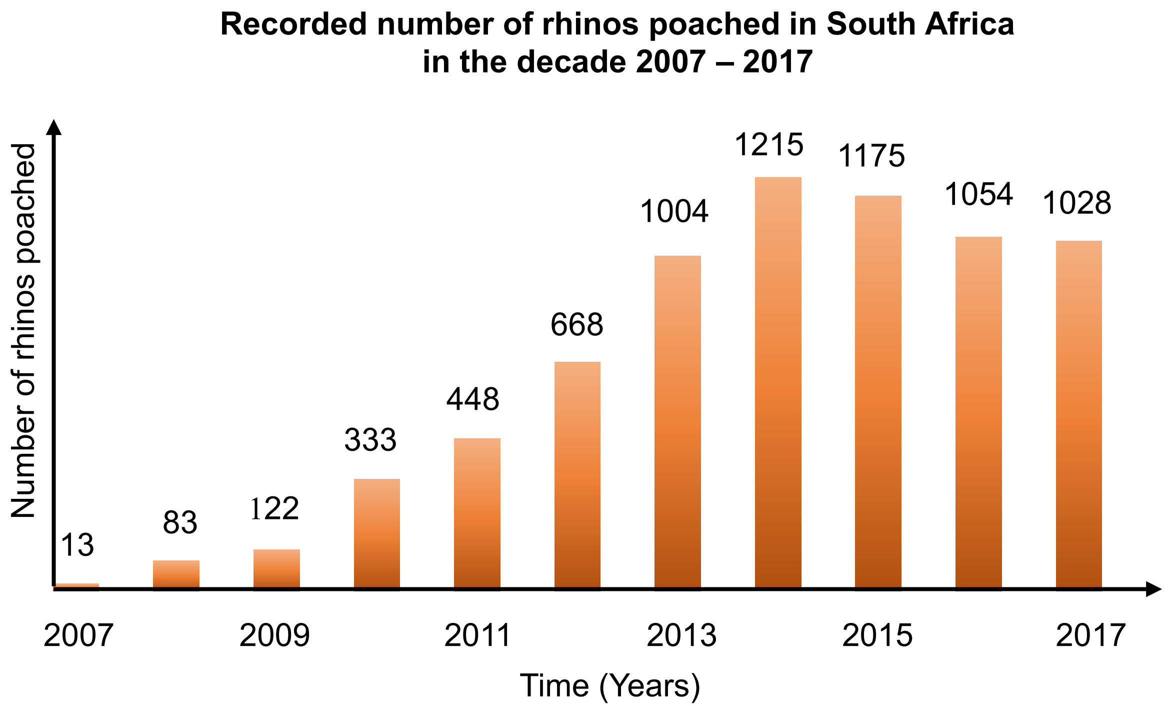
- ***Hoodia gordonii***

  Hoodia is a spiny succulent (Figure 71) which has been used generations of Khoisan people as an appetite and thirst quencher in the dry desert regions of the country. It is now marketed worldwide as an appetite suppressant and slimming agent.

  - It is a protected plant which may not be harvested in the wild, but thousands of tons have been harvested illegally and shipped out of the country.
  - This threatens the rights of the Khoisan to an income from the plants, as well as the sustainable harvesting of the plants.

Activity 4: Biodiversity

In the early 1800s there were more than a million wild rhinos worldwide. In 2018 there were less than 20 000 rhinos in the wild.



1. a) How many rhinos have been lost worldwide over the years from the early 1800s until 2018? Show your calculations. (2)

   b) Calculate the average number of rhinos lost per year over the 10 year period from 2007 to 2016. Show your calculations. (3)

   c) If rhinos continue to be killed at the same rate as calculated in 1.b), how long will it be (in years more or less) before they are extinct. Show your calculations. (3)

2. Explain why it is important to protect rhinos from extinction. (2)
3. Give two suggestions of what can be done to prevent rhino poaching? (2)

(12)

Solid waste disposal

Waste is material that is of no use to humans anymore. It needs to be disposed of in a safe and environmentally friendly way. Waste can be solid, liquid or gas. In this section we learn about the impact of solid waste on our environment.

Figure 72: Our green world is being smothered by solid waste

Figure 73: Overflowing rubbish bins

Key terminology

bio-degradable	organic matter that can decompose or breakdown by bacteria or other living organisms and avoid pollution
hazardous	extremely dangerous
radioactive	having or producing radiant energy that comes from breaking up of atoms
nuclear	energy produced when the nucleus of an atom is divided or joined to another nucleus
landfill	an excavated dumpsite which can be filled with rubbish
leachate	water that has filtered through solids and leached out some of the dissolved or broken down parts of the solids
rehabilitate	return something to its former or original good condition
bio-remediation	use of biological agents, such as bacteria, fungi, or green plants, to remove or neutralize pollutants in soil or water
nuclear reactor	a structure in which controlled nuclear reactions can occur to release energy

The need to reduce solid waste or find ways of managing it

Burying solid waste in landfills is becoming a big problem:

- Landfill or dumpsites can be unsightly, toxic, smell bad, be flammable and cause air pollution.
- Vermin (e.g. rats) and flies which can carry diseases breed in dumpsites.
- Toxins can leach from the site into underground water or nearby rivers and dams.

Figure 74: Landfill dumpsites are unsightly and smell disgusting

Figure 75: Chemical waste in drums is hazardous if not sealed properly

Aspects of solid-waste disposal

Management and rehabilitation of dumpsites

- Landfill or dumpsites are usually large excavated holes, eroded dongas or disused quarries or mines, where solid waste is dumped.
- Properly managed landfills are lined to isolate the dumped waste from ground water supplies so that toxic leachate does not cause contamination.
- Decomposition occurs anaerobically in a sealed and capped landfill and the resulting methane stays trapped unless it is tapped for use.
- Landfill sites can be rehabilitated to prevent soil and water pollution by:
  - planting species that absorb and detoxify contaminants in the soil, water, sediments or air surrounding landfills. This is called bioremediation.
  - developing parks or public use areas over landfills with planted vegetation, preferably trees, to stabilise the ground beneath

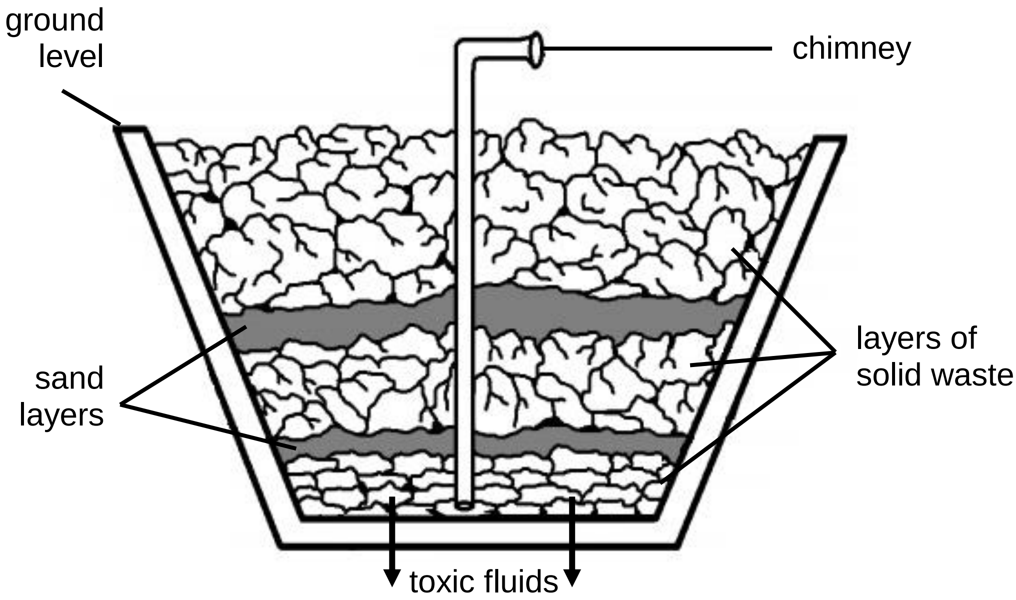


Figure 76: Diagram of landfill structure

Using methane from dumpsites for heat and lighting

- Solid waste is compacted and sealed in landfills. The moisture content and temperatures in landfills is high which perfectly suits the development of anaerobic bacteria. These bacteria decompose (and reduce) the waste and produce **methane** which stays trapped in the fill.
- Wells are then sunk into the landfill to tap off the methane in pipes. The pipes link to an underground mains which collects the methane. This is then extracted and burned to generate electricity (Figure 77).
- Burning methane does not emit toxins. The electricity generated can be fed into local power stations as a clean source of energy. From Waste-to-Energy!

Figure 77: A sealed landfill with biogas piping and a rubbish skip container

The need for recycling

Recycling is the conversion of waste into useful material

Recycling is important because it:

- reduces air, land and water pollution
- reduces the use of raw materials and saves energy
- reduces waste
- provides employment

Figure 78: Recycling by sorting waste into separate containers.

The need for safe disposal of nuclear waste

Nuclear waste is very toxic and is a threat to human health and the environment.

.

Figure 79: Hazardous (dangerous) waste should always be signposted and separated from general waste.

- Nuclear waste is disposed of by burying it deep under the earth or ocean in thick concrete or lead containers. South Africa's nuclear waste from Koeberg (western Cape) and Pelindaba (Gauteng) are handled in this way.
- Nuclear waste is not biodegradable so ways must be found that reduce the risks of these deadly emissions.

Activity 5: Solid waste disposal

1. Name any three problems that can occur when dumpsites are not managed properly. (3)
2. In well managed landfills what prevents toxic leachate from polluting ground water? (1)
3. Name three things you can do to reduce your solid waste? (3)
4. How can solid waste landfills be used to provide energy? (6)

(13)

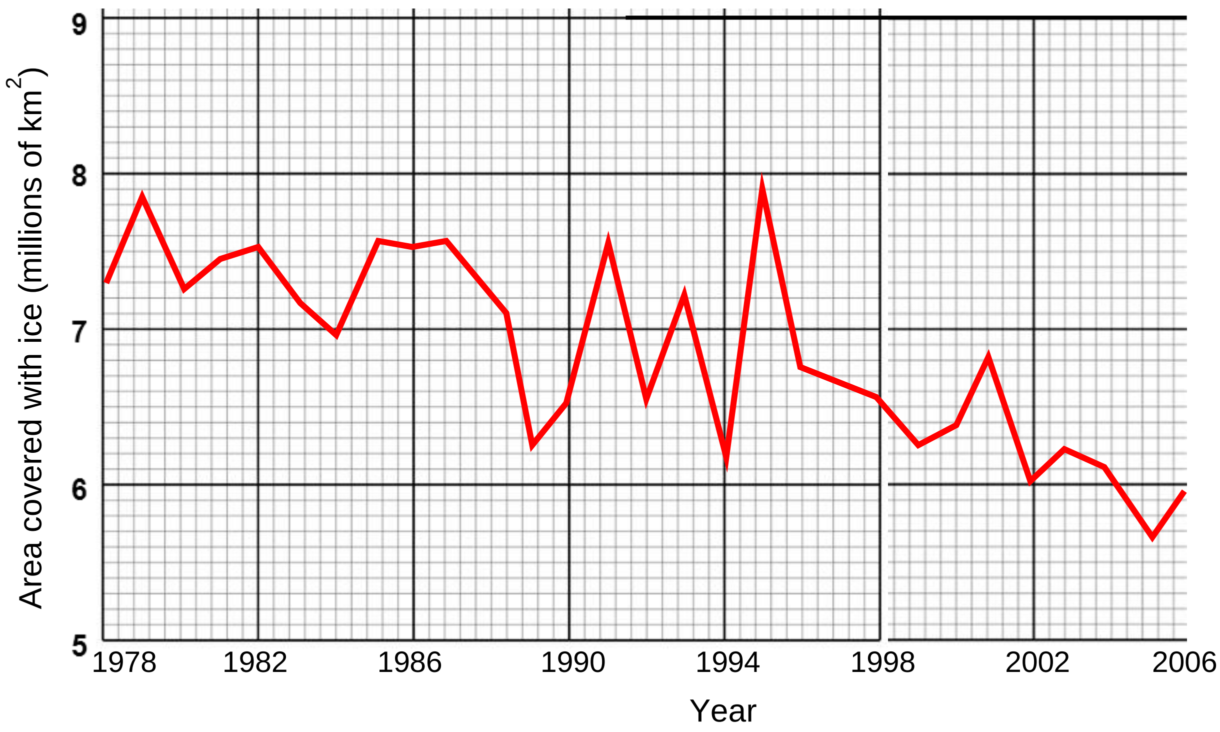
Human impact on the environment: End of topic exercises

Section A
Question 1

1.1 Various possible answers are provided to the following questions. Choose the correct answer and write only the letter next to the question number.

1.1.1 Rising temperatures on Earth have led to the melting of ice in glaciers. The graph shows the measured changes in the size of an area covered with ice in the Arctic region between 1978 and 2006.

Size of Arctic area covered with ice between 1978 and 2006



What is the difference between the size of the area covered with ice in 1978 and the size of the area covered with ice in 1998?

A 1,3
B 7,2
C 0,7
D 5,9

1.1.2 Which of the following is a source of CO_2?

A Process of photosynthesis
B Refrigeration
C Process of respiration
D Aerosol

1.1.3 Which of the following represents one advantage and one disadvantage of genetic engineering in developing desirable products?

	Advantage	**Disadvantage**
A	Increased rate of production	Cost of development is high
B	Cost of development is high	Possible release of GMO into the environment
C	Increased range of products	Increased rate of production
D	Increased rate of production	Increased range of products

1.1.4 The sector that uses the most water in South Africa is?

A Agriculture and forestry
B Mining
C Domestic
D Industry

1.1.5 Nuclear waste is...

A disposed of in desert dumpsites
B radioactive and hazardous
C used to generate methane gas
D destroyed by salt water

(5 × 2) = (10)

1.2 Give the correct **term** for each of the following descriptions.

1.2.1 The average weather conditions of a large area over a long period of time
1.2.2 The overall increase in temperature worldwide due to the Enhanced Greenhouse effect?
1.2.3 An ecological body or natural system which absorbs carbon dioxide from the atmosphere.
1.2.4 Treaty signed at the first International conference to formulate strategies to manage risk and effects of climate change.
1.2.5 Chemically corrosive and contaminated waste water from mining.
1.2.6 Pollution that is the result of warm or very hot water waste pumped into water bodies.
1.2.7 Algal bloom due to increase of nitrates and phosphates in water bodies.
1.2.8 Waste water and excrement.
1.2.9 The variety of all living organisms on Earth
.

(9 × 1) = (9)

1.3 Indicate whether each of the statements in Column I applies to **A ONLY**, **B ONLY, BOTH A AND B or NONE** of the items in Column II. Write **A only**, **B only**, **both A and B,** or **none** next to the question number (1.3.1 to 1.3.6).

Column I	Column II
1.3.1 Methane	A: Decomposition in landfill sites B: Global warming potential higher than CO_2
1.3.2 Ozone depletion	A: Loss of ozone from the troposphere B: Loss of ozone from car engines
1.3.3 Climate change in SA	A: Desertification B: More frequent and severe veldfires

(3 × 2) = (6)

1.4 Study the image of maize cobs and answer the questions that follow:

1.4.1 What does GMO stand for? (2)

1.4.2 Describe the process of genetic engineering. (3)

1.4.3 Give two possible advantages of GMO maize. (2)

1.4.4 Name three possible disadvantages of genetic engineering. (3)

(10)

1.5 1.5.1 Define the term 'ozone'. (1)

1.5.2 Where is the ozone layer found? (1)

1.5.3 Distinguish between good ozone and harmful ozone. (1)

1.5.4 How is good ozone useful? (1)

1.5.5 What is ozone depletion and how does it occur? (3)

1.5.6 Distinguish between the terms **climate** and **climate change**. (2)

1.5.7 What is meant by the term 'global warming'? (1)

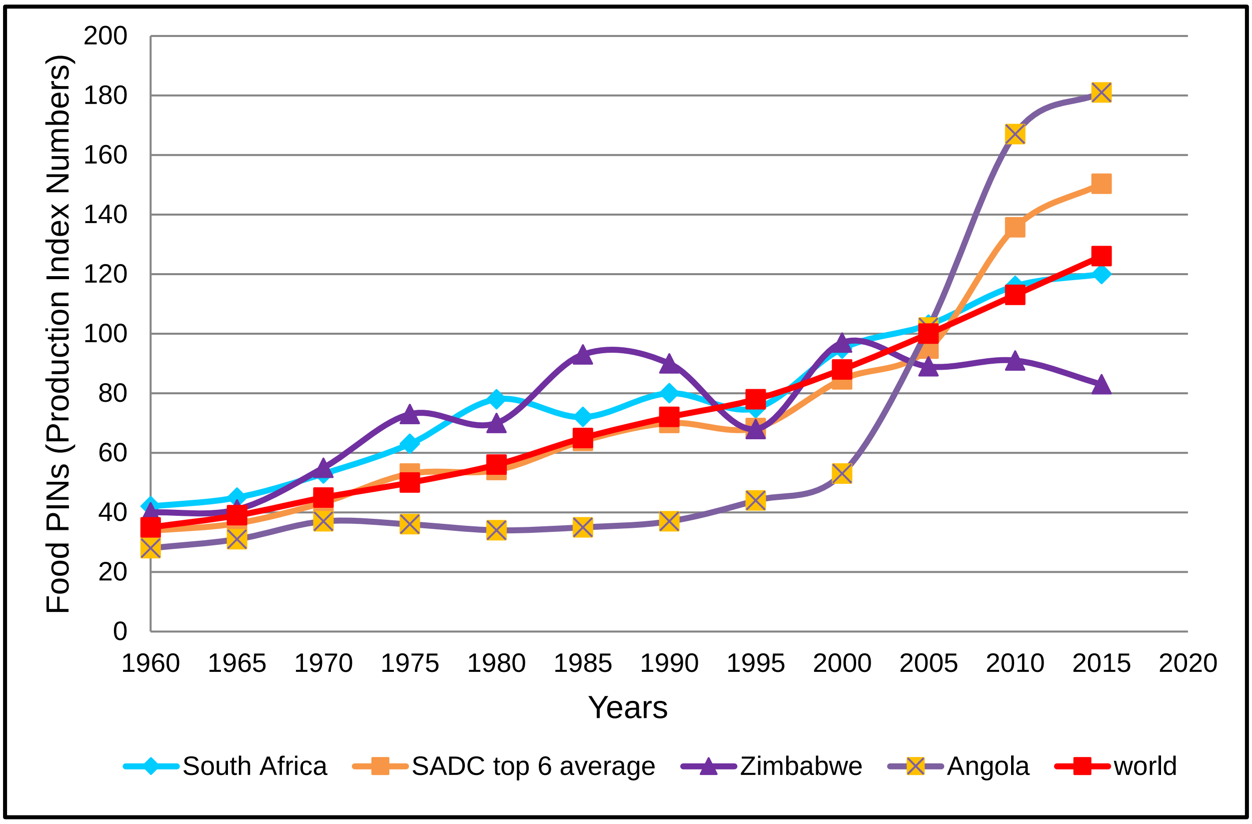
(10)

Section A: [45]

Section B

Question 2

2.1 The following is a graph of food production averages from 1960 to 2015, in South Africa, some SADC countries and in the world as a whole. Study the graph and answer the questions below.



(Adapted from Food and Agriculture Data from the FAO of the UN: http://www.fao.org/faostat/)

2.1.1 Identify the following for this graph

a) The independent variable

b) The dependent variable (2)

2.1.2 Which country had the lowest food production in 1985? (1)

2.1.3 Which country had the highest food production in 2015? (1)

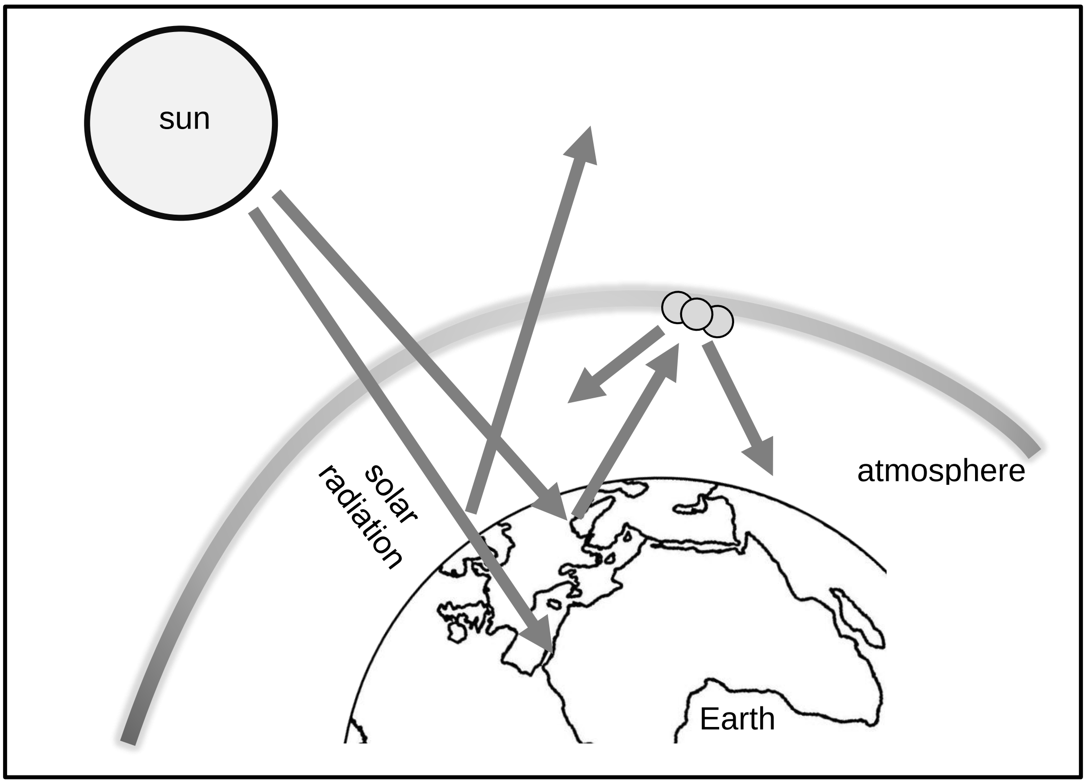
2.1.4 Give a possible reason for this change. (1)

2.1.5 Discuss exponential human population growth as one of the main factors causing food insecurity and compare the human growth rate with the graph above showing food production growth rate. (5)

(10)

2.2 2.2.1 Explain why current human activities are causing extreme crises in our natural environments? (5)

2.2.2 Use the figure below and explain why Earth's average temperatures are rising because of the rampant enhanced greenhouse effect. (5)



(10)

[20]

Question 3

3.1 Read the passage below about food wastage around the world.

> Every year a third of all food for human consumption, about 1,3 billion tons, is wasted in the world. The UN Food and Agriculture Organisation (FAO) estimated that the carbon footprint of wasted food was equivalent to 3,3 billion tons of carbon dioxide a year. The FAO suggests that more efficient use of food could contribute to global efforts to cut greenhouse gases to limit global warming. In the industrialised world, much of the waste comes from consumers buying too much and throwing away what they do not eat. In developing countries it is mainly the result of inefficient farming and a lack of proper storage facilities.
>
> *(adapted from Reuters Daily News, September 2013)*

3.1.1 What is meant by the following terms carbon footprint and food security? (4)

3.1.2 Explain how wastage of food contributes to loss of energy and global warming. (4)

3.1.3 Use the information in the passage to suggest two ways in which food wastage could be reduced. (2)

(10)

3.2 Many parts of South Africa are facing a water crises.

3.2.1 Write a brief summary of the water crisis facing South Africa? (4)

3.2.2 How do poor farming practices affect water availability? (4)

3.2.3 Which two overall factors influence water quality on Earth? (2)

(10)

3.3 Read the extract 'Hunting Wildlife for Food' given below:

An organisation, Trade Records Analysis of Fauna and Flora in Commerce (TRAFFIC), did an investigation to find out about the extent of the illegal killing of wildlife for use as bushmeat (meat from wildlife) and the influence of this on the environment.

The organisation reported that the illegal killing of wildlife, both for trade and consumption, had been on the increase in many African countries during the past two years. It also reported that some species, such as impala, were preferred to others species of wildlife.

One of the organisation's recommendations was that the hunting of wildlife should be legalised. This would enable governments in these countries to control the number of animals being hunted and also to restrict the age of animals that may be hunted. It also recommended that only those animals that were very old and weak in a population should be hunted.

(adapted from an article "Wildlife Under Siege', Endangered Wildlife, 2000)

3.3.1 What is the illegal hunting and killing of animals called? (1)

3.3.2 State one way in which humans destroy wildlife habitats. (1)

3.3.3 Give two reasons for the increase in the illegal killing of wildlife. (2)

3.3.4 Explain how the increase in the killing of wildlife will influence the environment. (3)

3.3.5 Discuss why TRAFFIC recommended that only very old and weak animals in a population should be killed if hunting is legalised. (3)

(10)

[30]

Section B: [50] **Total marks: [95]**

A FINAL WORD: ASSESSMENTS

The purpose of an assessment is to give an indication of your mastery of a subject. During the year, *informal assessments* allow you to be aware of your strengths and weaknesses, and to identify the areas in which you may need additional help. *Formal assessments* allow your parents and teachers to be aware of your progress.

Assessments will measure your understanding of the *content*, *concepts* and *skills* needed to move into Grade 12.

Informal daily assessments

These occur during the daily lessons, as you check your homework and classwork, answer questions posed by your teacher or work through questions in a group. This is where you will be able to become aware of areas that you are struggling in and take action through extra studying or consulting with peers or your teachers.

Formal school-based assessments

In Grade 11, your final mark is made up in the following way:

Formal Tests (× 2) and June exams Practicals (× 2) and Project / Assignment	25%
Final Exam	75%

Because school-based assessments only count 25% they are often neglected. But remember, *they help to prepare you as best as possible* for your final exam.

Assessment Content

Knowing science	40%	Recalling *learned* information – details, facts, formulas, terms and definitions or procedures.
Understanding science	25%	This will test your ability to expand upon given information, either by interpreting, giving an example, classifying or summarising, or comparing different concepts or objects.
Applying your knowledge	20%	This refers largely to your *practical skills* and your ability to follow procedures or given methods, and use your knowledge of theory to draw conclusions from your results
Analysis and evaluation	15%	Here you your given knowledge one step further to *solve non-routine problems* or *evaluate a new procedure* based upon your background knowledge. You could also be asked to *integrate pieces of information* to create a new idea.

Examples of useful verbs and what is required of you

Analyse - Separate, examine and interpret

Calculate - Used when a numerical answer is required. In general, you should show your working, especially where two or more steps are involved

Classify - Group things based on common characteristics

Compare - Point out or show both *similarities and differences* between things, concepts or phenomena

Define - Give a clear meaning

Describe - State in words (using diagrams where appropriate) the main points of a structure / process / phenomenon / investigation

Determine - To calculate something, or to discover the answer by examining evidence

Differentiate - Use differences to qualify categories

Mention - Refer to relevant points

Name - State something; *alternative keywords: give, identify, mention*

State - Write down information without discussion

Suggest - Offer an explanation or a solution

Tabulate - Draw a table and indicate the answers as direct pairs

Exam format

Each exam paper is 150 marks and written over 2 ½ hours. Your two exam papers will be broken up in this way:

- *Section A*- short answer questions, such as multiple choice, terminology, statements and response to data. (50 marks)
- *Section B*- two longer questions broken up into subsections. (100 marks)

Content per exam

- ***Paper 1***
  - Energy Transformations - photosynthesis (18%), animal nutrition (18%) and respiration (10%)
  - Gaseous exchange (15%)
  - Excretion in humans (15%)
  - Population ecology (24%)

- ***Paper 2***
    - Biodiversity and classification of micro-organisms (20%)
    - Biodiversity in plants and reproduction (20%)
    - Biodiversity of animals (13%)
    - Human impact on the environment (47%)

Tips and suggestions for examinations

Writing exams can be a source of stress. Here are some ideas to get the most out of your *learning time* (pre-exam) and *writing time* (in-exam)

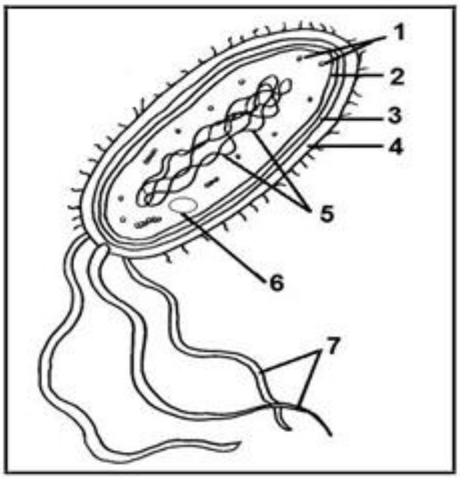
- **Be sure to plan thoroughly**. Don't leave your studying to the last minute, and try not to procrastinate during your learning time. Prepare a study time table – allow yourself enough time over the period of 4 weeks – focus on at least 3-4 topics per week.
- **Get yourself a study buddy -** you will be able to assist one another on difficult concepts/skills
- **Pay careful attention to your theory**. Remember that 40% of your exam will be based on that directly.
- **Spend time working through past exam papers and test papers** to familiarise yourself with the basic format. Time yourself during these practices so that you do not work too slowly.
- **Set yourself a goal** beforehand to work towards.
- Before the exam, be sure to **get enough sleep and eat a decent meal**.
- During your exam, consider the marks of each question. You have **150 minutes and 150 marks** so it is 1 mark per minute. It will benefit you if you *try to work slightly faster than this during Section A* to give yourself more time in Section B.
- **Read each question fully** before starting to answer it. Additionally, for Section B, *plan your answers as far as possible*, even if just with key word, before beginning to write.
- **Write neatly and be sure to number** your questions according to the question paper.

We wish you every success as you prepare!

ANSWERS TO ACTIVITIES

Chapter 1: Biodiversity & classification of micro-organisms

Activity 1: Kingdoms



1. Monera ✓, Protista ✓, Fungi ✓, Plantae ✓, Animalia ✓
2. 1 – ribosome, 2 – cell membrane, 3 – cell wall, 4 – waxy capsule, 5 – chromosome, 6 – plasmid, 7 – flagella ✓ - any 6 correct labels
3. Algae can photosynthesise ✓ whereas fungi cannot produce their own food ✓
4. Viruses exhibit some non-living characteristic ✓ e.g. cannot feed, reproduce, respire. ✓
5. Table

Organism	Unicellular/ Multicellular	Prokaryotic / Eukaryotic	Mode of nutrition
Viruses	acellular	neither	none ✓
Bacteria	cellular ✓	prokayotic ✓	some are autotrophic and others are heterotrophic ✓
Phytoplankton	cellular ✓	eukaryotic ✓	autotrophic
Zooplankton	cellular ✓	eukaryotic ✓	heterotrophic ✓
Fungi	cellular ✓	eukaryotic ✓	heterotrophic ✓

(27)

Activity 2: Practical investigation

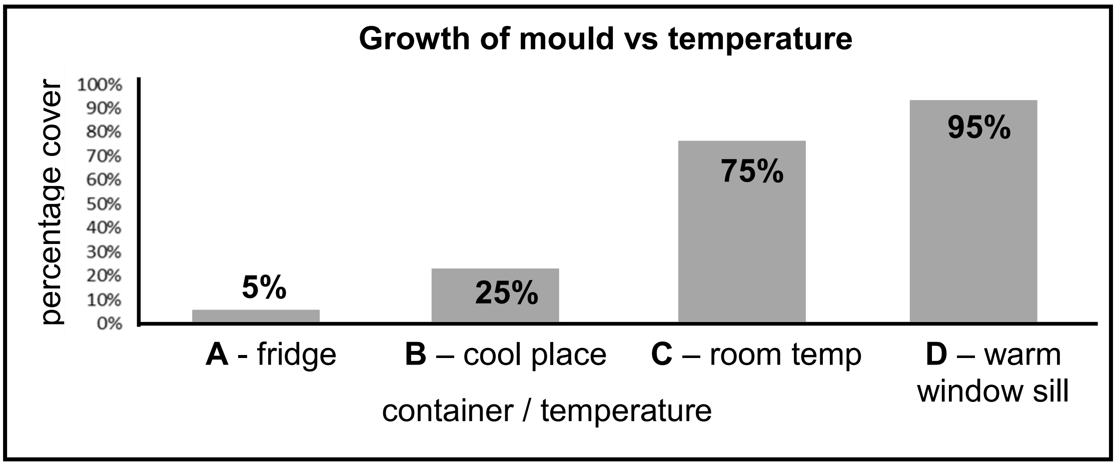
1. The bread mould placed in the container on the warm window sill will grow faster than any of the other bread moulds in the other containers. ✓ for each variable mentioned, and related
2. Dependent (a) rate of growth of the bread mould ✓; independent (b) temperature ✓
3. The warmer the temperature ✓ the faster the bread mould grows ✓.
4. The following variables were kept constant: size of bread slice, type of bread, amount of water, type of container ✓ - any three
5. Repeat the experiment ✓ or increase the number of slices of bread ✓ investigated.
6. Table: Percentage cover of bread mould in the various containers.

Container	A	B	C	D
Percentage Cover	5%	25%	75%	95%

✓ - for table, ✓ - for each correct estimation

7. See graph below – graph must show the relationship between temperature and the growth of breadmould. X-axis: container / temperature; Y-axis: percentage cover.

   bar graph ✓, correctly plotted ✓✓, appropriate title that mentions both variables ✓, each of the axes labelled and with proper scale ✓✓



(22)

Activity 3: Nitrogen use

1. Nitrogen must be in the form of nitrates ✓
2. Lightening converts nitrogen and oxygen to nitrates ✓; free living soil bacteria can form nitrates ✓, as can root nodule bacteria ✓
3. A lichen is a mutualistic relationship ✓ between a fungus ✓ and an algal species ✓.
4. Plants cannot use nitrogen directly from the air ✓. Bacteria are able to fix nitrogen ✓ in the form of nitrates which plants can use ✓. When plants and animals die ✓, nitrogen is returned to the atmosphere ✓ by decomposition bacteria ✓
5. 5.1 It is a filamentous fungus ✓ that can penetrate the roots of plants ✓.

   5.2 The fungus has penetrated the roots of the seedling on the right ✓, and so increased the absorption surface area of the roots ✓. Thus the plant can absorb more nutrients and water and grow faster than the seedling on the left ✓.

(18)

Activity 4: Diseases (one mark for each block filled in correctly)

Disease	Organism responsible	Symptoms	Management and cure
rabies	rabies virus	headaches, nausea, fatigue, fever / dogs foam at mouth	vaccination, immunization, destroying infected animals
AIDS	HIV (virus)	loss of weight, secondary infections	anti-retrovirals, no cure, education
influenza	virus	coughing, sneezing, aching body, fever	proper diet, antibiotics have no effect
cholera	bacterium *Vibrio cholerae*	diarrhoea	education regarding clean water, sanitation
tuberculosis	*Mycobacterium tuberculosis*	coughing, blood in sputum, weight loss, loss of appetite, fever and chills	antibiotics, education
anthrax	*Bacillus anthracis*	itchy bumps with a black centre, breathing problems	antibiotics and vaccines
malaria	*Plasmodium spp.*	fever, headaches, flu-like symptoms	prevention, anti-malaria medications, medication if infected
thrush	*Candida spp*.	white coating in the mouth	anti-fungal mouth wash, antibiotics
ringworm	fungus	scaly round spot on the skin	fungicide cream
athlete's foot	fungus	blistering of skin	fungicide cream or powder
rusts	fungus	loss of green colour in the leaf, raised rust-like spots on the underside	fungicide, remove and burn affected plant material
blight	bacterium	wilting and dying back	fungicide, remove and burn infected plant matter

(36)

Chapter 2: Biodiversity in plants

Activity 1: Pollination and parts of flowers

1. A: insect pollinated ✓ – bright colour, open flower ✓
   B: wind pollinated ✓ – stamens protrude from the flower ✓
   C: wind pollinated ✓ – large amounts of pollen produced ✓
   D: bird pollinated ✓ – narrow flowers on a study stem ✓
   E: insect pollinated ✓ – colourful, distinct markings ✓ (10)

2. Table (11)

Feature	Pollination by a pollinator	Wind pollinated
flower	colourful ✓	small and inconspicuous
stigma	held inside the flower ✓	protrude from the flower ✓
stamens	inside the flower ✓	protrude from the flower ✓
pollen	sticky pollen ✓	large amounts of dry pollen ✓
scent	strongly scented ✓	no scent ✓
energy spent	energy spent making nectar and pollen ✓	large amount of energy wasted on producing pollen ✓

3. 1. sepal (calyx) ✓, 2. petal (corolla) ✓, 3. pedicel ✓, 4. filament ✓, 5. anther ✓, 6. stamen ✓, 7. stigma✓, 8. style ✓, 9. ovary ✓, 10. pistil ✓ (10)

Activity 2: Seed banks

1. Maintain biodiversity, research purposes, keep seeds of rare and endangered species, often store original seeds rather than hybridised seeds. (✓ - for any two correct answers)
2. Prevents the seeds from rotting ✓, frozen water forms ice crystal which could damage the seeds ✓.

(4)

Chapter 3: Biodiversity in animals

Activity 1: Body symmetry and tissue layers

1.1 A – Bilateral ✓; B – Bilateral ✓; C – Bilateral ✓

1.2 The animal is able to move through the environment in one direction and focus senses on this direction which helps with feeding and avoiding predators. ✓✓

1.3 A, B and C ✓✓✓

2.1 A – Ectoderm ✓; B – Endoderm ✓; C – Mesoderm ✓

2.2 1 is diploblastic ✓ (2 is triploblastic)

2.3 1 – diploblastic because it only has 2 tissue layers ✓ (2 – triploblastic because it has 3 tissue layers)

2.4 Mesoderm can develop organs ✓ such as connective tissue, bone, blood, reproductive organs, cartilage, blood and lymphatic systems. ✓ - any one organ

(15)

Activity 2: Gut openings and coeloms

1.1 C ✓ because body cavity is outside of the mesoderm – not a true coelom

1.2 A ✓ because it does not contain a body cavity

1.3 B ✓ because the coelom is situated between the mesoderm

2. B ✓

3. - allows more complex organs to develop such as digestive organs, muscular system, blood system etc. ✓

- allows the creation of a hydrostatic force to be generated for movement in soft-bodied animals ✓

- it separates the endoderm and ectoderm from each other with a cavity which allows the layers to move independently of each other. This allows peristalsis to occur ✓

- in some organisms, the coelomic fluid (fluid found in the coelom) helps to transport nutrients and waste in the body ✓ (8)

Activity 3: Phyla characteristics

1. a) Porifera ✓, b) Chordata ✓, c) Cnidaria ✓, d) Annelida ✓, e) Arthropoda ✓, f) Platyhelminthes ✓

2.

Characteristics	Cnidaria	Platyhelminthes
Body symmetry	Radial ✓	Bilateral, dorso-ventrally flattened ✓
Cephalisation	None ✓	Yes ✓
Number of gut openings	One ✓	One ✓

Tissue layers	Diploblastic ✓	Triploblastic ✓
Coelom	Acoelomate ✓	Acoelomate ✓
Mode of living	Aquatic, sessile, free-floating, ✓ dimorphic lifecycle	Most are internal parasites, some aquatic, free-living ✓

Table ✓ and one mark for each as indicated …

3. Chordata ✓, because they have the most advanced characteristics ✓
4. Porifera ✓
5. It is a rod-like support ✓ in the body in all chordata ✓
6. Cnidaria ✓, to capture prey and for defence ✓
7. Haemocoel is the cavity that is filled with fluid which acts like blood to carry nutrients and gases around the body ✓. It forms the open circulatory system of arthropods ✓
8. Their exoskeleton must be shed regularly because it does not grow with the body ✓. The exoskeleton takes a lot of energy to build and therefore limits the size of arthropods ✓. (30)

Activity 4

1.

Model A	**Model B**
Surface area: Length × width of all sides ✓ = 2 cm × 2 cm × 6 sides (all equal) = 24 cm^2 ✓	Surface area: Length × width of all sides = 4 cm × 2 cm × 2 sides = 16 cm^2 ✓ Length × width of all sides = 1 cm × 2 cm × 2 sides = 4 cm^2 ✓ Length × width of all sides = 4 cm × 1 cm × 2 sides = 8 cm^2 ✓ Total: 16 cm^2 + 4 cm^2 + 8 cm^2 = 28 cm^2 ✓
Volume: Length × width × height ✓ = 2 cm × 2 cm × 2 cm = 8 cm^3 ✓	Volume: Length × width × height = 4 cm × 1 cm × 2 cm = 8 cm^3 ✓
Surface area/volume: 24/8 ✓ = 3 ✓	Surface area/volume: 28/8 ✓ = 3,5 ✓

2. Flat worms with have a more favourable surface area to volume ratio ✓ than segmented worms because they are flatter ✓. This means they have more surface area for gases to diffuse in and out of their bodies than segmented worms. ✓

(15)

Activity 5

1. Pollination ✓, soil aeration ✓, decomposition ✓
2. The earthworm is responsible for creating tunnels in the soil allowing more water and air to penetrate into the soil ✓ . They also act as a piston that pushes and pulls air through the tunnels as they move ✓. Earthworms also consume dead organic matter such as leaf litter and their waste is further broken down by bacteria releasing the nutrients back into the soil. ✓
3. Nutrients that are locked in dead organic matter must be decomposed to release these nutrients back into the soil ✓ so that plants can absorb the and use them for growth ✓. Therefore, decomposition ensures that nutrients are broken down from dead organic matter to be used in plant growth ✓.
4. If bee populations decrease the amount of pollination will decrease ✓ and will potentially result in fewer plants being pollinated ✓ which will decrease the production of seeds and therefore regrowth. ✓

(12)

Chapter 4: Photosynthesis

Activity 1: Photosynthesis

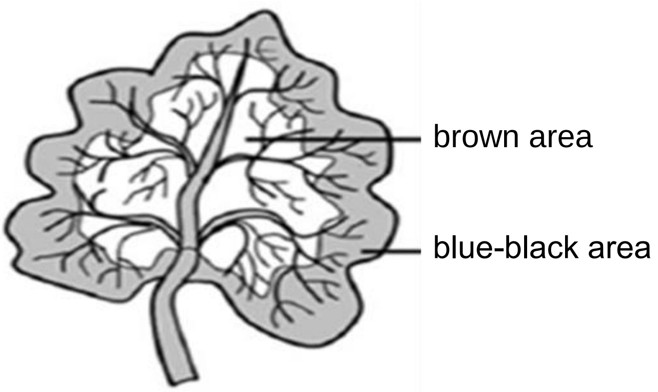
1. Photosynthesis is the process by which plants produce carbohydrates (glucose) ✓ using radiant energy from the sun ✓.
2. Chloroplast ✓
3. Phase 1: light phase ✓, occurs in the grana ✓;
   Phase 2: Dark phase ✓, occurs in the stroma ✓
4. From diagram
   a) Phase 1- light phase ✓;   Phase 2- dark phase ✓
   b) A – light ✓; B – water ✓
   c) Oxygen ✓
   d) Carbon dioxide ✓
   e) Glucose ✓
   f) Starch ✓ (15)

Activity 2: Exploring photosynthesis

1. To determine whether chlorophyll is necessary for photosynthesis ✓.
2. To destarch the plant ✓.
3. To ensure that the leaves are completely destarched ✓✓.
4.

Diagram 2:

Leaf after the second starch test



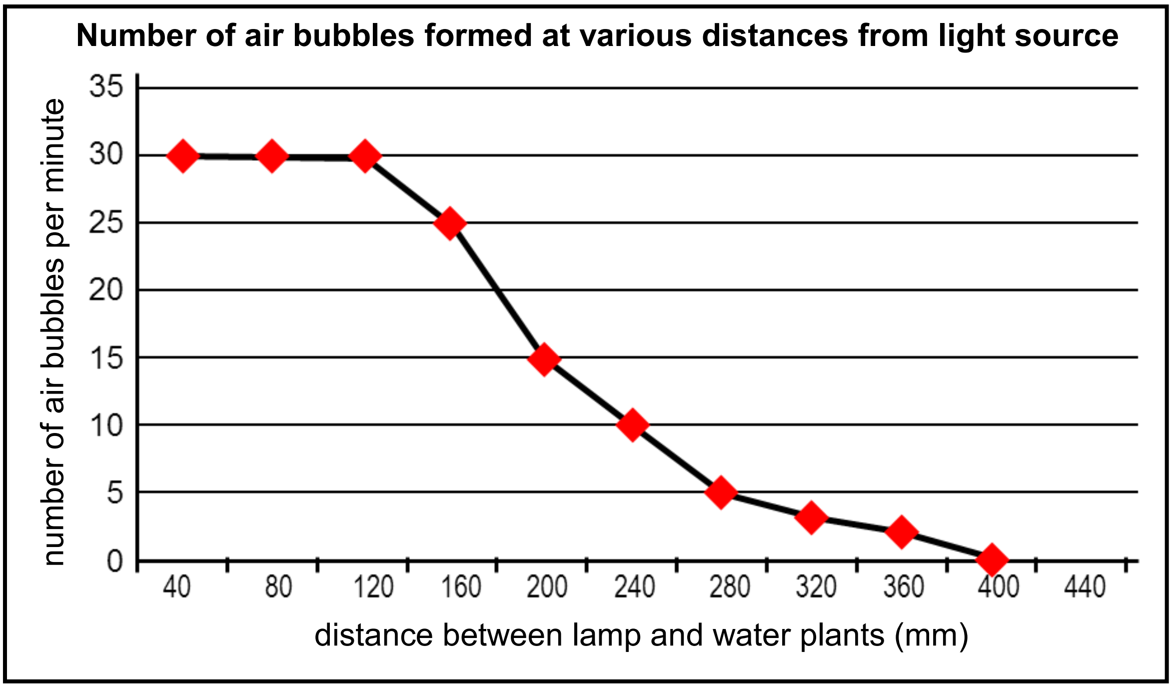
Guidelines for assessing diagram:

Correct caption / title	✓
Correct drawing / shape	✓
Correct drawing of shadow	✓
Correct labels for previously white and green areas.	✓ ✓

5. No ✓
6. Result obtained from the area of the leaf containing chlorophyll ✓ can be compared with the result obtained from the area of the leaf not containing chlorophyll. ✓
7. Chlorophyll ✓ is necessary for photosynthesis ✓

(14)

Activity 3: Investigating gas bubbles released

1. To increase the concentration of carbon dioxide in the water. ✓
2. Oxygen ✓
3. The closer / further the lamp, the faster / slower the rate of photosynthesis will be OR the lamp will have no effect on the rate of photosynthesis.
   ✓✓ - one for each variable mentioned with relationship
4. A glowing splint glows brighter (re-ignites) when inserted into a test tube containing oxygen ✓✓.
5. Amount of carbon dioxide ✓; the temperature of the water ✓.
6. 

   ✓ - each for: title of graph, for each axis labelled and appropriate scale, line drawn connecting points, two for correct plotting of points
7. (a) the rate of photosynthesis ✓
   (b) the distance between the lamp and the plant ✓.
8. The light intensity is directly proportional to the rate of photosynthesis ✓✓

   OR

   When the light intensity increases / decreases the rate of photosynthesis increases / decreases. ✓✓

(18)

Chapter 5: Animal nutrition

Activity 1: Dentition

1. a) skull B ✓
   b) skull A ✓
2. skull A – carnivore, because it has canines for biting and holding flesh of prey; has carnassial teeth instead of flat molars ✓
   Skull B – herbivore, there are large flat molars for grinding plant material. There are no canines. ✓
3. No ✓, carnassial teeth are specialized molars and premolars that have triangular edges that can cut through meat ✓.

(6)

Activity 2: Dissection of a sheep's digestive system

1. Sheep will have incisors and well developed molar and premolars but no canines.
4. The rumen is an enlarged stomach of the sheep which contains bacteria to assist with the digestion of plant material – it is specialized to assist digestion because plant material takes a long time to digest.
5. The inner surface of the stomach should be smooth and soft. The inner surface of the small intestine should have tiny transverse folds. The inner surface of the colon will be smooth without the transvers folds. All will be lubricated.

Activity 3: Human digestive system

1. A – oesophagus, B – stomach, C – duodenum, D – pancreas, E – descending colon, F – small intestine (ileum), G – rectum, H – anus, I – ascending colon, J – gall bladder, K – liver ✓ - for each correct answer
2. a) K ✓ b) D ✓ c) F ✓ d) I or J ✓
3. stomach ✓

(16)

Activity 4: Stages of animal nutrition

1. Ingestion ✓, digestion ✓, absorption ✓, assimilation✓, egestion ✓
2. Carbohydrates ✓, Proteins ✓, Lipids (fats and oils) ✓
3. Stomach ✓
4. • Peristalsis is the rhythmic contraction of the muscles ✓
   - in the alimentary above the bolus/digesting food to push it along the canal ✓.
   - The muscles below the bolus / digesting food must relax to allow the food to continue to move along the canal ✓.
5. Oesophagus ✓, small intestine ✓, large intestine / colon ✓

(15)

Activity 5: Villi

1. A section through a villus from the small intestine ✓
2. A – lacteal, B – arteriole, C – goblet cell, D – epithelial cell / columnar epithelium, E – venule ✓ - for each correct answer
3. microvilli ✓
4. B / E ✓ (E will contain more of these nutrients because they have had a longer time to absorb than B).
5. Active ✓, it requires energy
6. A ✓

(10)

Activity 6: Diabetes mellitus

1. Patient 2 ✓
2. Patient 2 has an elevated blood glucose level even after 120 minutes pass since the administration of glucose ✓ whereas Patient 1's blood glucose has returned to normal ✓.
3. approximately 120 minutes ✓
4. a) glucagon ✓
   b) insulin ✓

(6)

Activity 7: Food

1. Vegetarian / vegan ✓
2. Kwashiorkor ✓
3. Anorexia nervosa ✓ – a person refuses to eat in fear of gaining weight ✓
   Bulimia ✓ – when a person overeats and feels guilty and induces vomiting ✓

4.1 Carbohydrates / sugars ✓

4.2 Sodium ✓

4.3 No ✓, it has a high sugar content ✓ and excess sugar will be stored in the body ✓ if not used, potentially leading to obesity ✓

4.4 Obesity ✓, diabetes ✓, coronary heart disease ✓

(15)

Chapter 6: Cellular respiration

No activities

Chapter 7: Gaseous exchange

Activity 1: Dissection

1. Large and floppy looking. Spongy and soft feel. Deep/Light red in colour
2. C-shaped cartilage rings
3. Spongy tissue
4. The left and right bronchi
5. Slightly narrower in diameter
6. It floats
7. It started deflating (going down)

Activity 2: Breathing

1. a) Glass tube(plastic tube): trachea ✓
   b) Balloon (finger of rubber glove): lung ✓
   c) Bell jar (plastic cooldrink bottle): chest (thoracic) cavity ✓
   d) Rubber sheet (circle palm of rubber glove): diaphragm ✓
2. active ✓
3. decreases ✓
4. increases ✓
5. The bell jar (cool drink bottle) does not move ✓. Only demonstrating one lung ✓.

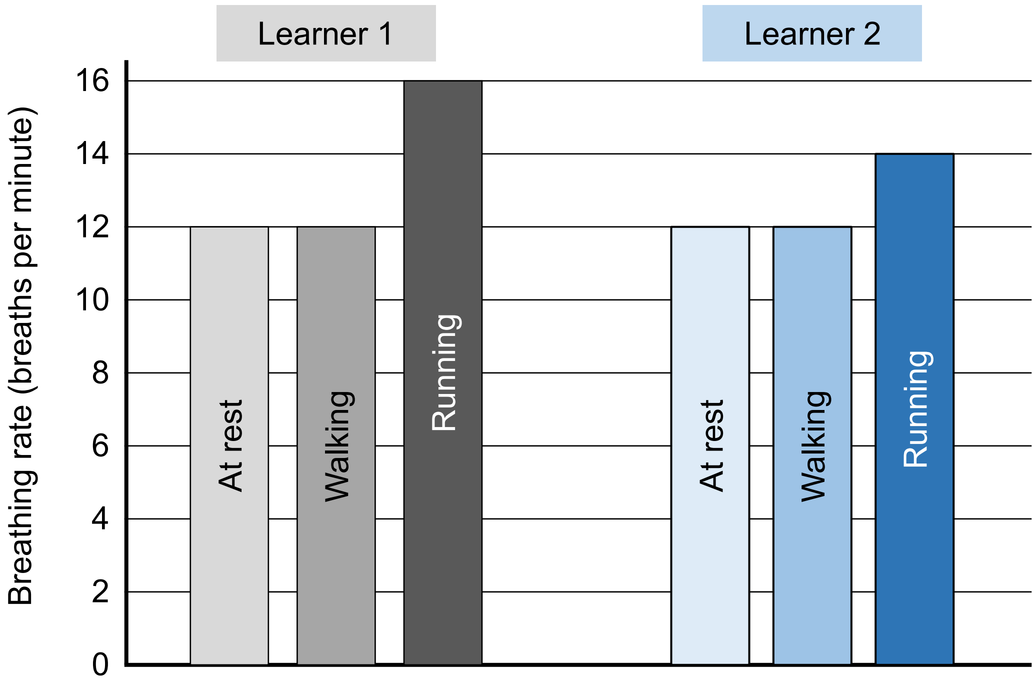
(9)

Activity 3: Breathing investigation

1. The aim is to determine the effect of exercise ✓ on the heart rate ✓ and breathing rate ✓ of 2 students.
2. Both their heart rates increased to over 100 bpm ✓
3. Their breaths per minute increased from rest to running up the stairs ✓.
4. Marking guideline for histogram

Appropriate title	✓
Correct type of graph	✓
Appropriate y-axis heading and scale	✓
Correct labelling of columns	✓✓
Key: learner 1 / learner 2	✓

Breathing rates of 2 learners at rest, walking and running up and down stairs



5. For both student's heart rates and breathing rates increased ✓ from rest to running up and down 2 flights of stairs ✓. For both students walking up the stairs did not result in a change of breathing rate ✓.

(14)

Activity 4: Effect of altitude

1. The red blood cell count increases ✓ at altitude; haemoglobin concentration increases ✓ at altitude
2. Erythrocytes ✓
3. Transport of oxygen ✓
4. Iron (Fe) ✓
5. 5,37- 4,69 ✓ = 0,68÷4,69 x 100 ✓ = 14,5% ✓
6. RBC (mill/mm^3) OR Haemoglobin (g/dl) ✓
7. Their increased number of RBC and haemoglobin will enable them to carry more oxygen ✓ and then improve their performance ✓
8. Males and females ✓ were used in the experiment and this could influence the validity of the results obtained ✓

(14)

Chapter 8: Excretion in humans

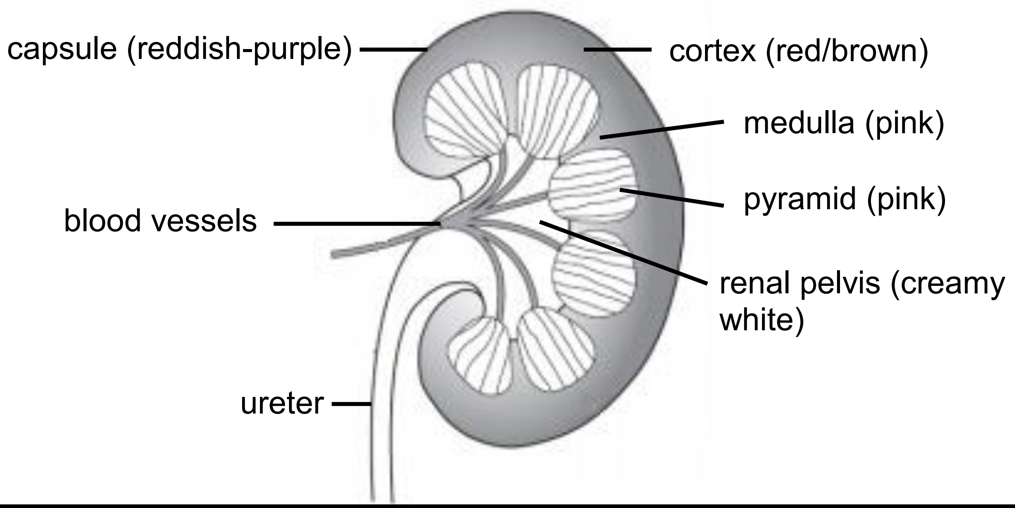
Activity 1: Excretory organs

1. The human urinary system with associated structures (or similar) ✓
2. A – adrenal gland, B – kidney, C – bladder, D – urethra, E – renal artery, F – renal vein, G – ureter ✓ - for each correct answer
2. Oxygenated, unfiltered blood ✓
3. Stores urine ✓
4. Nephron ✓
5. Removal of waste ✓. Regulation of water levels in blood/body fluids ✓. Regulation of salt levels in the blood/body fluids ✓. pH regulation ✓.
6. Urine ✓ and semen ✓ (16)

Activity 2: Sheep kidney dissection

1. Drawing of longitudinal section through kidney

Longitudinal section through a sheep's kidney



Marking guidelines:

Correct diagram ✓; caption / title ✓; any four correct labels ✓✓✓✓

2. a) It provides protection to the kidney in the region of the back ✓

   b) It protects the kidney from infection ✓
3. Increased kidney functioning ✓. Double the volume of blood can be filtered ✓
4. renal artery ✓
5. To the bladder ✓ which stores urine until urination ✓

(13)

Activity 3: Nephron – Malpighian body

1.1 A – renal artery, B – renal vein, C – podocyte, D – blood capillary, E – glomerular filtrate, F – renal tubule ✓ - for each correct answer

1.2 Glomerulus ✓ and Bowman's capsule ✓

1.3 D – squamous epithelium ✓ ; F – cuboidal epithelium (with microvilli) ✓

1.4 A has a wider diameter than B ✓

1.5 Filtration slits (gaps) ✓ and pedicels (little finger like extensions) ✓

1.6 Water, glucose, amino acids, vitamins, fatty acids (✓ any 4)

(17)

2.1 1 – glomerular ultrafiltration ✓ 2 – tubular re-absorption ✓ 3 – tubular secretion ✓ 4 – excretion ✓

2.2 Glucose, amino acids, vitamins, water (✓ - any 3)

2.3 pH levels in the blood ✓

2.4 Water ✓, excess salts ✓, urea ✓

2.5 Drugs are actively secreted into the distal convoluted tubule ✓ and passed into the urine ✓

2.6 Nephrons would have a longer Loop of Henle (the Loop of Henle conserves water) ✓; there would be many more nephrons in each kidney (prevents loss of water and dehydration) ✓

(15)

Chapter 9: Population ecology

Activity 1: Populations

1. A species is a group of living organisms consisting of similar individuals ✓ that are capable of exchanging genes ✓.

   A population is a part of a particular species ✓ that occupies the same habitat at the same time ✓.

   A community is formed by different species ✓ that interact with each other in a specific habitat ✓.
2. Density dependent factors exert an effect on a population in proportion to its size ✓. The greater the population number ✓, the greater influence density dependent factors will have ✓. Density independent factors will have an influence on a population irrespective of its size. ✓
3. Carrying capacity refers to the largest number of individuals of a biological species ✓ that an ecosystem can support over an indefinite time ✓
4. Enough food and water ✓, space ✓.

(14)

Activity 2: Determining population size

1. a) The quadrant method is an indirect method used to estimate organisms which are sessile and are fixed to one location ✓. The mark-recapture method is used in assessing more mobile organism ✓. Through quadrants an estimate can be generated of the number of individuals per quadrant and this can be divided into the number of quadrants that could fit over the entire geographic area (size) ✓.

   b)

Throw no.	Number of mussels in quadrat
1	25
2	13
3	31
4	19
5	22
6	26
Total	25+13+31+19+22+26 = 136 ✓
Average / quadrat	136 / 6 = 22,667 ✓
× Area / quadrat size	22,667 × (32 / 2,5) = 290,13 ✓
Population size	290 mussels ✓

c) (i) Validity has been ensured through using the same sized quadrant through-out the investigation ✓.

(ii) Reliability has been ensured through repeating throws, six times, and then creating an average estimate of the population size ✓.

2.

- The first sample is taken must be large enough to be a true representation of the population. ✓
- The mark used on the organism must remain for the entire period of the procedure. ✓
- The mark must be suitable to the type of organism. The mark must not harm or impair the movements and behaviour of the organism in its environment. ✓
- When the marked organisms are released back into the environment, they must be given enough time to mix with the existing population. ✓

(13)

Activity 3: Growth forms

1.

Geometric growth	**Logistic growth**
Three phases	Five phases
Micro-organisms (typically)	Higher order animals
Overshoots carrying capacity	Typically equalizes with carrying capacity
Example: bacteria	Example: mammals Elephant

Table: ✓

Example per growth form: ✓

Any 2 comparisons: ✓✓ per correct comparison – mark only first two.

2. Logistic growth ✓
3. Phase 1: lag phase ✓; phase 2: exponential phase ✓; phase 3: decelerating growth phase ✓, phase 4: equilibrium phase ✓

(11)

Activity 4: Symbiotic relationships

A – parasitism ✓; B – commensalism ✓; C – mutualistic✓; D – mutualistic ✓

(4)

Activity 5: Population pyramids

1. Stable growth ✓
2. Pre-reproductive cohorts are more-or-less the same in size as the reproductive cohorts ✓.

   Natality is consistent year-on-year ✓.

   Many individuals reach old age ✓.

Lower mortality rates amongst individuals ✓ (any 3).

3. USA / CHINA ✓

Life expectancy is high because of an increased standard of living ✓.

Education levels amongst the population are high ✓.

Countries are well developed ✓. (Country plus any 2)

Chapter 10: Human impact on the environment

Activity 1: Greenhouse effect

Methane: besides gas leaks, agriculture ✓, waste dumps ✓, sewerage works ✓

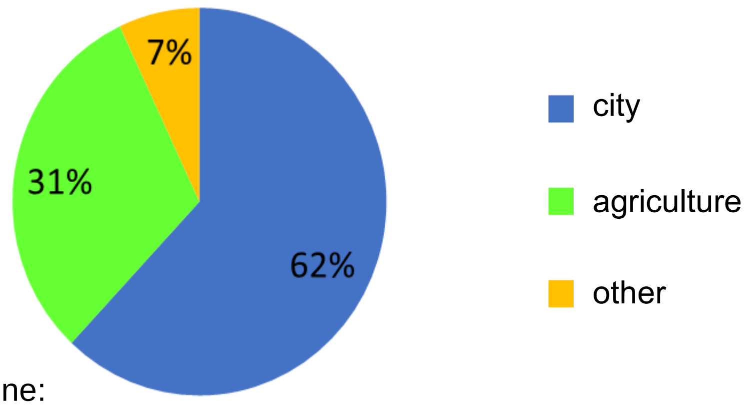
Nitrous oxide: 5% ✓; Ozone ✓, 13% ✓ (6)

Activity 2: Water availability

1. a) consumers ✓ b) water consumption in Mm^3 (millions of cubic metres) ✓
2. No ✓. Consumption depends on water usage restrictions each year and these depend on the amount of rain that falls. ✓
3.

Consumers	Water in Mm^3	Working out percentages	Proportion (degrees)
City	360	360/580 × 100 = 62	62/100 × 360 = 223
Agriculture	180	180/580 × 100 = 31	31/100 × 360 = 112
Other	40	40/580 × 100 = 7	7/100 × 360 = 25
Total	580	= 100	= 360

Western Cape: Percentage water consumption in 2018



Marking guideline:

Correct type of diagram	✓
Correct percentages	✓✓✓
Workings (percentages, degrees)	✓✓

4. No ✓. Population growth is increasing and climate change is unpredictable ✓.
5. A sample answer might be:
   Yes, they should be installed if possible and economically feasible ✓.
   Waterless composting toilets will save water ✓,
   prevent ground water pollution ✓
   and create safe bio-fertilisers from waste which can be used to grow plants ✓.

(16)

Activity 3: Food security

1. a) GMO: an organism that has its DNA altered ✓ for a specific purpose ✓

   b) food security: when people have enough food ✓ to live a good, healthy life ✓
2. GM maize ✓, GM soya ✓ and GM cotton ✓
3. Farmers are forced to buy seeds, pesticides and fertilisers at high cost. ✓

   Ownership and rights to the GMO seeds belongs to the companies and not to the farmers. ✓

   Farmers using GMO seeds cannot do independent research to improve their crops. ✓

   Profits go out of the country to enrich other wealthy countries ✓ (any three)
4. Benefits of GMO: higher yields ✓, pest and disease resistant ✓, can be grown in places where conditions where previously unsuitable ✓, they provide extra nutrients ✓ .. (any three)
5. GM could reduce the gene pool with the loss of variety ✓

   This will negatively affect or reduce biodiversity ✓

(15)

Activity 4: Biodiversity

1. a) 1 000 000 – 20 000 ✓ = 980 000 ✓

   b) 13 + 83 + 122 + 333 + 448 + 668 + 1004 + 1215 +1175 + 1054 = 6115 ✓

   6115 / 10 ✓ = 611,5 rhinos per year ✓

   c) 20 000 / 611,5 ✓✓ = 37,7 years ✓ (or 38 years)
2. Rhinos form part of the food chain ✓ and the natural biodiversity on Earth ✓
3. Education, dehorning rhino, dyeing or poisoning horn, armed anti-poaching task teams can patrol game reserves, stricter laws with jail sentence penalties instead of fines … ✓ for any two

(12)

Activity 5: Solid waste

1. Any three of the problems as given below …

   decomposing or burning waste adds to air pollution ✓

   methane can explode or burn causing dangerous fires and adding to air pollution ✓

   odour and dust pollution lowers the value of neighbouring properties ✓

   surface or ground water bodies are contaminated by toxic chemicals ✓

   soil pollution makes the land unusable for agriculture or building ✓

   pests, such as rats, mice and flies spread diseases ✓
2. Properly managed landfills are lined to isolate the dumped waste from ground water supplies so that toxic leachate does not cause contamination ✓.
3. Any of the Rs: refuse, reduce, reuse, recover, recycle, repair ✓ - any three
4.

   Methane gas can be collected from landfills ✓.

In the waste-to-energy process anaerobic bacteria decompose waste and produce methane which stays trapped in the fill ✓.

Wells are then sunk into the landfill to tap off the methane in pipes ✓.

This is then extracted and burned to generate electricity ✓.

Burning methane does not emit toxins so it is green energy ✓.

The electricity generated can be fed into local power stations ✓.

(13)

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Chapter 6: Cellular respiration

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2.1 and 2.2 – GMMDC constructions