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EXAM FEVER

Life Sciences II

Study Guide

Second edition

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A separate Workbook is also available

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1 Biodiversity, Change and Continuity

Biodiversity and Classification of Micro-organisms

In this section, viruses and three kingdoms of organisms will be studied. Viruses cannot be placed into any of the kingdoms as they show characteristics of both non-living things as well as living organisms. The three kingdoms to be studied are Monera (Bacteria), Protista (Protists) and Fungi. Organisms in these four groups play an important role in the environment. Micro-organisms may affect the health of other living organisms. Micro-organisms which cause diseases are referred to as pathogenic. Humans use some of the micro-organisms for their own needs.

A. Viruses

Introduction

Viruses are unique in that they display characteristics of living organisms as well as characteristics of non-living things. Therefore viruses cannot be placed in any of the five kingdoms of living organisms. Hence viruses are best described as infectious particles. The study of viruses is termed virology.

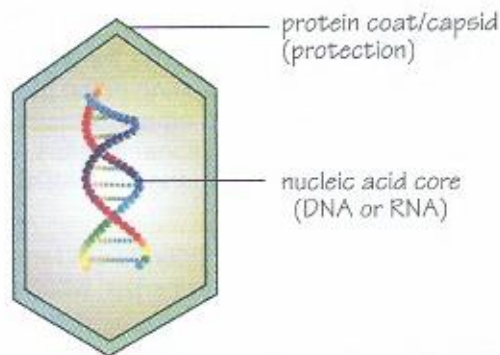
Viruses do not breathe, eat, respire or respond to stimuli. They have the ability to reproduce, but this can only occur once the virus is inside a living cell, hence they are obligate endoparasites. A particular virus usually only attacks a certain type of tissue. Hence viruses are referred to as being host specific.

Basic structure of a virus

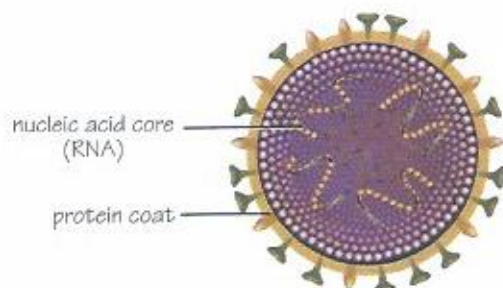
Viruses are very small (20 - 300 nm) and are only visible with an electron microscope.

- The outer protein coat or capsid encloses a nucleic acid core of DNA or RNA.
- Viruses that infect plant cells contain RNA.
- Viruses that infect animal cells have either DNA or RNA, but never both.
- Viruses that infect bacterial cells are known as bacteriophages and have a nucleic acid core of DNA.

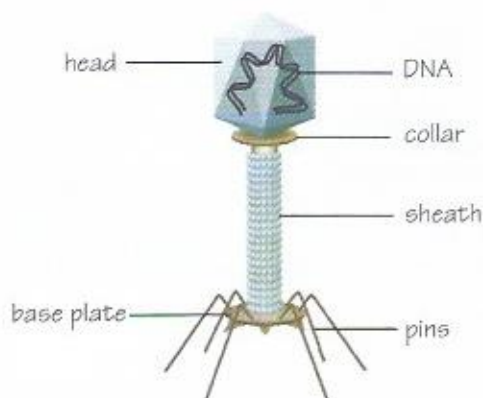
Most viruses are symmetrical in shape. Some viruses are spherical.



Generalised structure of a virus



The influenza virus



**A bacteriophage
(virus that attacks bacteria)**

Examples of viruses

General characteristics of viruses

- Are ultramicroscopic and are able to pass through most micro-filters.
- Are acellular and contain no cytoplasm or organelles.
- Do not perform metabolic activities e.g. cellular respiration.
- Are host specific, i.e. infect a particular host tissue.
- Are obligate endoparasites as they are only able to reproduce when inside a host cell.
- Are all parasitic, and can infect plants, animals and bacteria.
- Most are pathogens as they cause disease in their host.
- Some have an outer covering surrounding the capsid, which is composed of the host cell's plasma membrane.
- Antibiotics are ineffective against viruses since they are non-living.

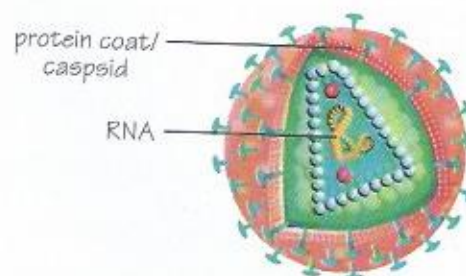
Viral diseases

Viruses cause many diseases. Viruses are spread through the atmosphere, in water or by vectors. When viruses infect living cells, they replicate in the host cells and cause infectious diseases.

HIV and AIDS

The Human Immuno-deficiency Virus (HIV) enters human blood through open wounds or via body fluids. The virus attacks white blood cells (also known as T4 lymphocytes), making them incapable of producing antibodies. Antibodies fight against other disease causing organisms that enter the human body.

When active, the HIV destroys the WBC and the person's immune system is destroyed, resulting in the person becoming highly susceptible to contracting other diseases. When a person is HIV positive and has an additional disease, such as TB, then the person is said to be suffering from AIDS (Acquired Immune Deficiency Syndrome).



The HI virus

Some symptoms of a person suffering from AIDS

- Weight loss
- Sweating
- TB
- Pneumonia
- Diarrhoea

Ways in which HIV is transmitted

- Blood transfusion.
- Sexual intercourse.
- Sharing hypodermic needles - this is common practice when needles are shared whilst injecting drugs e.g. heroin into the blood stream.
- Mother to child transmission. The HIV can pass through the placenta and enter the foetus. The virus can also pass from an infected mother to her baby via the breast milk.

How to avoid getting AIDS

- Do not share hypodermic needles.
- Married couples should be faithful to each other and not have sex with a third party.
- Use a condom. This also prevents contracting STDs (sexually transmitted diseases).
- When attending to a person who is bleeding, wear protective clothing and gloves to avoid infection.

Treatment for those infected with HIV

There is, to date, no cure for HIV/AIDS. The two treatments available are the PEP (post exposure prophylaxis) treatment and ART (anti-retroviral therapy).

PEP treatment:

PEP treatment is available to health care professionals and to people who may have been exposed to the HI virus by accident or by being raped. Treatment must start within 24 hours of exposure and must be adhered to for 28 days.

Anti-retroviral therapy (ART)

This medication is given to patients who have been HIV+ for some time. The drugs inhibit the life cycle of the HI virus, causing it not to reproduce rapidly. Patients on ARTs can live long and healthy lives as long as the medication is taken strictly as prescribed for the rest of their lives.

Incorrect beliefs, attitudes and values concerning HIV and AIDS

False: When an HIV positive man has sex with a virgin, he will get cured.

False: Mosquitoes spread the HI virus.

False: Married people cannot get AIDS.

False: You can pick up the HI virus from a toilet seat.

False: You can pick up the HI virus from shaking hands.

Economic and Environmental Importance of Viruses

Environmental effects

As viruses are pathogens, they cause disease in other organisms which may lead to the death of the host organisms. In nature, viral diseases help to control the numbers of the host species and in so doing, they play an important role in maintaining healthy population sizes in ecosystems. Viruses may also be used as biological control agents in the management of certain pests of plants and animals.

Gene therapy

Viruses can be reprogrammed with a healthy gene from humans which can compensate for abnormal or malfunctioning genes in people with medical disorders. A virus can target the unhealthy tissue and incorporate the healthy gene into the DNA of these cells. The cells can now make the correct proteins and function normally e.g. gene therapy developed for cystic fibrosis sufferers.

Vaccines

Attenuated viruses are weakened forms of a virus that can be used to make vaccines. Vaccines stimulate the immune system to make antibodies that fight off viral infections.



Oral and injection vaccines

B. Bacteria Kingdom: Monera

Introduction

Bacteria are unicellular organisms that are larger than viruses but are also microscopic in structure. They are **prokaryotic** cells i.e. they lack membrane-bound organelles. Some bacteria are **pathogenic** i.e. they are disease causing. Most bacteria are **heterotrophic** (cannot manufacture their own food), while some are **autotrophic** (can manufacture own food). Most bacteria are useful to the environment and humans.

Classification of bacteria

Bacteria may be classified by the way they obtain their energy:

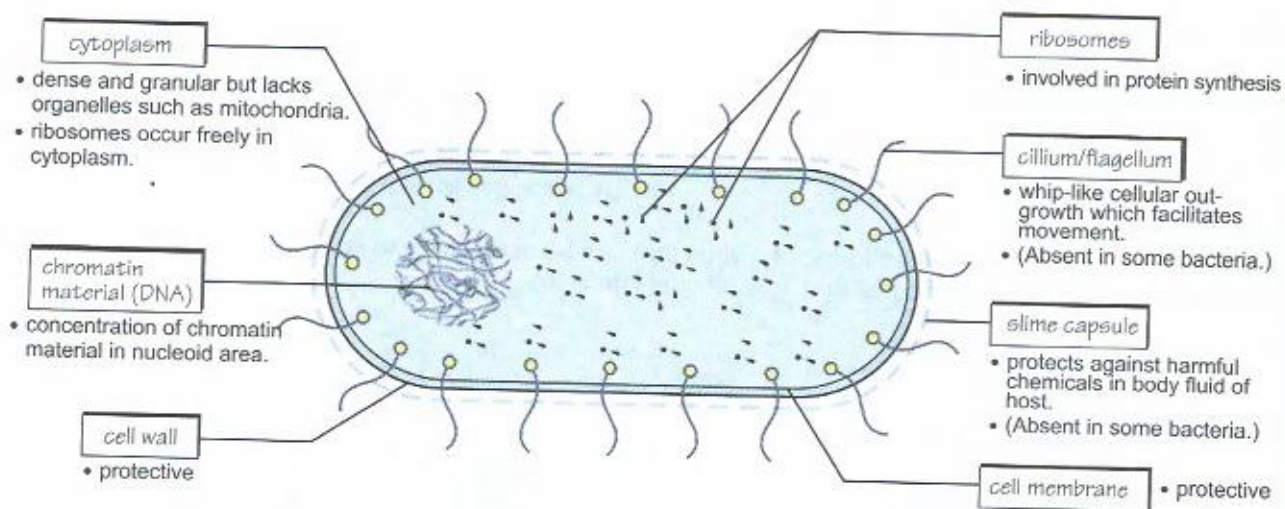
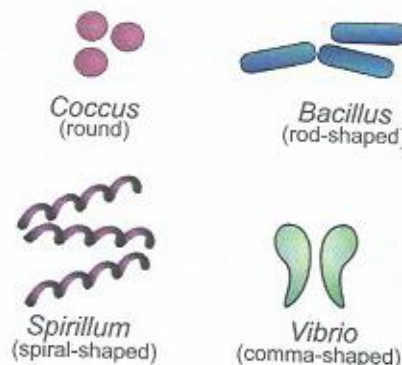
- Photosynthetic bacteria: utilise radiant energy from the sun.
- Chemosynthetic bacteria: obtain energy from the breakdown of chemical compounds.
- Heterotrophic bacteria: feed on organic matter to release energy.

Structure

Bacteria are unicellular and are visible with a microscope. The different types of bacteria are distinguished from each other by their shape. Bacteria do not have a clearly defined nucleus. The DNA is confined to one area called the nucleoid.

DNA also occurs freely in the cytoplasm in the form of circular molecules of DNA called plasmids.

All bacteria are prokaryotes, i.e. they are simple cells, with no membrane-bound organelles, and no true nucleus.



Structure of a typical bacterium

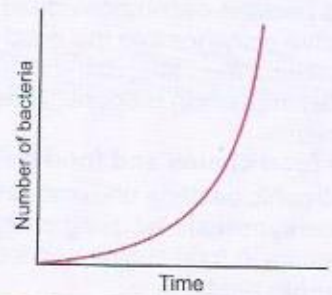
General characteristics of bacteria

- They are unicellular, prokaryotic organisms which belong to the kingdom Monera.
- They are the oldest living organisms, having evolved 3 800 mya.
- Bacteria are found in all habitats: in the hottest, coldest, deepest and highest parts of the Earth, and even in the alimentary canal of humans.
- Some bacteria have "pili", which are hair-like structures that are used to attach onto cells, or to join onto other bacteria to transfer segments of DNA between them.
- Many bacteria have cilia and/or flagella.

Reproduction

Reproduction is asexual and occurs through the process of binary fission (mitosis) during favourable conditions (sufficient food, water, space; correct temperature, pH; lack of toxins). The chromatin material divides into two identical masses prior to the division of the cell. The cytoplasm then splits into two identical cells with identical amounts of chromatin material. The process occurs rapidly causing bacterial populations to grow exponentially. During unfavourable conditions, bacteria may form endospores. They develop thick resistant walls and may remain dormant for long periods of time.

Exponential growth of bacteria



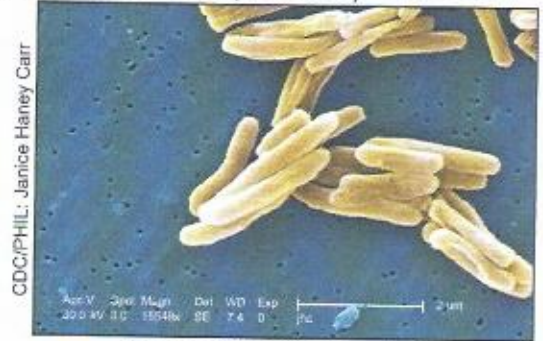
Bacterial Diseases

Tuberculosis (TB)

Tuberculosis is a disease in humans that is caused by the bacterium *Myobacterium tuberculosis*. If not treated properly, TB can lead to death. There are about three million deaths due to TB in the world annually. The bacterium usually attacks and destroys the lung tissue. When an infected person sneezes or coughs, the bacteria pass through the air and enter the lungs of other people. The bacteria then multiply in the lungs and may move via the blood to the kidneys and central nervous system (brain and spinal cord). TB in the kidneys, brain and spinal cord is usually not infectious.

Symptoms of TB

- Fever
- Sweating at night
- Loss of appetite
- Weight loss
- Chest pains
- A cough that lasts for more than two weeks
- Coughing up blood-stained sputum (phlegm)



Myobacterium tuberculosis

Test to confirm TB

1. X-rays of the lungs:

The infected person will have visible patches of destroyed lung tissue.

2. TB skin test:

The chemical tuberculin is injected under the skin in the lower arm. If there is a positive reaction, seen as a raised lump or rash at the injection site, the person has a latent TB infection, meaning they have been exposed to the TB bacteria, but the TB bacteria are not currently active in the body.

3. Tissue Culture:

A phlegm sample is cultured in a laboratory under sterile conditions. The growth is then examined under the microscope for the presence of TB bacteria.

Treatment of TB

- A course of antibiotic medication must be taken daily for the full duration of the course (usually 6 months).
- If the patient does not complete the course, a relapse could occur and the TB bacteria could become resistant to the drugs that were taken. It is very difficult to cure drug resistant TB.

Preventing TB

- Newborn babies must be given the BCG vaccine immediately after birth to boost their immune systems.
- TB patients must not come into contact with anyone that has a weakened immune system.
- Health care workers must be screened regularly for TB and treated immediately if they test positive.
- The immune system should be strengthened by having a healthy diet and exercising regularly.



The BCG vaccination wound

Biological importance of bacteria

Ecological Role

Some bacteria decompose dead plant and animal matter. They are **saprophytes**. The bacteria secrete digestive enzymes into the dead plants and animals. These enzymes break down the organic matter and the bacteria then absorb the nutrients. Water, carbon dioxide and nitrogenous wastes are by-products of the decomposition process. These by-products are returned back to the environment for use by other organisms.

Role in food chains and food webs.

Autotrophic bacteria undergo **photosynthesis** by using energy from the sun. Some bacteria undergo **chemosynthesis** by using energy from chemical processes to produce food. Many bacteria are important producers in food chains and food webs.

Pathogenic bacteria

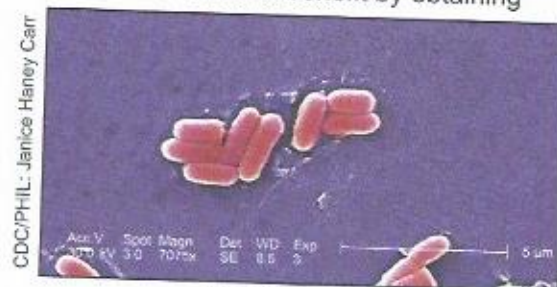
These bacteria cause diseases in plants and animals. They are parasitic and bring harm to the plant or animal they infect. Some infectious diseases in humans that are caused by bacteria are: cholera, bronchitis, anthrax, pneumonia and tuberculosis. These diseases can be treated with antibiotics.

Role in Symbiotic Relationships

Plants are unable to use atmospheric nitrogen. Nitrogen-fixing bacteria are able to convert atmospheric nitrogen into nitrates. Plants use nitrates to manufacture proteins. These bacteria may be free-living or live within nodules of certain plants, e.g. legumes, where there is a mutualistic relationship between the plant and the bacteria. The plant benefits by getting nitrates from the bacteria. The bacteria also benefit by obtaining carbohydrates from the plant. This is an example of mutualism since both organisms benefit from the relationship.

Mutualistic bacteria are also found in the digestive tract of herbivorous animals. The bacteria break down cellulose into simple sugars, which are then absorbed by the animals. The bacteria benefit by obtaining nutrients from the digested food.

Bacteria (e.g. *Escherichia coli*), present in the intestine of humans, release vitamin B12, vitamin E and vitamin K from certain foods, which are then absorbed into the human blood system. These bacteria also share a mutualistic relationship with their hosts because they obtain some nutrients from the partially digested food.



E. coli bacteria

Economic importance and the role of bacteria in Biotechnology

Biotechnology involves using living organisms to produce products that are of benefit to humans. It is used in the manufacturing of certain foods and chemicals. Some examples are given below:

- **Oil spill clean-up:** Genetically modified bacteria are able to clean up oil spills by rapidly digesting the oil.
- **Production of chemicals:** Bacteria are used in the production of chemicals such as ethanol and acetone.
- **Production of food and drinks:** Yoghurt, cheese, vinegar and wines are produced by bacterial fermentation.
- **Obtaining precious metals from rock:** Copper, gold and uranium are now being extracted from rocks by bacteria that have been modified to have a greater bioleaching ability.
- **Production of hormones:** Using recombinant DNA technology, bacteria are used to produce hormones for human use. Some of these hormones that are produced are insulin (used in the treatment of diabetes) and the human growth hormone (used to treat dwarfism). The genetically modified bacteria have the human genes required to manufacture these hormones inserted into their plasmids.

Use of bacteria by the indigenous people of Southern Africa

Alcoholic and non-alcoholic drinks such as 'mahewe' and maas, are made by bacterial fermentation. In the production of *mahewe*, maize meal (a source of glucose) and wheat flour are mixed and allowed to stand for a few days. Due to bacterial fermentation, lactic acid is produced which gives the drink a sweet-sour taste.

In the production of *maas*, milk is poured into clay pots. The bacteria present on the clay pot surface causes the milk to ferment, producing lactic acid that sours the milk.

Introduction

The kingdom Protista is a large and highly diverse group of organisms which include slime moulds, protozoans, diatoms and algae. Some protists are unicellular, while others are multicellular. Organisms in the kingdom Protista can be divided into three sub-groups, viz.:

- **Protozoa:** unicellular heterotrophic, animal-like organisms, e.g. *Amoeba*.
- **Algae:** plant-like protists that are autotrophic, e.g. green algae.
- **Slime moulds:** fungus-like protists that are heterotrophic decomposers.

Protozoans have the following characteristics:

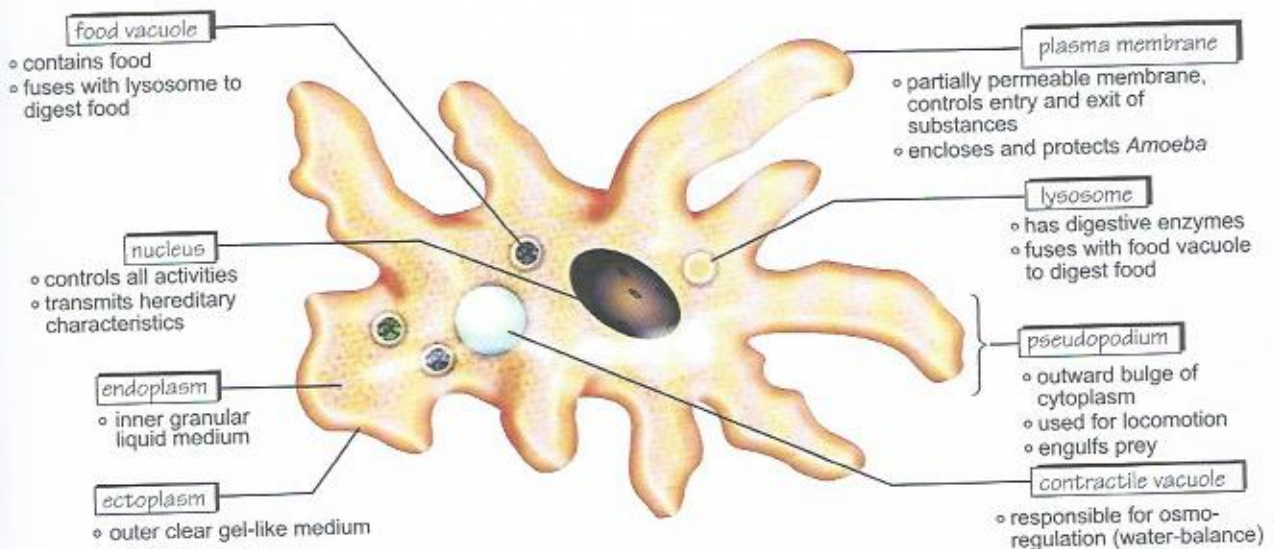
- Are eukaryotic (has a true nucleus and has membrane-bound organelles)
- Are unicellular.
- Have pseudopodia, cilia or flagella to assist in locomotion.
- Are aquatic organisms that live in fresh or saline water.
- Reproduce asexually.

Amoeba as an example of Protists

Structure

Amoeba is a unicellular (one-celled) organism that lives in streams and ponds. It is asymmetrical with many pseudopodia (false feet) which assist in locomotion and in engulfing small prey. *Amoeba* has the following structures:

- **Plasma membrane:** encloses and protects the organism. Allows for gaseous exchange and diffusion to occur.
- **Nucleus:** controls the cell activities.
- **Contractile vacuole:** controls the water balance within the organism by osmo-regulation, by collecting excess water from the cytoplasm and ejecting it from the surface of the *Amoeba*.
- **Food vacuole:** engulfed food is digested within the food vacuole. Enzymes for digestion are contained in a lysosome which fuses with the food vacuole.
- **Ectoplasm:** outer part of the cytoplasm that is semi-solid (gel-like).
- **Endoplasm:** inner part of the cytoplasm that is more liquid in nature.
- **Lysosome:** is a structure that contains digestive enzymes.
- **Pseudopodia:** bulges of the cytoplasm that flow to one end and are used for locomotion or to engulf food (phagocytosis).

Structure of *Amoeba*

D. Fungi

Kingdom: Fungi

Introduction

All fungi lack chlorophyll and cannot manufacture their own food. There are many different types of fungi. Some examples of fungi include:

- Mushrooms
- Toadstools
- Bracket fungi
- Ringworm (parasitic)
- Bread mould
- Penicillium
- Rusts

Most are saprophytic decomposers, while some are parasitic and cause diseases in plants and animals. Most fungi are multicellular, however, some fungi are unicellular e.g. yeast.

Some examples of fungi

Sporangium fungi

Produce spores within sporangia, e.g. Bread mould.



Club fungi

Spores are produced in club-shaped structures, e.g. Mushroom.



Sac fungi

Spores are produced in sac-like structures, e.g. *Penicillium*.



Penicillium through a microscope

Courtesy: CDC/Lucille Georg

Imperfect fungi

Fungi that cause diseases in humans, e.g. athlete's foot; ringworm; candidiasis.



Ringworm on the arm

Courtesy: CDC/Dr Lucille K Georg

Structure of the bread mould, a filamentous fungus (*Rhizopus sp.*)

Bread mould is a thallus structure (i.e. it does not contain true roots, stems or leaves) that lacks chloroplasts. It consists of a mass of threads called mycelium. Each thread is called a hypha. Hyphae are aseptate with many nuclei present. Three types of hyphae are present. They are the:

- Sporangiphores which grow upright and hold the sporangia above the substrate.
- Stolons that grow along the substrate (bread), giving rise to new hyphae.
- Rhizoids that penetrate the substrate and act as "roots".

The walls of the hyphae are strengthened by a polysaccharide known as fungal-chitin.

Key words

Hyphae: tube-like filamentous structures (hypha is singular).

Mycelium: collective term for the mass of threads of the breadmould.

Rhizoids: hyphae that penetrate the substrate (bread)

Sporangiophores: upright growing hyphae that hold the sporangia.

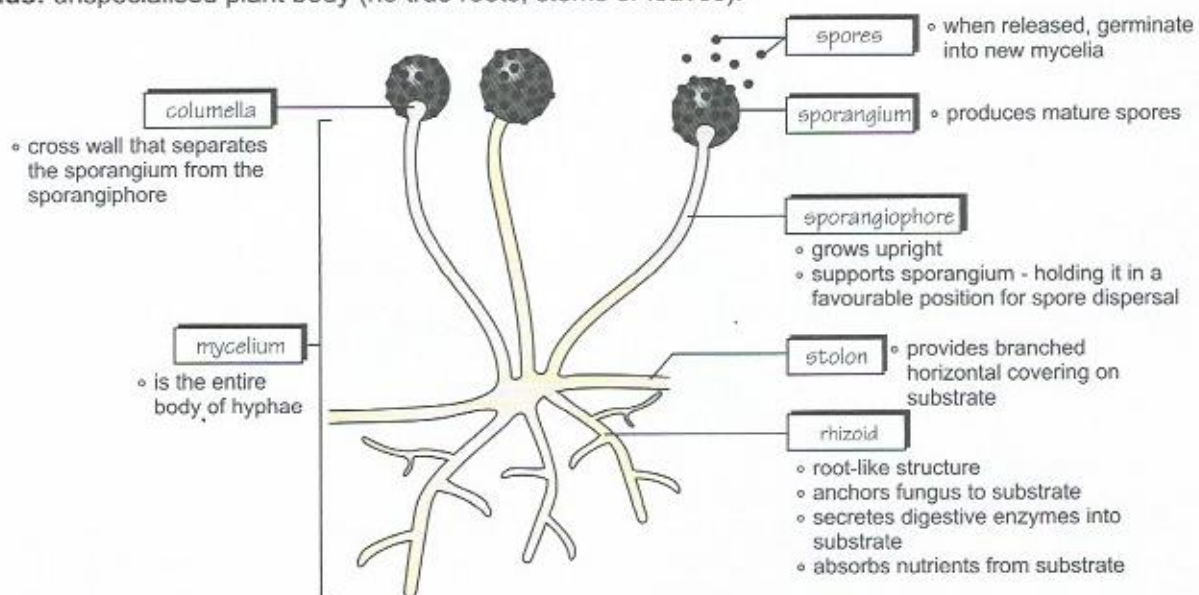
Sporangia: produce spores for asexual reproduction.

Stolons: hyphae that grow horizontally.

Aseptate: refers to the absence of cross walls.

Columella: a cross wall that separates the sporangium from a hypha.

Thallus: unspecialised plant body (no true roots, stems or leaves).



Structure of *Rhizopus*

General characteristics of fungi

- Some are unicellular e.g. yeast; most are multicellular.
- Fungi are eukaryotic, as they have true nuclei and membrane-bound organelles.
- Their bodies are made up of a network of thread-like filaments called hyphae.
- Hyphae walls are made of fungal chitin.
- Many hyphae are multinucleate.
- Most hyphae have cross walls called septa, but some e.g. bread mould, have no septa and their cytoplasm is continuous.
- All the hyphae of a fungus are collectively referred to as the mycelium.
- In mushrooms, all hyphae fuse together to form a fleshy body. The rest of the mycelium grows in the soil.
- Fungi lack chlorophyll and are heterotrophic.
- Most are saprophytes, secreting digestive enzymes into organic matter, digesting it, and absorbing nutrients from the substrate.

Fungal infections

Candidiasis

Candidiasis is an infection caused by *Candida* fungi, especially *Candida albicans*. These are found almost everywhere in the environment. Some may live harmlessly along with resident species of bacteria that normally colonise the mouth, gastrointestinal tract and vagina. Usually, *Candida* fungi are kept under control by the resident bacteria in the body and by the body's immune defences. If the resident bacteria are depleted by antibiotics, or if the person's immune system is weakened by illness (especially AIDS or diabetes), malnutrition, or some medications, *Candida* fungi can multiply and cause infection.

Types of candidiasis and symptoms :

Thrush:

Common name for a mouth infection caused by the *Candida albicans* fungus. Affects moist surfaces around lips, inside of cheeks, tongue and palate. Common in people with cancer and AIDS.

Symptoms: Forms curd-like white patches inside the mouth, which can be sensitive and painful.

Other types:

- Oesophagitis
- Cutaneous (skin) candidiasis.



Oral thrush

Treatment

1. Gargling with an anti-fungal mouthwash.
2. Applying anti-fungal medication.

Prevention

1. In general, one can prevent most *Candida* infections by keeping the skin clean and dry.
2. Only use antibiotics that have been prescribed by a doctor and use them as directed.
3. Follow a healthy lifestyle – this means proper nutrition and regular exercise.
4. People with diabetes should try to keep their blood sugar levels under control.

Athlete's foot, Ring worm

These infections are mild fungal infection of the skin caused by the fungus *Tinea*. Different species of *Tinea* infect different parts of the body, e.g. *Tinea corporis* is the typical ringworm found on the body; *T. pedis* is found on the feet (commonly known as athlete's foot). Other species affect the scalp and the groin area (jock itch). The typical ringworm rash on the body looks like a red, circular lesion with a scaly border. These areas on the body may be itchy. On the scalp it may cause scaling which appears like dandruff, and on the feet, it causes an itchy rash with scaling between the toes. Ringworm is only mildly contagious, so children undergoing treatment may continue to attend school or daycare centres. One can also get ringworm from infected cats and dogs.



Ringworm

Courtesy: CDC/Dr Lucille K Georg



Athlete's foot

Plant fungal diseases

Plant fungal diseases:

- rusts: disease of stems and leaves of cereals e.g. wheat, and many other flowering plants
- downy mildew: affects grape vines, cabbages and onions
- smuts: damages cereal plants and seeds.

Rusts

Symptoms

Rusts begin as small yellow spots on leaves and stems of plants. These spots then form elongated orange pustules on the undersurface of leaves that later turn reddish-brown. These pustules are about the size of pinheads. Shortly after pustule development, the upper surface of the leaves develop yellow to orange spots with reddish centres. Severe infection leads to pustules developing even on the upper surface of the leaves, as well as the stems and green parts of the plant.



A typical rust infection

Cause

The fungus survives the winter on leaves and stems that have been infected during the growing season. In the spring, the fungus produces spores. Favourable conditions, viz. moderately warm air temperatures and good moisture for 10 -12 hours is sufficient for the spores to infect plants.

Rust fungi require two hosts to complete their life-cycle. Spores are carried by air currents to young plants and to the second host. Rusts cause severe losses to wheat farmers and can also destroy turfgrass very quickly. This disease seems to be more severe in turf which is deficient in nitrogen.

Management of the disease

- For turfgrass, rusts can be managed with proper mowing, fertilizing and good irrigation practices.
- For other plants, rust infected leaves and stalks are removed and burnt to destroy the spores.
- Spraying or dusting plants, especially the undersurface of the leaves, with fungicides.
- Complete removal of the second host plant.

Prevention

- Plant disease-free turf or seeds.
- Treat seeds and equipment used for planting with fungicide before planting starts.
- Plant rust-resistant varieties.

Biological Importance of Fungi

Role of Fungi as Decomposers

Saprophytic fungi act as decomposers. They secrete enzymes that break down organic material into soluble nutrients that can be absorbed. During this process, water, carbon dioxide, ammonia and heat are released into the environment for use by other organisms.

Economic Importance of Fungi

Some fungi are a source of food for humans:

Mushrooms



Cheese making



The blue-green mould *Penicillium* is used by humans to produce the characteristic flavour of Camembert and Roquefort cheeses.

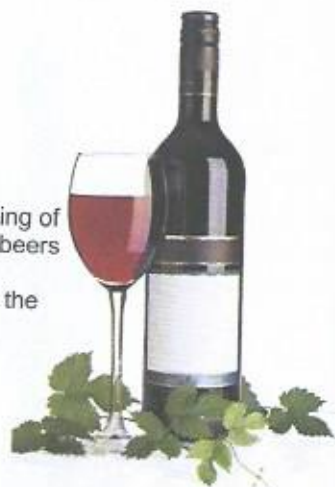
Alcohol and Carbon dioxide

Yeast is used to convert sugar to alcohol and to produce CO_2 .



- Carbon dioxide is used to make dough rise, e.g. during baking of bread.

- Yeast is used in the making of alcoholic beverages like beers and wines. The carbon dioxide is retained within the beverage for beers and sparkling wines, but is released for still wines.



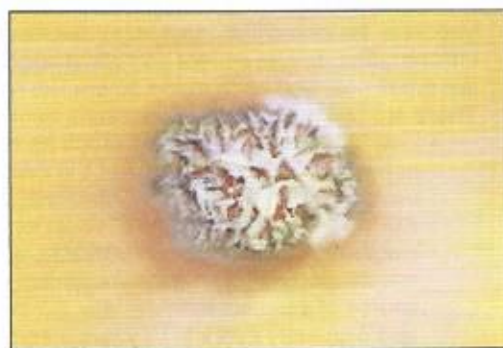
In South Africa, traditional "Zulu beer" is made from a mixture of water, yeast, maize, maize malt or sorghum malt. The beer has a sour smell and a low alcohol content of usually less than 3% when compared to commercially prepared beer, which has an alcohol content of approx 4,5 - 5,5%. Since commercially prepared beer is distilled up to three times, much of the water evaporates, resulting in the beer having a higher alcohol content. The maize malt or sorghum malt provides the glucose that is needed by the yeast for the process of alcoholic fermentation. The maize or sorghum is soaked in water to initiate germination so that enzymes are released to convert the starch, that is stored in the grains, into simple sugars for fermentation. As the fermentation process takes place, the accumulation of alcohol kills the yeast cells which do not produce any more alcohol, thus leading to the beer having a lower alcohol content. In commercially prepared beer, the conversion of starch to glucose is accelerated by the use of genetically modified yeast cells which can also withstand higher alcohol concentrations. Hence, the higher alcohol content found in commercially prepared beer. Traditional Zulu beer is known as "Umqombothi".

Economic Importance of Fungi - Summary

- Mushrooms serve as a food source for many people.
- Certain types of cheese require the fermenting of milk with the fungus *Penicillium*.
- Bread is produced by the alcoholic fermentation of yeast. The carbon dioxide produced causes the dough to rise.
- Yeast is also used to produce beer and wine via alcoholic fermentation.
- Some fungi are used to produce certain antibiotics e.g. penicillin.
- Pathogenic fungi cause diseases in plants and animals, e.g. rusts and potato blight in agricultural crops. Humans are affected by certain parasitic fungi such as ringworm and athlete's foot.
- Certain fungi decompose stored food like maize and wheat resulting in the food becoming mouldy.
- Traditional Zulu beer is made from yeast, together with water, maize, maize malt or sorghum malt.
- Industries that use fungi in the manufacturing of consumer products, create jobs for many people in South Africa.

Role of fungi in medicine

Certain fungi are used to produce antibiotics, e.g. penicillin, which is produced from the blue-green mould, *Penicillium notatum*. Penicillin is an antibiotic widely used in fighting many kinds of infections.



The *Penicillium* fungus

Certain fungi are used to produce antibiotics, e.g. penicillin, which is produced from the blue-green mould, *Penicillium notatum*. This mould was accidentally discovered by Alexander Fleming in 1928 while he was carrying out investigations using the bacterium *Staphylococcus*. During his investigations, he noticed the presence of a blue-green mould on some of the cultures of his bacteria, and it seemed that the bacteria did not grow underneath or around this mould. He later discovered that this mould was *Penicillium* and he carried out investigations to check whether the substance that it produced was capable of destroying the bacteria. Fleming named the substance that was produced by the fungus, penicillin. Further investigations revealed that penicillin could also destroy other micro-organisms. However, his discoveries were not easily accepted by the medical field with regard to treating diseases in humans, and it was also very difficult to produce penicillin on a large scale.

During the early 1940s, two scientists, H.W. Florey and E.B. Chain and a team of researchers at the Oxford University decided to treat human patients with penicillin. The treatment was successful as penicillin was very effective in fighting bacterial infections. In 1945, Fleming, Florey and Chain were awarded the Nobel Prize for Medicine.

IMMUNITY

Immune Response in Humans

Immunity is the body's ability to resist infection. The immune system in humans aids the body in resisting disease and infection. It also recognises and rejects foreign cells and tissues. Antibodies and white blood cells produced in the body are able to fight infection and protect against diseases. Antibodies produced by the body are specific and will only attack a particular microbe. Once produced, the antibodies remain in the body to fight off diseases and infections for life.

The two types of immunity are:

Natural Immunity Is the body's inherent ability to produce antibodies and fight diseases.

Acquired Immunity

Passively Acquired:

Passively acquired immunity does not use the person's own immune system. Immunity is obtained naturally from breast milk or from ready-made antibodies supplied in a serum.

Actively Acquired: Obtained through natural infection or vaccination.

Vaccinations

A vaccine is a liquid containing the proteins of the micro-organism that causes a particular disease. When a protein from outside the body enters the body, it is referred to as an **antigen**. The WBCs are able to recognise foreign antigens, and destroy them. To help identify antigens, our WBCs produce **antibodies**. These antibodies bind to antigens and mark them, so that the WBCs know which proteins to destroy.

When one is vaccinated, usually by injection, the WBCs will produce a large number of matching antibodies which will quickly destroy the particular pathogen should it enter the body at a later stage.

How vaccines work

Vaccines are one of the most important strategies available to help prevent infectious diseases. In the past, many children died, or had severe complications following infections. Vaccines have helped to eliminate certain diseases like small pox, and have made others like measles and polio, very rare.

There are two main types of vaccines, namely, live "attenuated" vaccines and non-living vaccines.

- Live "attenuated" vaccines (such as vaccines against measles, mumps, rubella and the oral vaccine against poliomyelitis), are solutions of the micro-organisms which have been altered in such a way as to render them incapable of producing the infectious disease, but capable of stimulating an immune response. These are the most successful types of vaccines, generally providing life-long immunity.
- Inactive vaccines (such as vaccines against Hepatitis B, diphtheria, tetanus, whooping cough and influenza), are solutions of dead micro-organisms which can still produce an immune response. They require a primary course of immunisation, usually 2-3 injections over a period of time. Booster immunisations may be needed approximately every 5-10 years if immunity is to be maintained.

When we receive vaccinations, a weakened form of the virus or bacterium is introduced into our bodies. Our white blood cells then respond by producing antibodies against these microbes. Any subsequent infection that enters our bodies will be recognized by the WBCs which will then protect us by fighting off the infection. Usually we are very well protected against infections for which we have received vaccinations. However, it may be necessary to receive the 'flu vaccine every year. The reason for this is that when micro-organisms replicate, not all the new viruses are identical to the original. The sequence of genes may be altered i.e. the micro-organism has mutated. This then means that a new microbe has been created that can infect humans, who will have had no pre-exposure to that microbe, and therefore no immunity. A new vaccine will be required against the altered/mutated virus. Especially in the case of seasonal influenza, a new vaccine is required every season.

Immune response by plants

Plants also have an active immune response to pathogens which works as follows:

- Infected cells die immediately, known as hypersensitive response (HR).
- The entire plant becomes resistant to the pathogen by producing a chemical that prevents further infection. This is known as Systemic Acquired Resistance (SAR).

Defense mechanisms against infections

There are three categories of defense mechanisms in living organisms:

1. Barriers to prevent entry.
2. Phagocytic white blood cells.
3. Protective proteins.

1. Barriers to entry

a) In Animals

- The skin and the mucous membranes lining the digestive and respiratory tracts act as a mechanical barrier preventing entry by bacteria and viruses.
- The respiratory tract is lined by ciliated columnar epithelial cells and these cilia beat in an upward direction to drive out the mucus and trapped foreign particles into the throat, where they can be swallowed or coughed out.
- The secretion of sebum (oil) by the sebaceous glands of the skin, contain chemicals that weaken or kill micro-organisms.
- The stomach has an acidic pH, due to the presence of hydrochloric acid, which inhibits the growth of many different types of bacteria.
- A mixture of different types of bacteria that normally reside in the intestine and other organs, such as the vagina, prevent pathogenic bacteria from taking up residence in these areas, preventing infections.

b) In Plants

- The thick, waxy cuticle prevents bacteria and other micro-organisms from entering the cells, while also reducing water loss.
- Thick bark covering the stems of woody plants serves to protect the underlying, delicate tissues from invasion.
- Sticky secretions produced by many plants serve as a deterrent for insects and other animals that try to eat or gain entry into plant organs.
- Chemical secretions produced by many plants are poisonous to micro-organisms, preventing them from growing on, or entering the plant.

2. Phagocytic White Blood Cells (in animals only)

- Should microbes gain entry into the body, the inflammatory response is initiated. White blood cells that are phagocytic start to surround the foreign bodies and engulf them so that they can be destroyed.

3. Protective proteins in animals

- A number of different proteins are produced by the liver of animals and are present in the blood plasma. They are activated in a certain sequence. Some coat the micro-organism e.g. bacterial cell, and others attract phagocytes to the bacterial cell. Some complement proteins form holes in the bacterial cell walls and membranes, causing fluids and salts to enter so that the bacteria expand until they burst.
- When viruses infect an animal cell, the infected cell produces a protein called interferon, which binds to receptors on non-infected cells to prevent the virus from entering these healthy cells.

Response of micro-organisms to medicinal drugs

Micro-organisms which have mutated may develop a resistance to drugs that were previously used for a particular vaccination or infection and the micro-organism is then said to be "drug resistant". It is unsure whether it is the drugs themselves that cause the micro-organisms to mutate, but we do know that the mutant forms can actually become resistant to many different medicines. Extreme drug TB resistant is an example of a mutated micro-organism.

Extreme Drug Resistant TB

In September 2006, the world's most lethal TB strain, extreme drug resistant TB (XDR TB) was identified in Kwa-Zulu Natal (KZN). It is known that TB can become resistant if a patient is not treated correctly. This may be caused by the patient not completing their course of medication, or the patient not receiving the correct antibiotic. This then can lead to multi-drug resistant TB (MDR TB), where the bacteria are resistant to at least two of the primary drugs used to treat TB. In this case, the disease becomes very difficult to treat. Moreover, the patient remains infectious for longer periods of time, increasing the risk of infection to the public and healthcare workers. XDR TB is a complication of MDR TB, whereby patients do not respond to three or more of the TB drugs. At least three antibiotics are needed in combination to kill the bacteria that causes TB. The KZN strain of XDR TB, is effectively untreatable because it is immune to seven of the nine standard TB drugs used in South Africa. Resistance to one or several forms of treatment occurs when the bacteria develop the ability to withstand antibiotic attack and pass on that ability to newly produced bacteria. Since the entire strain of bacteria inherits this capacity to resist the effects of the various treatments, resistance can spread from one person to another. It is thought that the XDR TB strain in KZN was actually a strain that was identified as multi-drug resistant in the mid-1990s, and that it has mutated over the past decade into the untreatable form identified recently. The first known case of XDR worldwide occurred in the late 1990s at Sizwe Hospital in Johannesburg, where several patients who attended the hospital for normal TB treatment were infected by the drug-resistant form from another patient. All of them subsequently died.

MDR and XDR TB can be transmitted from person to person and can infect those with normal TB. KZN's XDR strain appears to be very aggressive and infectious. The only way to prevent the spread of XDR TB is to isolate its carriers, especially those patients who would not, or could not take the full course of initial drugs. MDR TB also appears in association with HIV infection and AIDS, further compromising the health and the immune systems of these patients. HIV itself does not increase the chance of drug resistance. HIV does, however, accelerate the progression of a TB infection into an active TB disease. MDR TB can cause death within a few weeks in persons with HIV/AIDS. More than half of adult South Africans have latent TB in KZN, with three quarters of TB patients in the province being HIV-positive.

Plant Biodiversity

Introduction

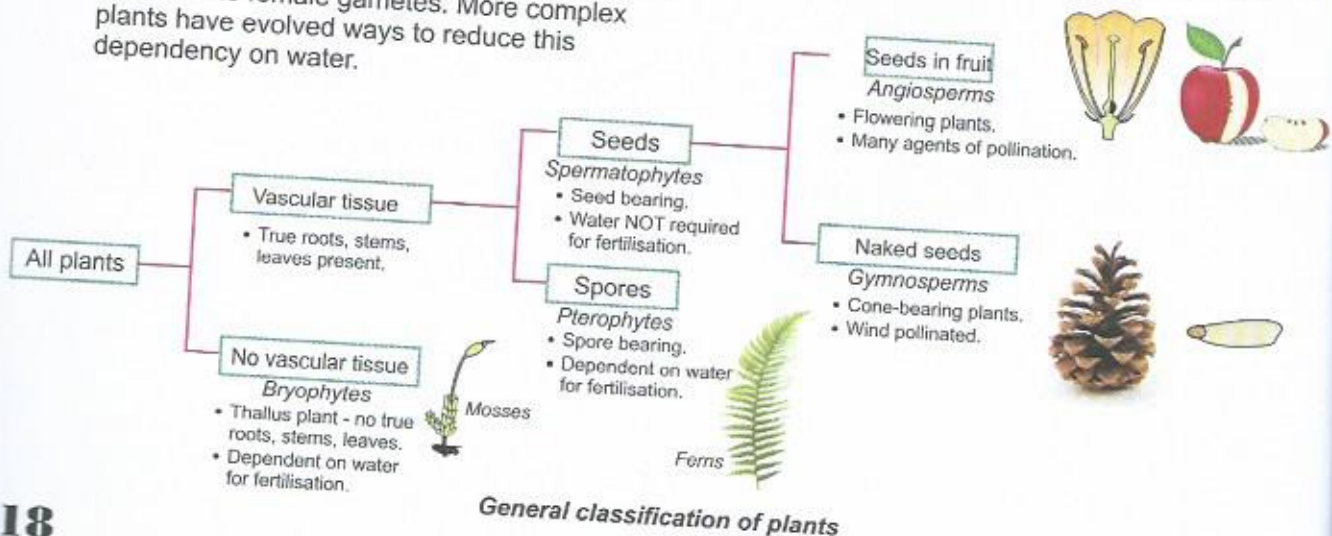
The first plant-like organisms to appear on earth were the single-celled green algae that lived in the warm oceans about 570 mya. These algae gave rise to all the land plants. According to the fossil record, the first land plants appeared about 480 mya in the Ordovician period of the Palaeozoic era. The first plants were early primitive types and were poorly adapted to life on land. Over time the more advanced plants have become adapted to a terrestrial lifestyle. Flowering plants are the most highly evolved land plants. They appeared on land about the time that the dinosaur era was coming to an end and since then their adaptations to life on land have enabled them to become highly successful and survive in a wide variety of habitats. Plants living on land need to develop the following adaptive traits:

- A waxy cuticle to reduce water loss, and stomata to enable gas exchange.
- True roots, stems and leaves which are plant organs that are responsible for: the absorption of water and nutrients; distribution of material to all parts of the plant body; and support.
- Vascular tissue (made of xylem and phloem tissue) is mainly concerned with support and transport.
- A method of reproduction which enables the propagation and dispersal of the species and provides for the protection and nourishment of the germinating offspring.
- A reduction in the dependence on water for reproduction and dispersal.

Not all plants are well adapted to life on land and the more primitive types of plants show varying degrees of reliance on water to complete their life cycles.

Plants are grouped according to the following features:

- **The presence or absence of vascular tissue:** vascular tissue in plants consists of xylem and phloem. Xylem transports water and mineral salts from the roots to all parts of the plant and phloem transports nutrients from the leaves to all parts of the plant.
- **The presence or absence of true roots, stems and leaves:** true roots, stems and leaves are complex organs containing different types of tissues such as xylem, phloem and supporting tissue. Some plants have root-like or leaf-like structures, but they lack the complex tissues necessary for them to be classified as true roots and leaves.
- **Whether they reproduce using spores or seeds:** the type of reproductive structure produced by a plant is important for the continuation of the plant species. Spores are simple reproductive structures found in early land plants. Seeds are much more complex and more successful than spores. They provide nutrition and protection to the embryonic plant, enabling plants to be dispersed widely and to survive harsh environmental conditions.
- **The presence or absence of fruit:** the production of fruit is important as it aids in the dispersal of the seed and also protects the embryo before germination.
- **The dependence of the plant on water for reproduction:** simpler plants are dependent on water for reproduction as the male gametes have to swim to reach the female gametes. More complex plants have evolved ways to reduce this dependency on water.



General classification of plants

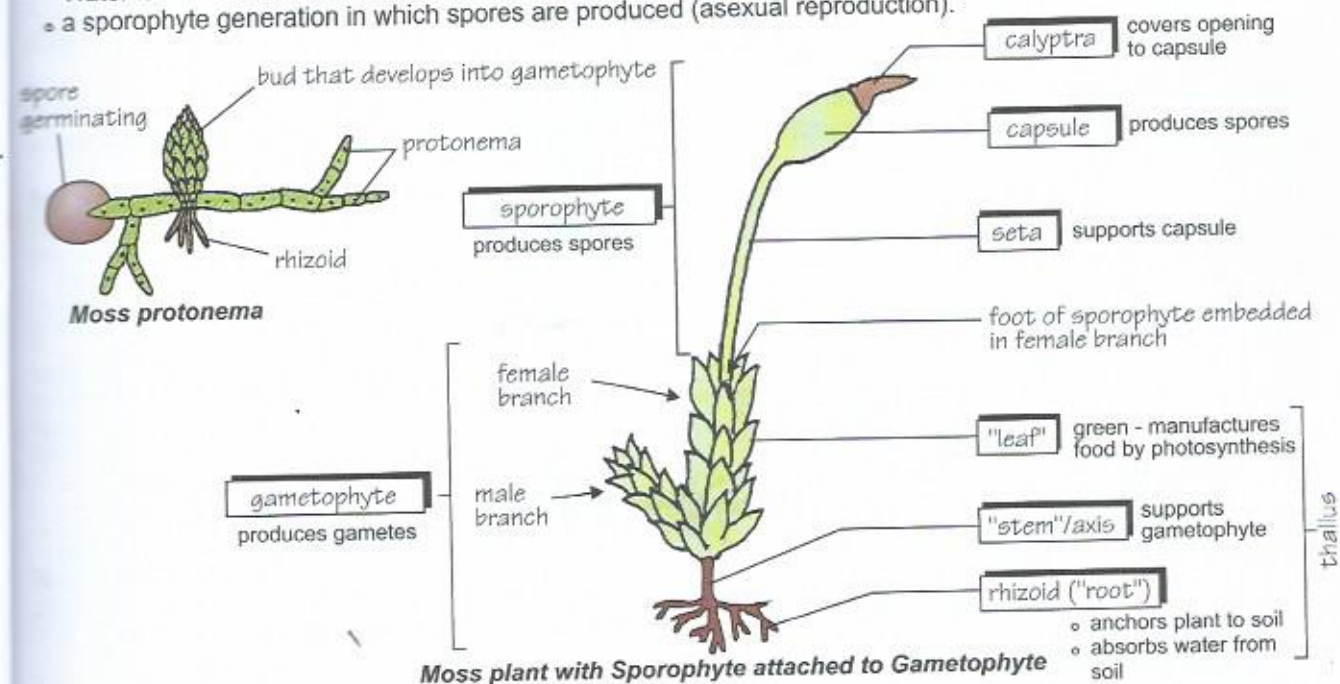
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Division: Bryophyta

Bryophytes are the most primitive land plants. They are very small plants that grow in damp shady areas. The two main groups are the mosses and liverworts.

Structure and characteristics of a moss plant

- Moss plants have a thallus structure, i.e. they lack true roots, stems and leaves.
- No vascular (conducting) tissue is present. Vascular tissue is not required since the plant, being small, can rely on diffusion. Plant units are also closely grouped, supporting each other and are able to trap water, preventing dehydration. The lack of vascular tissue also limits the size of the plants so they grow close to the ground.
- Rhizoids (root-like structures) anchor plant and absorb water and mineral salts from the soil.
- The "stem" lacks supporting tissue since mosses grow in clumps to support each other. Male and female shoots arise from the "stems".
- The "leaves" are small and are one cell layer thick. The central portion of the "leaf" may have a few layers of cells. The "leaves" lack cuticle, stomata, xylem and phloem (conducting tissue). The lack of cuticle means that water can be lost from the entire body of the plant. So the moss plant is restricted to growing in damp and shady places. The leaves are green as they contain chlorophyll and photosynthesise.
- There are two phases or generations to the life cycle of a moss plant:
 - a gametophyte generation that has male and female organs which produce gametes (sexual reproduction). Water is needed for fertilisation.
 - a sporophyte generation in which spores are produced (asexual reproduction).

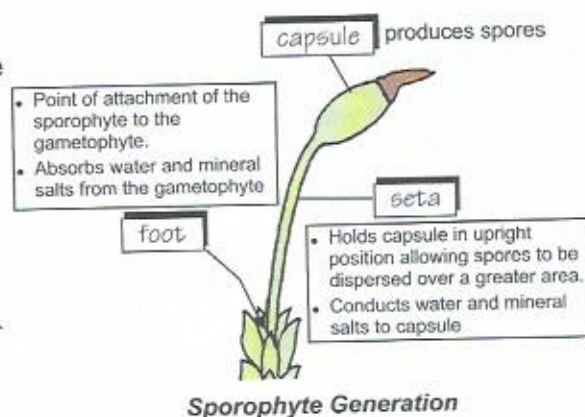


Bryophyte Reproduction

Moss plants have a two-phase life cycle. Adult moss plants are called gametophytes because they produce gametes on their male and female branches. Sperm are produced on the male branches and ova develop on the female branches. Under wet conditions, sperm swim to the ova to fertilise them. The fertilised ovum is now called a zygote and grows on top of the female branch, to produce a sporophyte.

The sporophyte consists of a foot, seta and capsule. Inside the capsule, spores are produced. When the spores are mature, the calyptra breaks off the capsule and the spores are released. Each new spore germinates into a protonema. Buds on the protonema develop into new gametophyte.

Because the sperm have to swim to the ova, water is essential for reproduction in Bryophytes.

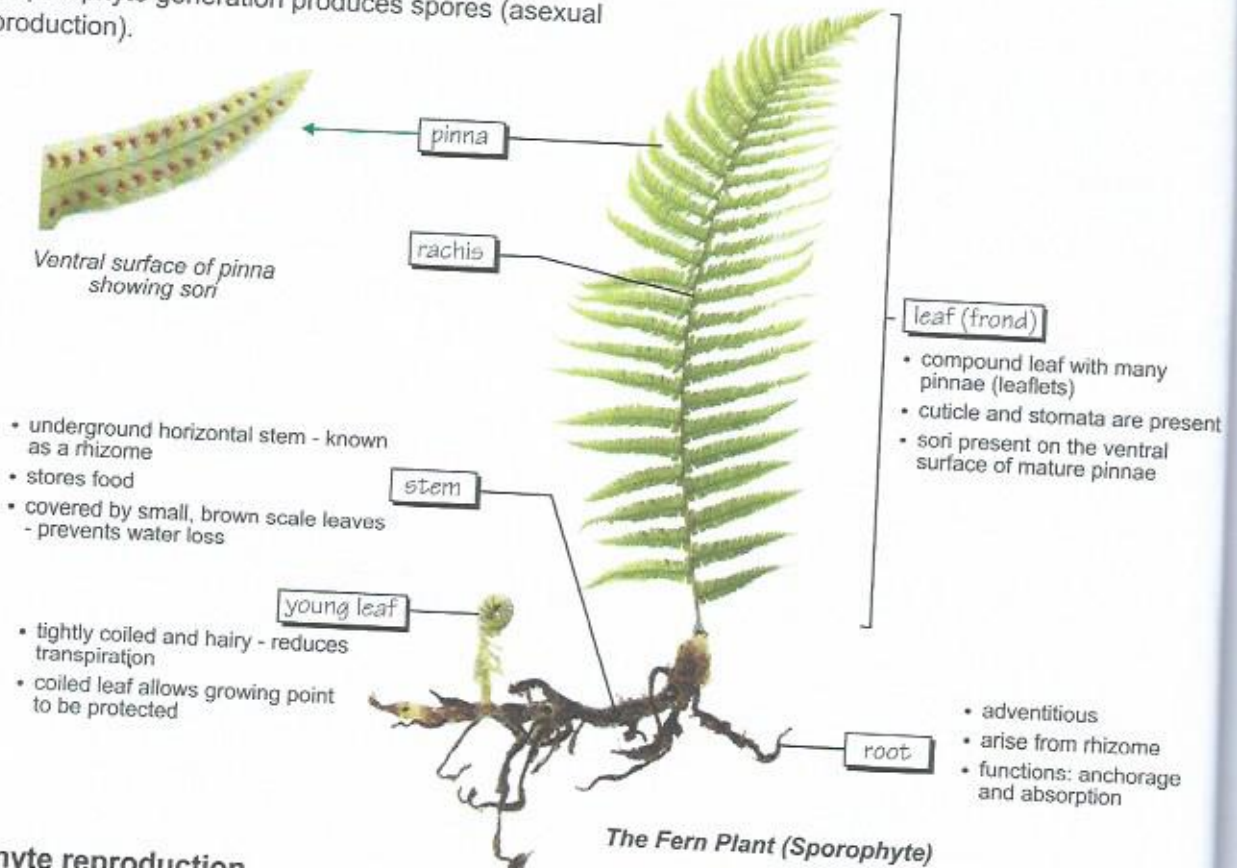


Division: Pterophyta (Ferns)

Pterophytes (or Pteridophytes) are an intermediate group of plants that show some advanced terrestrial features and yet are still reliant on water for certain aspects of their life cycle. They are the largest group of non-seed producing vascular plants.

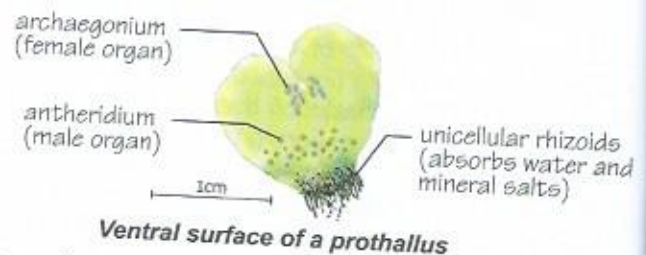
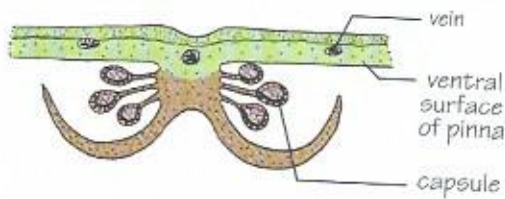
Structure and characteristics of ferns

- Ferns have true roots, stems and leaves.
- Ferns can grow into large plants because they have vascular and strengthening tissue (phloem + xylem).
- Ferns can live in a wider variety of areas than mosses, because their leaves are covered by a waxy cuticle which prevents dessication. Their dependence on water for reproduction restricts them to cool moist areas.
- The gametophyte generation is a prothallus, which is small in size. Sperm produced by the male organs require water to swim to the ova for fertilisation.
- The sporophyte generation produces spores (asexual reproduction).



Pterophyte reproduction

On the undersurface of mature pinnae are small structures called sori. Each sorus consists of many sporangia that produce spores. When the spores are mature, the sporangia snap open and fling out the spores. The spores are dispersed by wind currents and start to germinate when they land in a suitable moist habitat. Each spore grows into a small heart-shaped structure called a prothallus. Male and female reproductive organs develop on the underside of the prothallus and produce gametes. The sperm swim to the ova in a film of water, so ferns are dependent on water for reproduction. The embryo that forms after fertilisation grows into a new fern plant that is well adapted to life on land.



Division: Spermatophyta (Seed-bearing plants)

Spermatophytes are the most highly advanced group of plants. Seed plants evolved about 400 mya during the Devonian era and they rose to dominance in the late Carboniferous as the climate became drier. The spermatophytes are divided into two subgroups: the Gymnosperms and the Angiosperms.

Significance of seeds

- Seeds are adapted for dispersal in a variety of ways which allow them to be transported away from the parent plant, thereby reducing competition for resources.
- Seeds have a protective coat (testa) which allows them to lie dormant until conditions are right for germination.
- Seeds store food that nourishes the embryo when germination starts.
- Seeds have a greater chance of survival than spores.

Sub-Division: Gymnospermae (Naked seeds)

Gymnosperms include conifers, ginkgoes and cycads. Conifers are the most diverse group of gymnosperms. Pine trees are conifers that belong to the species *Pinus*. The wood from pine trees is important in the furniture and building industries.

Structure of a pine tree

A pine tree has true roots, stems and leaves. Well developed strengthening and conducting tissue is present and the plant itself can grow into a large tree (the sporophyte).

Roots

Gymnosperms have a tap root system with lateral roots. No root hairs are present. There is a mutualistic relationship between a mycorrhizal fungus and the roots of pine trees. The fungal hyphae absorbs water and mineral salts from the

Stem

The stem is protected by a bark called the rhytidome. Two types of branches occur:

- branches of **unlimited growth** which lengthen each year
 - **dwarf shoots** (limited growth) which grow to a length of about 5cm.
- Dwarf give rise to needle-shaped leaves.

Leaves

Scale leaves are found on the branches of unlimited growth.

Needle shaped leaves arise from the dwarf shoots.

Transpiration is minimised by the:

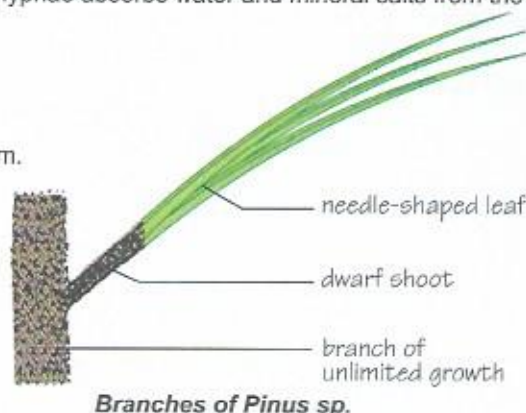
- reduced surface area of the needle shaped leaves
- thick cuticle
- sunken stomata.

Reproduction

- Gymnosperms produce male and female cones. Inside male cones thousands of pollen grains, containing male gametes, are produced.
- Mature pollen grains are dispersed by wind; Gymnosperms are therefore the first group of plants that are not dependent on water for fertilisation.
- Female cones house the ova (female gametes) on their bracts (woody scales).
- Fertilisation occurs when a male gamete fuses with an ovum on the bracts of the female cone. A zygote is then formed which develops into an embryo that is enclosed in a seed. The seeds of the pine have papery wing-like structures, which aid in dispersal by wind. Because seeds are not enclosed within a fruit, they are referred to as "naked seeds".

Adaptations of *Pinus* to a terrestrial mode of life

- It has a large tap root system for anchorage and absorption of water and mineral salts.
- In addition, the root system has a mycorrhiza for assisting with water and mineral salts absorption.
- The stem is protected by bark.
- The stem has conducting and strengthening tissue.



Branches of *Pinus* sp.



Female cone



A pine seed

- Needle-shaped leaves reduce water loss through transpiration.
- The leaves also have a thick cuticle which assists in reducing water loss.
- The gametes are protected by cones.
- Pollen grains are light and have air sacs which facilitate dispersal by wind.
- Pine seeds have "wings" which aid in dispersal of the seeds
- The seeds have a testa (seed coat) which prevents drying out (desiccation).
- Seeds have an endosperm which provides nutrients for the germinating embryo.

Sub-Division: Angiospermae (Flowering plants)

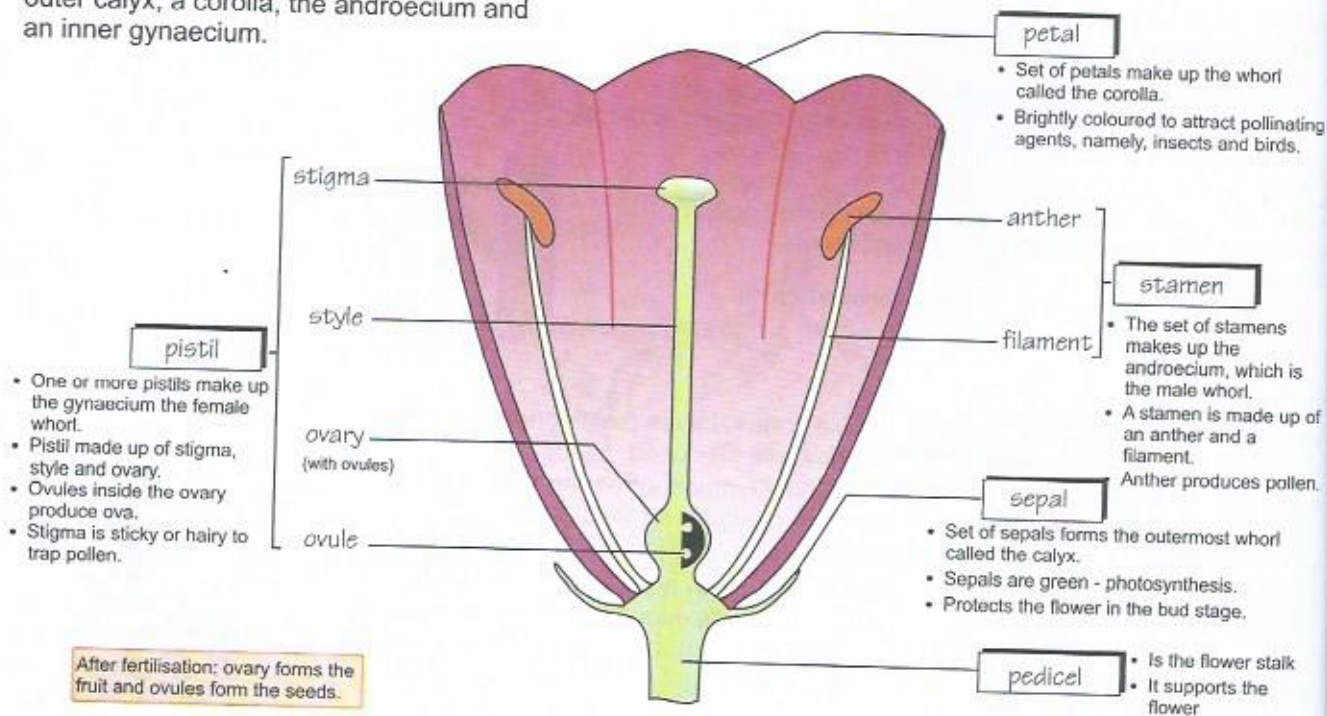
Flowering plants are the most highly developed plants. They emerged towards the end of the Mesozoic era and have become the dominant form of plants on Earth. Angiosperms are vascular plants and are the only plants that produce flowers and fruit. The flowers contain male and female reproductive organs. The ovaries are chambers in the female parts that enclose one or more egg-producing ovules. After fertilisation the ovule matures into a seed and the ovary becomes a fruit. Fruit aid in the dispersal of seeds

Some characteristics of Angiosperms

- They are vascular plants with true roots, stems and leaves.
- Plant sizes vary in height as strengthening tissue allows for the growth and development of large trees.
- Produces flowers and seeds. Seeds are found within fruit, which protects seeds and aids in their dispersal.
- The process of pollination ensures water is not required for fertilisation.
- The sporophyte is dominant and the gametophyte, within the flower, is very much reduced.

Generalised Structure of a Flower

Flowers consist of four whorls or layers: an outer calyx, a corolla, the androecium and an inner gynaecium.



L/s of a typical dicotyledonous flower

Reproduction

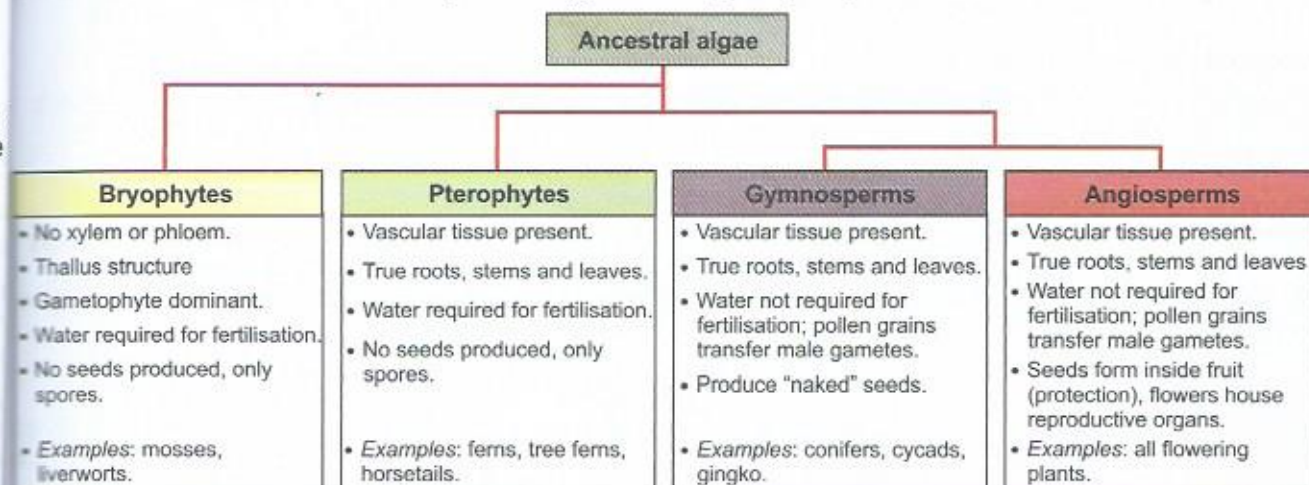
Fertilisation in Angiosperms is completely independent of water. The anthers produce pollen grains which contain the male gametes. Pollen grains are transferred from the anthers to the stigma of a flower by pollinating agents, such as wind, birds or insects.

The female part consists of the stigma, style and ovary. The ovary may contain one or more ovules. Each ovule produces an ovum (female gamete). The zygote which forms after fertilisation develops into the embryo. The ovule develops into a seed which contains the embryo. The ovary develops into the fruit.

Adaptations of Angiosperms (e.g. *Hibiscus*) to pollination

- Many pollen grains are produced to ensure successful pollination.
- Petals are brightly coloured to attract agents of pollination.
- Nectaries at the base of flowers produce sugary nectar that attracts birds and insects.
- The stigma is sticky or hairy to ensure pollen adheres to it.
- Pollen grains are small and light, making them easily transported by the pollinating agent. They are produced in large numbers.

Characteristics and relationships among the four group of plants



The Significance of Seeds

Seeds as a food source

- Seeds of cereal grasses are called grains e.g. oats, rice, wheat, maize.
- Grains provide a major part of the energy requirements of humans and form the staple diet of many people.
- Grains contain carbohydrates, fibre, essential vitamins and minerals.
- Pulses are the seeds of leguminous plants e.g. peas, beans, soya and lentils.
- Pulses are a good source of protein.
- Many seeds are a rich source of oils e.g. nuts, olive oil, grapeseed and sunflower seeds.

Seed banks

Humans are causing a great change to the biodiversity on Earth. As a result of human activities such as urbanisation, farming practices and human population growth, severe strain is put on plant resources.

Plant biodiversity is decreasing. Many species are vulnerable and many more are becoming extinct. Seed banks have been established in an attempt to conserve seeds from all species of plants.

- Seeds from all over the world are sent to seed banks.
- Endangered plants can be protected and reintroduced to the environment.
- Original wild types of food and crop plants are conserved to maintain their gene types in case our food supplies become threatened.
- Seeds are stored under the right environmental conditions that keep them dormant for many years.
- If required, they can be germinated when exposed to the right conditions.
- There are over a 1 000 seed banks in the world.

The Svalbard Seed vault in Norway

This is the most famous seed bank in the world. It is built deep into the side of a mountain and can withstand earthquakes and bombings. This vault acts as a backup for all other seed banks across the world. Norway's cold climate is ideal for storing seeds and can keep them viable for thousands of years.

Endemic species in South Africa

South Africa has a rich biodiversity of plants and many of them are endemic. The South African National Biodiversity Institute (SANBI) and the Royal Botanic Gardens at Kew in England, are working together to conserve our seeds as part of the Millennium Seed Bank Project. The seeds of more than 2 500 species have been collected and preserved. Many are endangered, threatened or very rare South African plants. SANBI is also working on programs to cultivate critically endangered plants so that they can be reintroduced into the environment.

Reproduction in Plants

Asexual and Sexual Reproduction

Introduction

Plants and animals reproduce so that the offspring can be produced ensuring that the species does not become extinct. There are two types of reproduction:

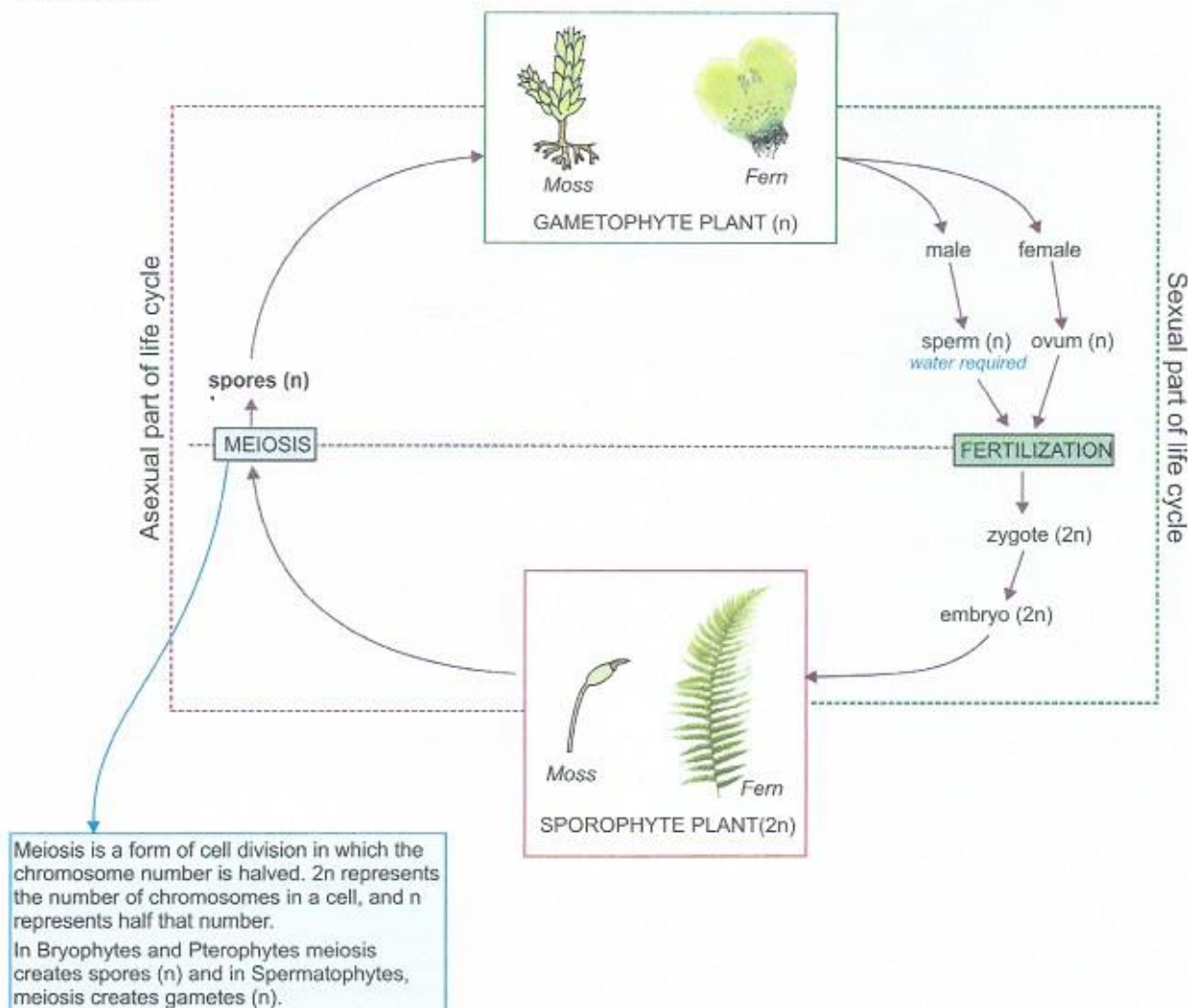
- **asexual:** reproduction without the formation of gametes (sex cells).
- **sexual:** involves the fusion of sex cells (gametes).

Asexual Reproduction in Plants

Asexual reproduction does not involve sex cells (gametes). Offspring formed from asexual reproduction are genetically identical to the parent, as the process involves producing new structures, or growing parts of plants by simple mitosis. The following are ways in which asexual reproduction can occur:

Asexual Reproduction by Spores

Some plants like the moss and fern do not form seeds. During their life cycles, they reproduce both sexually and asexually. They reproduce asexually by producing spores. The spores germinate into gametophyte plants. When the gametophyte matures and produces gametes, sexual reproduction occurs, because sperm fertilise ova.



Reproduction in low order plants viz., mosses and ferns

Asexual Reproduction (Vegetative Reproduction) in Plants

Vegetative reproduction does not involve the male and female sex organs of the plant; vegetative parts of the plant are responsible for producing new plants. As new plants are formed from the parent plant, by mitosis, the genetic make-up of the new plant is identical to the parent plant. Different plants have different ways in which they may reproduce by asexual means. Vegetative organs such as tubers (potatoes), bulbs (onions) and corms (garlic), may also serve as food for animals and humans.



A sprouting potato (tuber)



Onion (bulb)



Garlic (corm)

Artificial methods of vegetative reproduction include cuttings of stem, tissue culture and grafting.



Rose cuttings

Advantages of Asexual Reproduction in Plants

- Only one plant is needed.
- Offspring are genetically alike. Hence if the parent plant is well adapted to the environment, so will be the new plants.
- New plants are produced relatively quickly.
- Agents of pollination and seed dispersal are not required.
- One can select a plant with desirable characteristics, e.g. producing beautiful flowers and create identical plants with that characteristic.

Disadvantages of Asexual Reproduction in Plants

- A weak parent plant will produce weak offspring since they are genetically alike.
- If there are changes to the environment, the new plants may not survive since all offspring are genetically alike, e.g. vulnerability to a particular pest, or frost.

Sexual Reproduction in Angiosperms (Flowering Plants)

Sexual reproduction occurs in most plants and animals. It involves the fusion of a sperm cell with an egg cell to form a zygote. The zygote develops into an embryo and after repeated mitosis, a new individual is formed.

Advantages of Sexual Reproduction

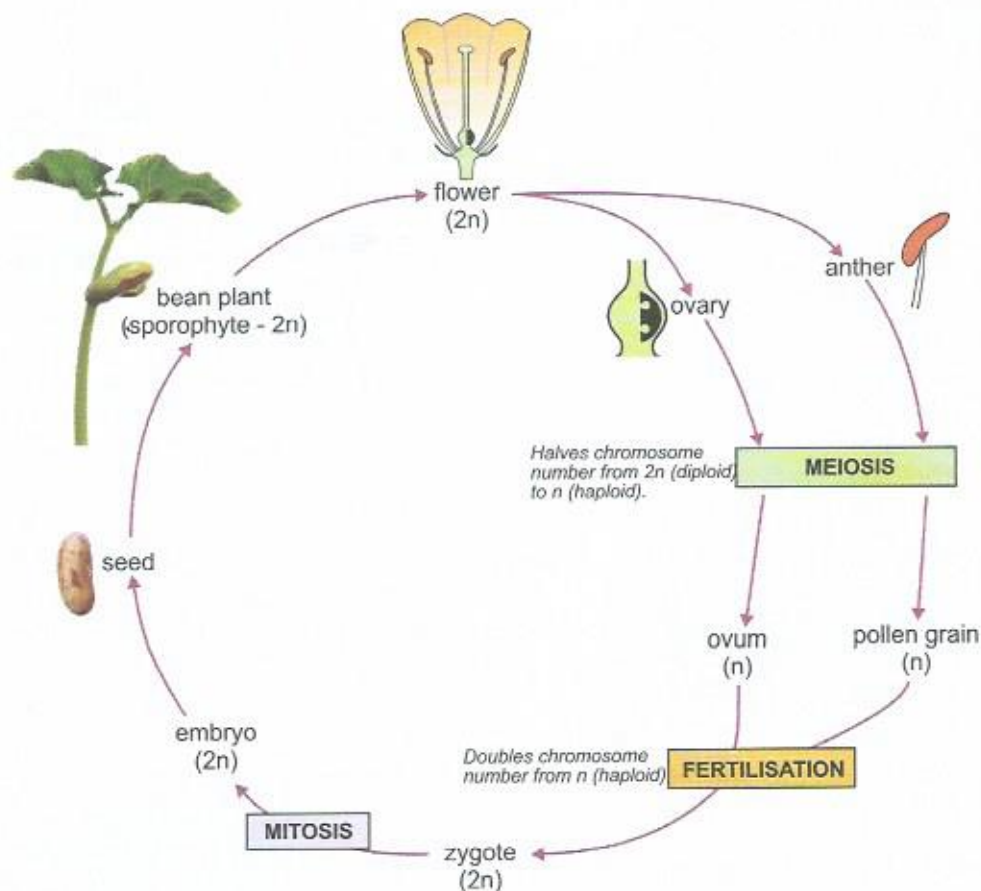
- Offspring are genetically different.
- Allows offspring to adapt to and evolve in an ever-changing environment.
- May lead to the formation of new species.

Disadvantages of Sexual Reproduction

- It is a relatively slow process.
- Adult male and female organisms are required in order to produce gametes.
- Mutations may occur.
- In plants pollen transfer and seed dispersal requires special agents like insects, birds and bats.

Life Cycle of Flowering Plants

Inside a flower, pollen, which contain male gametes, and the ovary produces ovule, each ovule containing a female gamete. Following the fertilisation of the ovum by the sperm, a zygote is formed. The zygote develops into an embryo, which is protected inside a seed. After dispersal of the seed, and when conditions are favourable, the seed germinates and a new plant grows.

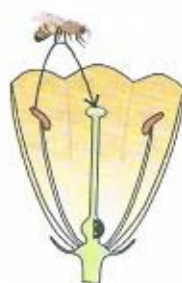


Life cycle of a flowering plant e.g. bean plant

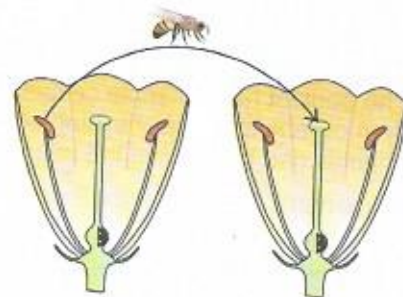
Flowers as reproductive structures

Adaptation of flowers for Pollination

Pollination refers to the transfer of pollen grains from the anther to the stigma. When this occurs within the same flower, it is known as self-pollination. When it occurs between different flowers of the same species, it is referred to as cross-pollination. Insects, birds and wind are the main agents of pollination.



Self pollination



Cross pollination

Insect-pollinated flowers (e.g. Asters, Salvia)

Flowers that are pollinated by insects have the following

- They are brightly coloured to attract insects.
- They have large petals which serve as a landing area for insects.
- They have a scent or nectar to attract insects.
- Pollen grains are sticky and become attached easily to the insects.
- Anthers are firmly attached so that they cannot be broken by visiting insects.



Salvia

Bird-pollinated flowers (e.g. Aloe, Strelitzia)

Flowers that are pollinated by birds have the following

- Flowers are long and trumpet-shaped.
- Flowers are usually red, orange or yellow.
- Flowers are not scented.
- Flowers produce nectar.



Aloe flowers

Wind-pollinated flowers (e.g. maize, grass)

Flowers that are pollinated by wind have the following features:

- They do not have brightly coloured petals.
- They do not have a scent and do not produce nectar.
- They produce large amounts of pollen which increases the chances of pollination.
- The pollen grains are light and float easily.
- Their anthers are large and hang out of the flower. This allows the pollen grains to be carried easily by the wind.
- Stigmas are large and feathery which easily trap pollen grains



Maize plant

Animal Diversity

All multicellular animals have descended from a common ancestor. They display varying levels of complexity. The earliest had a simple cellular level of organisation, while the more advanced animals developed tissues, then organs and finally systems, which enabled them to become increasingly more complex. The evolution of animals can be seen in the increasing complexity of their body parts.

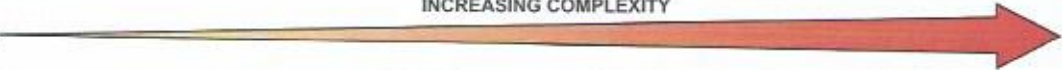
Important Features of Body Plans

1. Symmetry
2. Cephalisation
3. Embryonic tissue layers
4. Development of a coelom
5. Number of gut openings
6. Blood systems

1. Symmetry

The way in which body parts are arranged in the body plan is referred to as its symmetry. Three types of symmetry are possible.

Asymmetry	Radial symmetry	Bilateral symmetry
- No symmetry in the body shape. - No pattern to body parts; unicellular animals are irregular. - Cannot divide animal into halves that are mirror images. - Animals usually sessile (attached to substrate).	- Body parts are arranged around a central axis. - Mirror images will be seen along a number of planes if sliced longitudinally. - Radial animals have no front or back end. - Radial animals are mostly sessile.	- Body parts are arranged on either side of a central axis. - Can be cut in two mirror images in only ONE plane to give a right and a left half. - Bilateral animals are motile. - They have a front (anterior) and a back (posterior) end. - There are definite dorsal (top) and ventral (bottom) surfaces.
 <i>Amoeba - asymmetrical</i>	 <i>Starfish - radially symmetrical</i>	 <i>Human - bilaterally symmetrical</i>

INCREASING COMPLEXITY		
SIMPLE		COMPLEX
Asymmetry (Porifera) - irregularly shaped - no symmetry - simple organisms - sedentary - obtain food from water which flows through them - no need to sense environment for food	Radial Symmetry (Cnidaria) - sedentary/sessile organisms - senses stimuli from all directions	Bilateral Symmetry (higher order phyla) - body plan shows two equal halves - mobile organisms - allows for cephalisation, making detection of prey, danger etc. much easier

2. Cephalisation (*cephalos* means head)

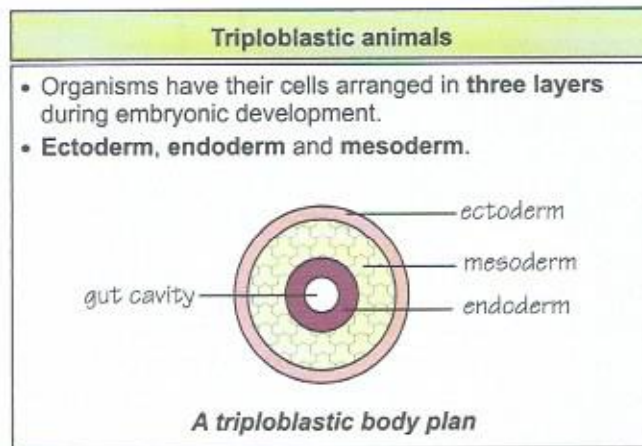
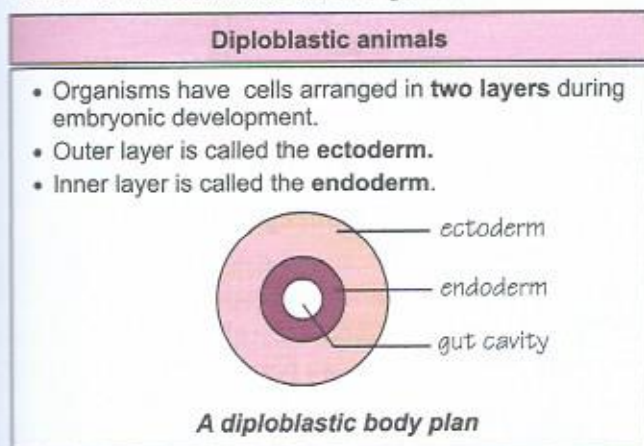
- Cephalisation is a characteristic of bilaterally symmetrical organisms.
- The head forms the anterior end in which there is a concentration of nerve cells. This concentration of nerve cells is a simple brain in primitive animals. In highly advanced animals, the mass of nerve cells in the head form a more complex brain, which receives and interprets stimuli from sensory cells.
- Sense organs are housed in the head region, which places them near the concentration of nervous tissue or 'brain'. Animals move forward with their heads entering their environment head first.
- The organism is able to detect food, danger and other stimuli and respond quickly.

3. Embryonic tissue layers

An animal's body plan is laid out during its embryological stage. An embryo develops layers of cells called germ layers. These germ layers give rise to specific tissues and organs that make up the body of a fully developed animal.

There are three living germ layers: **ectoderm** - (outer layer that forms the skin)
endoderm - (inner layer which lines the gut)
mesoderm - (middle layer that gives rise to internal organs)

More primitive animals had only two germ layers in their embryos, the ectoderm and the endoderm and are termed diploblastic. The more advanced animals have all three germ layers and thus triploblastic. The evolution of a three-layer embryo allowed an increase in complexity. Most modern animal groups have organs derived from the mesoderm. Simple animals e.g. sponges, do not form tissues and organs – they remain at the cellular level of organisation.



4. Development of a Coelom

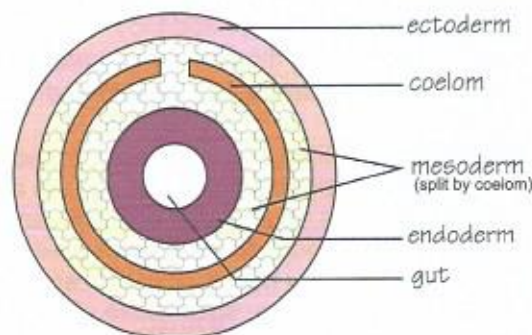
In certain triploblastic animals, a fluid filled cavity called the coelom develops in the mesoderm. The coelom separates the gut from the body wall. This allows the outer parts of the body to move independently from the inner parts of the body.

Tissues in the outer part of the mesoderm form muscle layers of the body and tissues on the inner layer of the mesoderm form muscles of the gut. Separating these two muscle layers with a coelom allows muscles of the gut, which aid digestion, to contract without affecting the rest of the body.

Triploblastic animals without a coelom are called acoelomate. They have a more or less solid mass of tissue in the mesoderm which surrounds the digestive cavity and contains the organs of the body.

A coelom provides a number of advantages:

- It allows materials to diffuse rapidly through the fluid in the coelom to body cells.
- Redistribution of body fluid can help an animal alter its body shape and aid in locomotion.
- Organs are not restricted by a mass of tissue and are able to grow larger and move more freely.
- The fluid in the coelom serves as a **hydrostatic skeleton**.



A triploblastic coelomate body plan

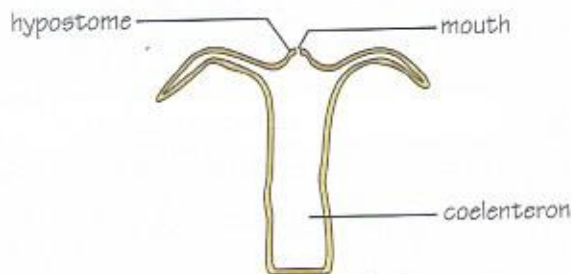


Increasing complexity from unicellular to triploblastic coelomate

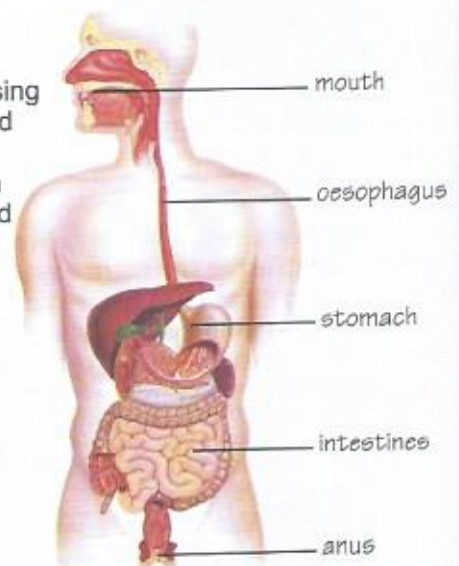
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5. Number of gut openings

More advanced animals have two body openings. The head end of a bilateral animal has an opening for taking in food (the mouth), a tubular gut, and an anus at the posterior end. This has the advantage of increasing specialisation along the digestive system – different parts are specialised for taking in food, digesting food, absorbing food and releasing wastes. Simpler animals have only one body opening. They take in food through this opening into a sac-like digestive cavity and wastes are also released through the same body opening e.g. *Hydra*. The digestive cavity or coelenteron is termed a **blind gut** or **blind-ending gut**.



The blind gut of hydra



A through gut

Disadvantages of a blind gut

- The animal cannot ingest and egest at the same time.
- The ingestion, digestion and egestion are not systematic.
- There is a mixing of digested and undigested food.
- Digested food is also expelled during egestion.

Significance of a through gut

- Allows specialisation: mouth ingests food; stomach and intestines digest food; intestines absorb food; anus egests undigested food.
- The ingestion, digestion and egestion are systematic processes.
- There is no mixing of digested and undigested food.

6. Blood systems

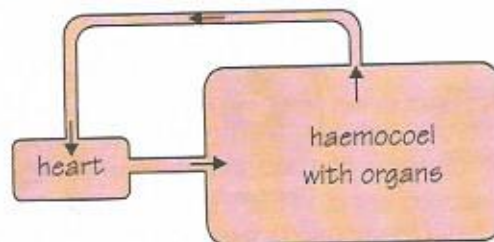
Small animals can obtain sufficient gases and nutrients through diffusion of these substances in the body. Large animals cannot move sufficient substances through their bodies quickly enough to keep them alive by simple diffusion. Special transport systems are required to carry gases, nutrients and metabolic wastes to and from body organs. Circulatory systems transport these substances in the blood of the animal.

There are two types of blood systems found in animals:

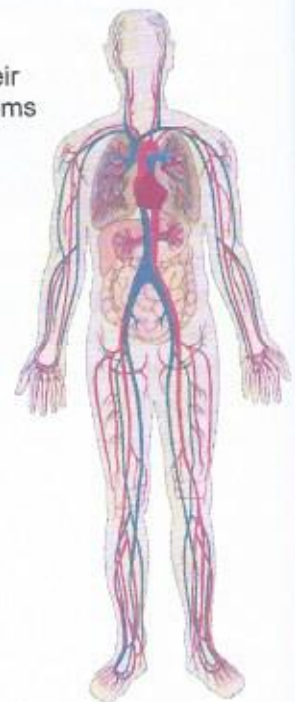
Open blood system: blood flows through blood vessels that open into a body cavity called a haemocoel. Inside the haemocoel blood comes into direct contact with the tissues of the organs and diffusion of gases and exchange of nutrients and wastes occur. Blood returns through open vessels to the heart and is kept circulating in one direction. Arthropods have an open blood system with a haemocoel.

Closed blood system: a heart acts as a pump which propels the blood through a continuous system of tubes around the body.

The blood remains in the vessels and does not come into direct contact with the cells of the tissues. Substances diffuse out of the blood vessels into the cells and vice versa. A closed blood system allows for a faster circulation of blood, be more active and allows an animal to increase in size e.g. as in all mammals.



An open blood system



A closed blood system

Animal Phyla

Animals are classified into about thirty phyla. Only the following phyla will be studied in detail:

1. Porifera – sponges.
2. Cnidaria – *hydra* and jellyfish.
3. Platyhelminthes – flatworms e.g. tapeworms.
4. Annelida – segmented worms e.g. earthworms.
5. Arthropoda – animals with jointed appendages and an exoskeleton e.g. insects, spiders and crabs.
6. Chordata – animals with a spinal cord e.g. fish, amphibians, reptiles, birds and mammals

Phylum: Porifera (Sponges)

Sponges are **asymmetrical** animals that consist of a collection of cells that are arranged in the shape of a vase. The cells are not differentiated into tissues and no coelom is present. They have a hole at the top to let out water that is sucked in through pores in the body wall.

Features of Porifera

- No tissues or organs are present.
- Adults are sessile – attached to a surface e.g. rock.
- Larvae are motile and swim around for a while before settling and maturing.
- They filter bacteria out of the water for nutrition.
- No coelom is present.
- They are vase shaped and have a water-filled internal cavity called the spongocoel.
- One body opening exists at the top called the osculum.
- Pores are found in the sides which draw in water and food. Water is circulated in the cavity by the action of flagella and then ejected through the osculum.
- The body wall has two layers of cells. Each layer of cells is not regarded as a tissue. A jelly-like substance is found between the two layers.

Sponges are commercially harvested and sold for use in bathing and as cleaning products.



Sea sponges

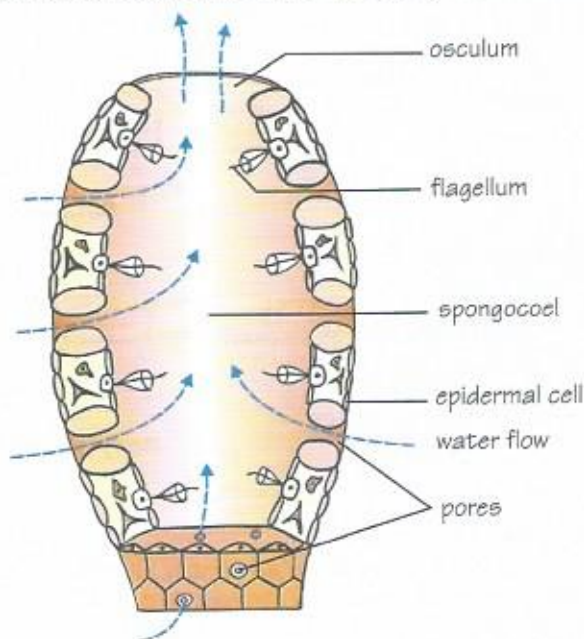


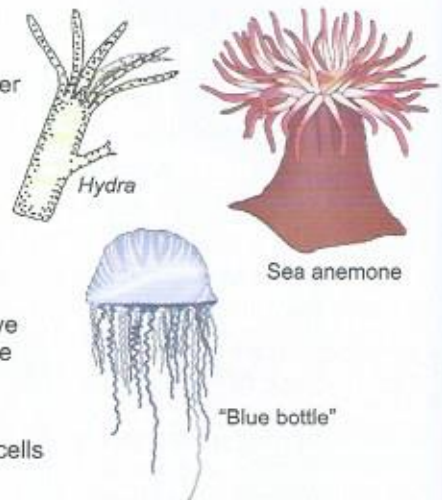
Diagram showing the structure of a sponge

Phylum: Cnidaria

(hydra, sea anemone, jellyfish and coral)

Features of Cnidaria

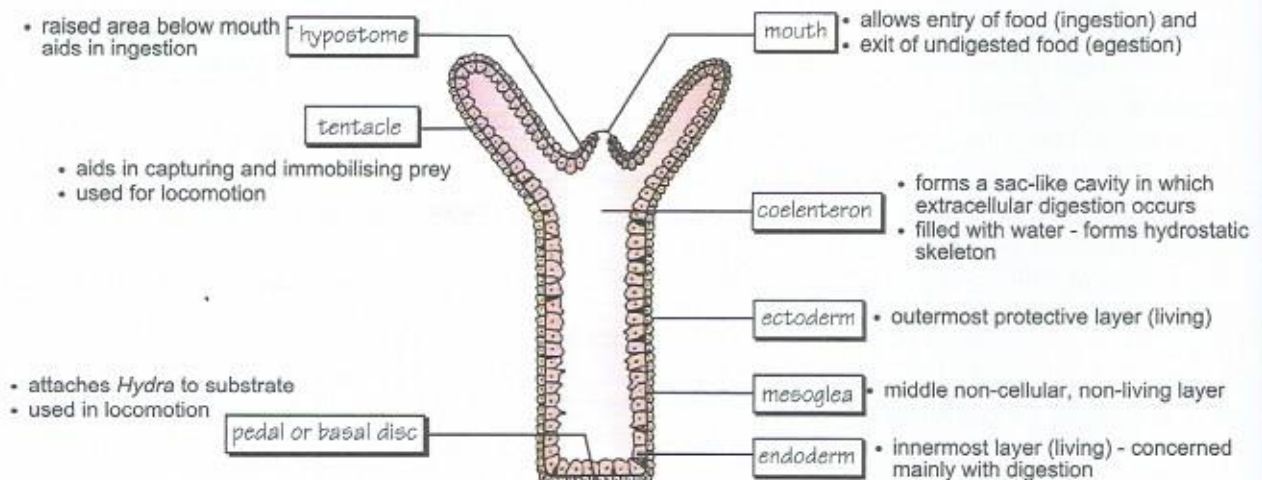
- Radially symmetrical; has a circular nerve net so it can sense food or danger equally well from all sides.
- All are aquatic - most live in the oceans and some are freshwater.
- Simple body plan with tentacles and stinging cells (nematocysts).
- One body opening - mouth, surrounded by the tentacles.
- Body wall surrounds sac-like body cavity.
- No blood system is present; simple diffusion allows for gaseous exchange.
- No coelom is present.
- Have a more complex body plan than sponges; e.g. nerve cells form a nerve network through the body wall which allows it to detect stimuli and move the body or body parts towards or away from the stimulus.
- Are diploblastic with a jelly-like matrix between the ecto- and endoderm:
 - Ectoderm - outer layer with specialised protective cells such as stinging cells with poison that can paralyse prey.
 - Endoderm - inner layer with modified cells for digestion.



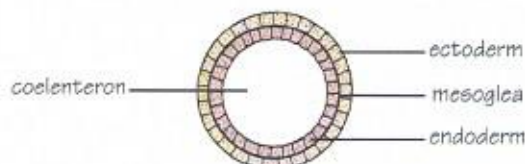
Example of cnidarians

Example of a Cnidarian - Hydra

Hydra lives in fresh water. It occurs in ponds and slow-flowing streams. It is a small animal that is attached to the substrate by the **pedal (or basal) disc**. It is cylindrical in shape and **radially symmetrical**. The mouth, which is the only opening into the digestive cavity, is situated on the **hypostome** (raised cone-shaped structure). The **tentacles** (6 to 8 in number) are attached in a ring at the base of the hypostome.



Structure of Hydra (l/s)



Body plan of cnidarians (T/S)

Radial Symmetry

a) Advantages

Since sensory cells are distributed equally all around the body, the animal can react to a stimulus, e.g. food or danger (predator), from any direction. A radially symmetrical animal can move in any direction. Radial symmetry thus suits a sessile organism like the *Hydra*.

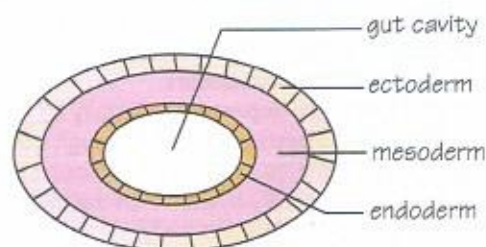
b) Disadvantages

A disadvantage of radial symmetry is that no head or anterior end exists and therefore no cephalisation can develop. The nerve network does not form a 'brain' and movement will not be directed - movement is random. No specialised sensory organs exist.

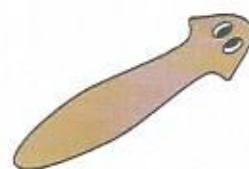
Phylum: Platyhelminthes (Flat worms: tapeworm, planarian, liver fluke)

Features of Platyhelminthes

- Bilaterally symmetrical.
- Bodies are flat and soft.
- Most are aquatic or living in damp places, e.g. Planaria which live in fresh water.
- Some are parasites and live in the bodies of other animals e.g. flukes and tapeworms.
- Triploblastic: ecto-, endo-, and mesoderm layers in the body wall
- No coelom is present and this limits the size of the animal.
- No blood system is present. Gases diffuse into or out of the body from the environment.
- Body is dorsoventrally flattened and this facilitates diffusion of gases and nutrients as all body cells are close to the gut or the environment.
- Mesoderm separates the ectoderm and endoderm. It gives rise to organs such as muscles and reproductive organs.
- Cephalisation is simple with a 'head' (front) end that has a cluster of nerve cells forming a ganglion and light detecting eyespots.
- They have a single body opening and a branched gut. The mouth takes in food and lets out waste.
- Flatworms are typically hermaphrodites (bisexual).



Generalised body plan of Platyhelminthes



Drawing of a planarian

Example: The tapeworm (*Taenia solium*)

Habitat

Taenia solium is an endoparasite (living inside its host). This tapeworm has two hosts in its life cycle. The primary host is **man** (small intestine) and the intermediate host is the **pig** (liver and especially the muscles).

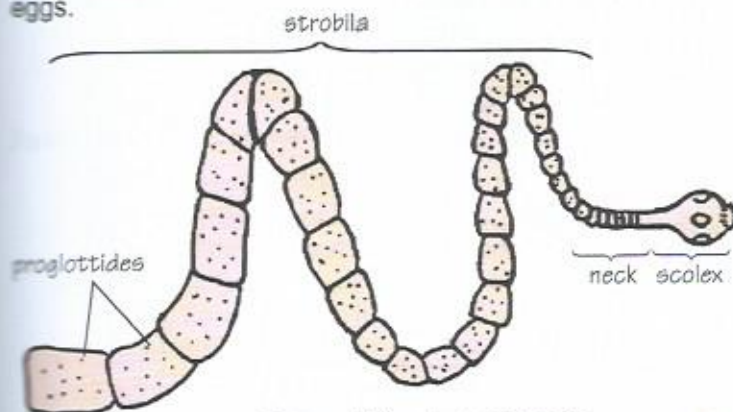
Structure

Taenia is a long, flat, ribbon-like animal. It can reach a length of 5 metres. The body is covered by a tough **cuticle** which protects it from the digestive enzymes of its host. The body has a head (**scolex**), a **neck** and **strobila** (composed of segmented divisions or **proglottides**). It is bilaterally symmetrical.

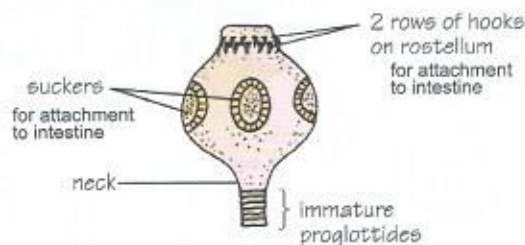
The scolex has 4 **suckers** and a **rostellum** with 2 rows of hooks for attachment to the intestinal wall.

The neck is narrow and new proglottides are produced here. The strobila is the longest part of the animal.

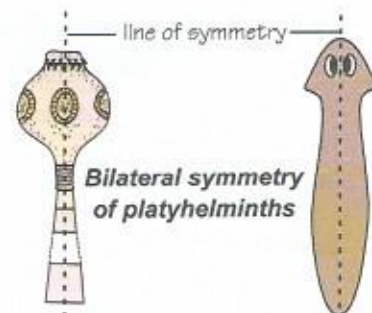
Young proglottides are found near the neck, mature proglottides towards the middle and gravid proglottides are at the end. The **gravid proglottides**, which leave the human host via the anus, are filled with fertilised eggs.



External Structure of *Taenia*



Scolex and neck of *Taenia*



Bilateral symmetry of platyhelminths

Some advancements that Platyhelminths show over Cnidarians

Platyhelminth

- triploblastic (three-layered)
- bilaterally symmetrical
- cephalisation evident

Cnidarian

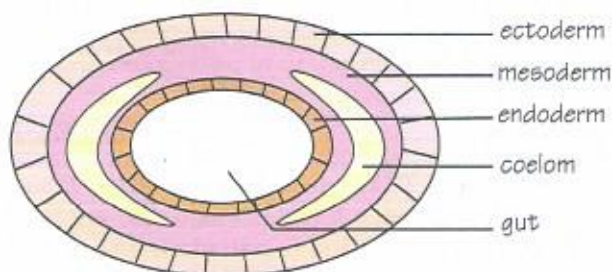
- diploblastic (two-layered)
- radially symmetrical
- no cephalisation

Phylum: Annelida

(Segmented worms: earthworm, fanworm, leech)

Features of Annelids

- Bilaterally symmetrical.
- Round segmented bodies.
- Segments are separated internally by membranes and they compartmentalise body organs.
- Complete digestive system (through-gut) with a mouth at one end and an anus at the rear end.
- The gut is a tube that extends through the body with specialised regions that process the food efficiently.
- Closed circulatory system with a simple heart and continuous blood vessels that circulate nutrients, metabolic wastes and gases through the body.
- Cephalisation is well developed with a collection of sensory organs at the front. A simple 'brain' is formed from a collection of nerve cells
- The body is triploblastic – an ectoderm, mesoderm and endoderm are present.
- A coelom divides the mesoderm and contains coelomic fluid which provides a hydrostatic skeleton for the body.
- Separation of gut and body muscles allow them to work independently.



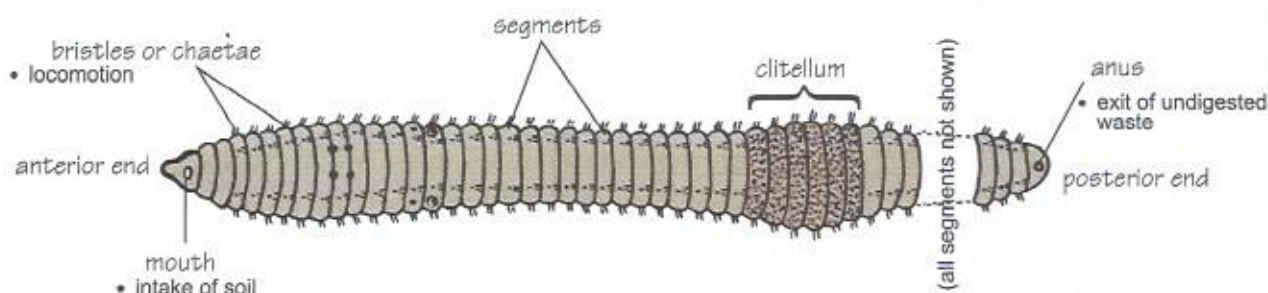
T/S Body plan of triploblastic coelomate animals



An earthworm

Habitat

Earthworms live in moist soil that is rich in organic material. They eat their way through the damp soil, creating burrows. They are nocturnal (active at night) so as to avoid the drying effect of the air and ultraviolet rays of the sun.



Ventral view of an earthworm

Some advancements that Annelids show over Platyhelminths

Annelids

- has a coelom with coelomic fluid
- has a through gut
- gas exchange surface is moist skin
- blood system present
- greater degree of cephalisation
- hydrostatic skeleton present

Platyhelminthes

- no coelom (acoelomate)
- one body opening; branched gut
- no special surface; simple diffusion through ectoderm
- no blood system; simple diffusion
- lesser degree of cephalisation
- no skeleton present

Phylum: Arthropoda (Animals with jointed appendages)

Arthropods are a large and successful group with more than a million living species. They are invertebrates (have no backbone) and have **jointed appendages** and an exoskeleton. Arthropods have adapted to every type of habitat, on land and in water.

The four main classes of arthropods are: .

Class: Insecta

It is the largest class in this phylum. In addition to having jointed appendages and an exoskeleton, they have three body divisions (head, thorax and abdomen) and three pairs of legs. Examples - locusts, flies, bees.



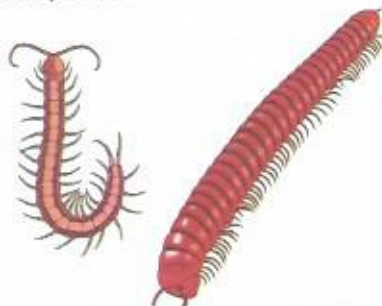
Class: Arachnida

Two body divisions: cephalothorax and abdomen, and 4 pairs of legs.
Examples: spiders, scorpions, ticks.



Class: Myriapoda

Have many legs.
Examples: centipedes and millipedes.



Class: Crustacea

Have 5 pairs of legs.
Examples: crabs, crayfish, prawns.



Features of Arthropods

- Bilaterally symmetrical.
- Well advanced cephalisation. Many sense organs and a 'brain' exist. The sense organs include simple and/or compound eyes and antennae on the head that detect touch, odour and vibrations.
- The bodies are covered with a hard exoskeleton made of chitin. This restricts the size of arthropods and they have to moult in order to grow.
- Their bodies are segmented and specialised paired appendages appear on the segments.
- All arthropods are triploblastic.
- They have a coelom in which the excretory system and reproductive organs are housed.
- They have an open blood system with a haemocoel – gases are transported to and from their respiratory surfaces and nutrients from the digestive system diffuse into the haemocoel, from where they are circulated to the rest of the body.
- A through gut with differentiated sections extends the length of the body. Specialised mouthparts are found around the opening of the mouth.
- The body plans of most arthropods change during their lifecycle and they undergo metamorphosis.

Role of invertebrates in agriculture and ecosystems

Pollinating agents

Invertebrates such as insects play a vital role in plant reproduction. As they move from one flower to another, feeding on nectar and pollen, they act as pollinating agents. Many crops such as most fruits and vegetables that humans consume, are dependent on insects for pollination.

Decomposers

Decomposition results in the minerals and nutrients from dead organisms being released and becoming available to the environment. Invertebrates such as earthworms and insects play a vital role in the recycling of nutrients.

Aerators of the soil

Burrowing invertebrates such as worms and insects create tunnels and spaces in the soil that are filled with air. Well aerated soil allows more oxygen to be available for the roots of plants and for the animals living in the soil. It enables water to drain through the soil more efficiently. Invertebrates improve the quality of the soil, which in turn allows healthy plants to survive and grow.

Pest and diseases

Many invertebrates act as vectors of pathogens, spreading diseases like malaria (mosquitoes) and sleeping sickness (tsetse flies). Aphids, grasshoppers and caterpillars cause damage to crops.

Biological control

Some invertebrates can be used as predators of pests, thereby controlling pest populations. Ladybird beetles attack aphids; wasps attack caterpillars of moths and butterflies and dragon flies eat the larvae of mosquitoes.

Many other invertebrates also have ecological and agricultural importance, such as bees, which make honey, and insects which are used as biological control agents to prevent pest species from destroying crops and eradicating alien plant and animal species.

Phylum: Chordata

(Animals with backbones)

Chordates are a very diverse group in terms of body plan and size. They are very successful and occupy all environments. The majority of chordates are vertebrates, i.e. they have a vertebral column or backbone.

Features of Chordates

- Bilaterally symmetrical.
- Highly developed cephalisation – a large brain in the head region. The brain is protected by the skull.
- Sensory organs are concentrated in the head region.
- A central nervous system co-ordinates the whole body.
- Triploblastic.
- A highly specialised through-gut exists, with a mouth at one end and an anus at the other.
- The processing of food is highly efficient.
- There is a well-developed coelom.
- A closed blood system with a heart and a continuous system of blood vessels conveys substances around the body.

The classes of chordates (with their body covering in brackets) are shown below:



Class: Osteichthyes
(slimy scales)



Class: Aves
(feathers)



Class: Amphibia
(moist skin)



Class: Mammalia
(fur or hair)

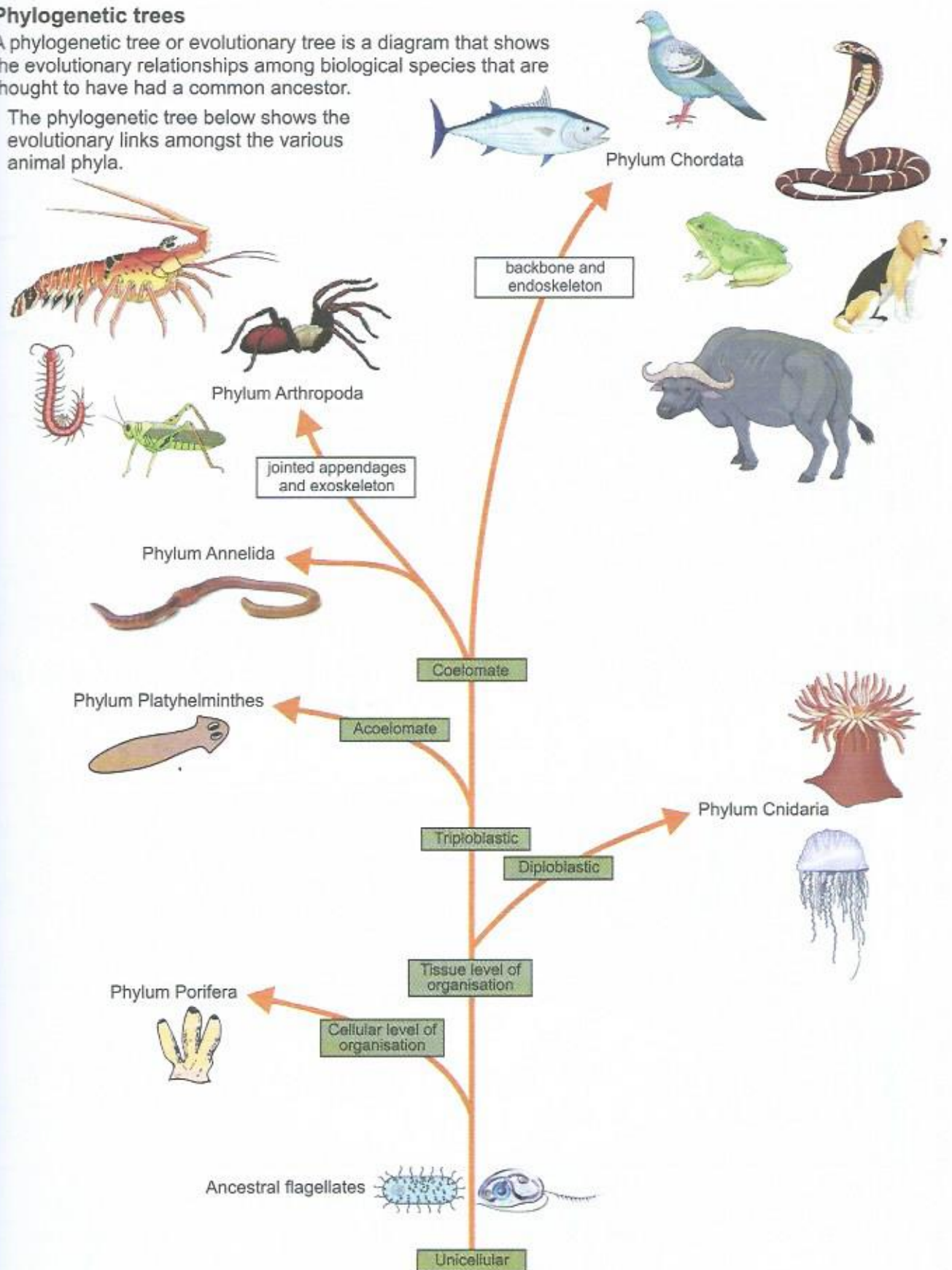


Class: Reptilia
(dry scales)

Phylogenetic trees

A phylogenetic tree or evolutionary tree is a diagram that shows the evolutionary relationships among biological species that are thought to have had a common ancestor.

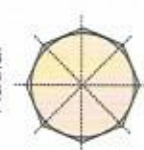
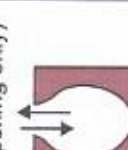
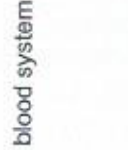
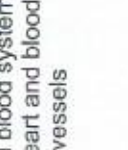
The phylogenetic tree below shows the evolutionary links amongst the various animal phyla.



A phylogenetic tree for the animal kingdom

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Summary of the biodiversity of animals with respect to body plans

Phylum	Symmetry	Cephalisation	Embryonic layers	Coelom	Gut openings	Blood system
1. Porifera 	Asymmetrical 	No Cephalisation 	Cellular level of organisation 	Acoelomate (no body cavity) 	No Gut 	No Blood System 
2. Cnidaria 	Radial 	No Cephalisation 	Diploblastic (ectoderm + endoderm) 	Acoelomate (no body cavity) 	Blind Gut (one opening only) 	No Blood System 
3. Platyhelminthes 	Bilateral 	Cephalised 	Triploblastic (ecto-, meso- & endoderm) 	Acoelomate (no body cavity) 	Blind Gut (one opening only) 	No Blood System 
4. Annelida 	Bilateral 	Cephalised 	Triploblastic (ecto-, meso- & endoderm) 	Coelomate (has a true body cavity) 	Through-gut (mouth and anus) 	Closed blood system with pseudohearts and blood vessels 
5. Arthropoda 	Bilateral 	Cephalised 	Triploblastic (ecto-, meso- & endoderm) 	Coelomate (has a true body cavity) 	Through-gut (mouth and anus) 	Open blood system 
6. Chordata 	Bilateral 	Cephalised 	Triploblastic (ecto-, meso- & endoderm) 	Coelomate (has a true body cavity) 	Through-gut (mouth and anus) 	Closed blood system with heart and blood vessels 

2 Life Processes in Plants & Animals

A: Photosynthesis

Introduction

Almost all life on earth is directly or indirectly dependent on the process of **photosynthesis** which occurs in green plants. Photosynthesis is a complex chemical process that converts radiant (light) energy into chemical potential energy (carbohydrates). Plants are **autotrophic** organisms since they manufacture their own food and are therefore the producers in any ecosystem.

Photosynthesis occurs within the chloroplasts of plant cells. During the process, water and carbon dioxide are required, glucose is made and oxygen is given off. This section outlines briefly this important process.

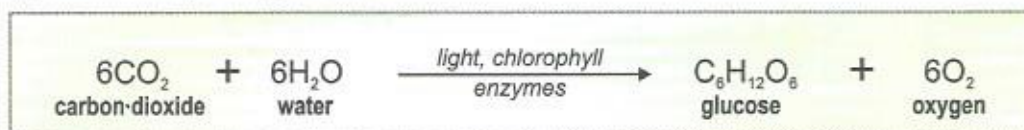
Requirements
• carbon dioxide: from atmosphere • water: absorbed by roots and delivered via xylem • chlorophyll (present in chloroplasts) • energy (sunlight) • enzymes

Products
• glucose: high-energy; soluble; converted to insoluble starch and stored • oxygen: released into atmosphere via stomatal pores

Definition:

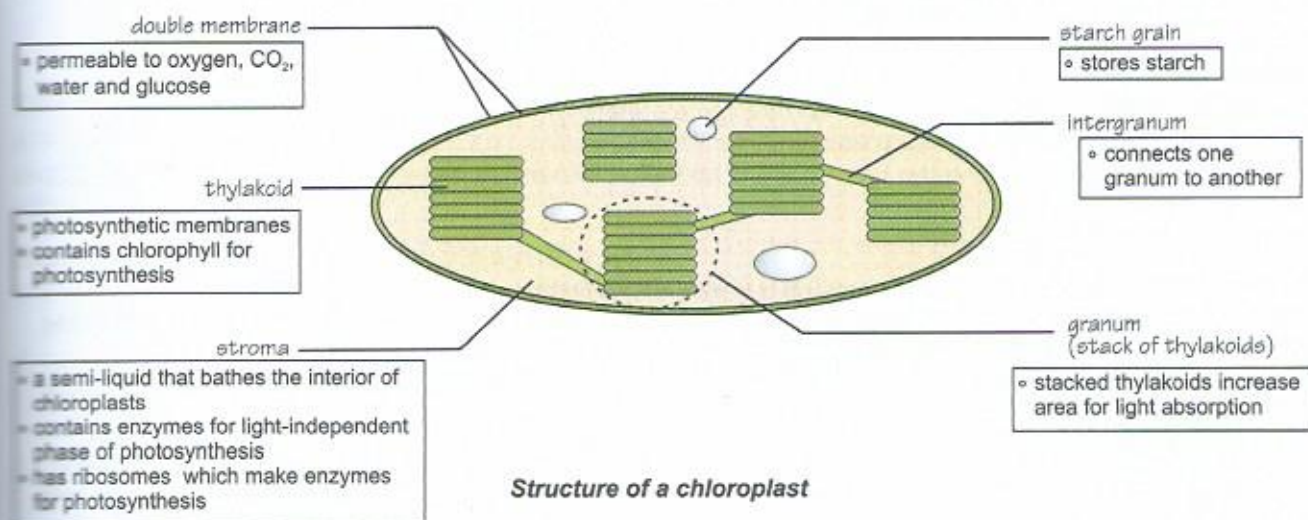
Photosynthesis is a process whereby carbon dioxide and water are combined, in the presence of chlorophyll and light energy, to form energy-rich carbohydrates. During the process oxygen is released.

The summary reaction for photosynthesis is:

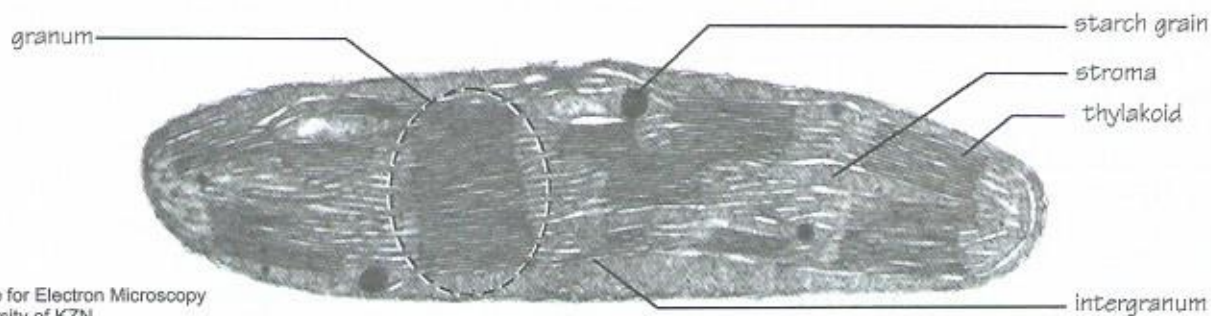


The process of photosynthesis

Photosynthesis takes place in the chloroplasts of cells. The process may be divided into two phases: the **Light-dependent Phase** (Light Phase) in which light energy is essential; and the **Light-independent Phase** (Dark Phase) where light is not required. Light dependent reactions occur on photosynthetic membranes.



Structure of a chloroplast



Centre for Electron Microscopy
University of KZN

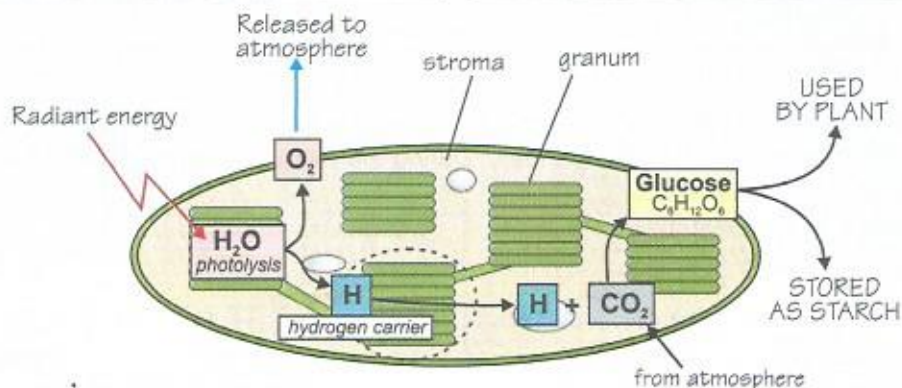
An electron micrograph of a chloroplast

Light Phase (Light-dependent) - in grana

The Light-dependent Phase occurs in the grana of the chloroplast. The chlorophyll molecules absorb radiant energy. Some of this energy is used to split water, obtained from the soil, into hydrogen and oxygen. This process is known as photolysis. The oxygen is released into the atmosphere via the stomatal pores. The energized hydrogen is taken up by a carrier and used in the next phase.

Dark Phase (Light-independent) - in stroma

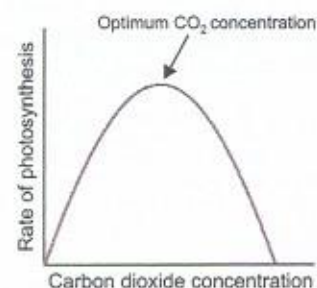
This phase occurs in the stroma of the chloroplast. It occurs immediately after the light phase. Carbon dioxide from the atmosphere enters the leaf through the stomatal pores. In the stroma of the chloroplast, the carbon and oxygen of carbon dioxide, combines with the energized hydrogen which was released in the light phase to form glucose. The energy required for this phase comes from the light phase.



Factors affecting the rate of photosynthesis

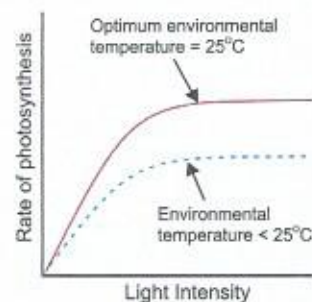
Carbon dioxide concentration

Carbon dioxide is essential for photosynthesis. When CO_2 concentration is low, the rate of photosynthesis is low. As the CO_2 concentration increases there is a corresponding increase in the rate of photosynthesis. Very high CO_2 levels in the plant cause the rate of photosynthesis to drop. This happens because the excess CO_2 combines with H_2O to form carbonic acid. The acidic conditions damage the enzymes that control photosynthesis, causing a drop in the rate of photosynthesis.



Light intensity

At low light intensity, the rate of photosynthesis is low. As the light intensity increases the rate of photosynthesis also increases up to the optimum for a particular environmental temperature. Any increase in light intensity beyond the optimum light intensity does not result in an increase in the rate of photosynthesis.

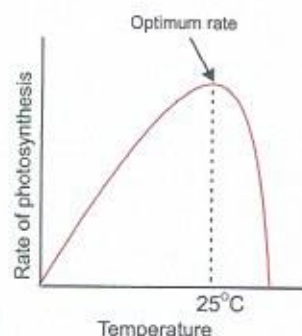


Temperature

Photosynthesis can take place in mesophytic plants between 10°C and 35°C , the optimum being 25°C . As the temperature increases, the rate of photosynthesis also increases, until an optimum temperature of 25°C is reached.

Increasing temperatures above 25°C , cause the rate of photosynthesis to rapidly decline, to the point at which photosynthesis can no longer take place. This is because, when exposed to very high temperatures, the enzymes involved in photosynthesis become denatured (lose their shape) and are rendered useless.

At low temperatures photosynthetic enzymes become inactive and the energy available for the reaction is reduced.



Greenhouse Systems

A greenhouse is a structure built specially for the growing of plants in a controlled environment. The greenhouse allows sunlight to get to the plants in order for photosynthesis to take place; while preventing pests, birds and other animals from getting to the plants. The amount of water and nutrients that the plants receive are controlled.

Other environmental conditions that may be controlled in a greenhouse are the carbon dioxide levels, light and temperature. These three environmental conditions play a significant role in determining the rate at which the plants photosynthesise.



Inside a typical greenhouse

Role of CO_2 enrichment, optimum light and optimum temperature in greenhouse systems

1. Carbon dioxide enrichment

By enriching the CO_2 concentration within the greenhouse, plants will increase the rate at which photosynthesis occurs. This will result in an increase in plant growth and crop yield.

2. Optimum light

The amount of light in a greenhouse can be adjusted so that the plants receive the optimum light to maximise the rate at which photosynthesis occurs. Artificial lighting may be used to enhance the light conditions, while shade cloths are used to reduce the amount of light that gets to the plants.

3. Optimum temperature

The temperature within the greenhouse is kept at the optimum temperature for maximum plant growth. On cold days, heaters are used, while on hot days, fans are used. In this way, the plants in the greenhouse grow in an ideal temperature to improve crop yield.

Role of ATP in the cell

ATP is the high-energy carrier in plant and animal cells. When ATP breaks down, energy is released and is used by the cell for all metabolic work. Some ATP is formed in the cytosol, while most of the ATP is formed within the mitochondria.

Biological importance of photosynthesis

1. Energy-rich carbohydrates are formed during photosynthesis. These compounds form the basic source of energy for almost all organisms.
2. Large volumes of carbon dioxide are released into the atmosphere as a result of cellular respiration, decomposition and the burning of fossil fuels. During photosynthesis, carbon dioxide is utilised, thereby maintaining the atmospheric carbon dioxide levels at a relatively constant level.
3. Oxygen is released as a by-product of photosynthesis. This replenishes the oxygen in the atmosphere that is used by organisms during cellular respiration.

Practical Work: Photosynthesis

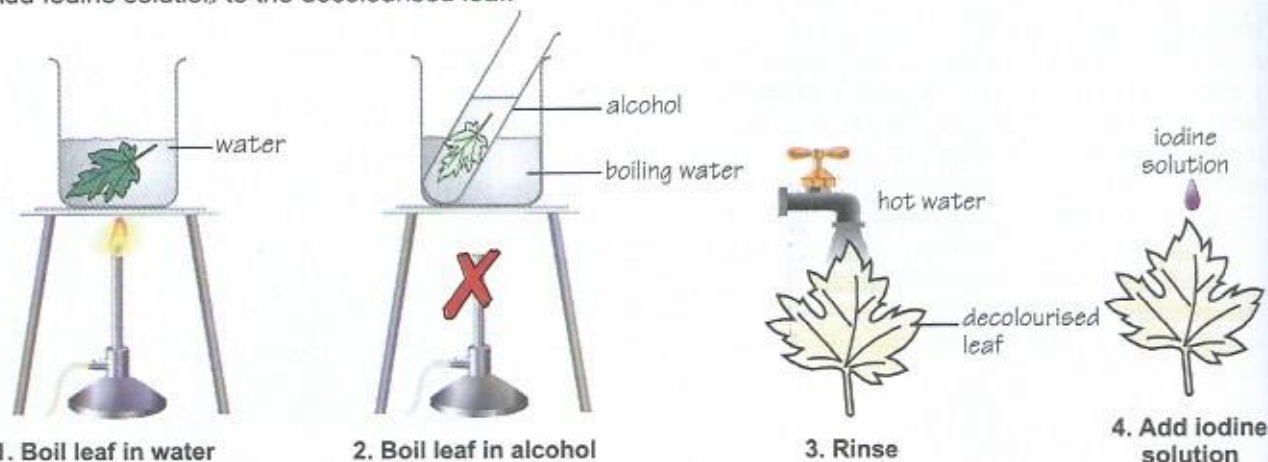
Experiment 1

Aim: To test a green leaf for starch

The starch test is important to remember, as it will be repeated in later experiments in this chapter.

Method:

1. Boil the leaf in water to stop all functions and soften the tissues.
2. Boil the leaf in alcohol (with care!) to remove the chlorophyll. Chlorophyll dissolves in alcohol and is therefore extracted.
3. The leaf is then rinsed in hot water to soften it.
4. Add iodine solution to the decolourised leaf.



Precaution

Alcohol is highly inflammable! Ensure that the burner is off when boiling the leaf in alcohol. Alcohol boils at 78°C . Its vapour catches alight very easily.

Results and Conclusion

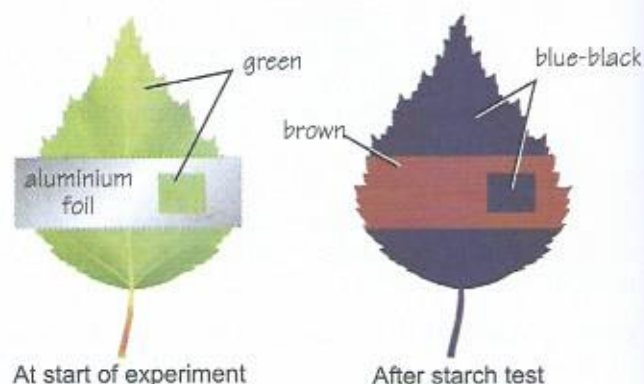
When iodine solution is added the leaf turns black (blue-black). This colour change proves that the leaf contains starch, since starch turns black (blue-black) in the presence of iodine.

Experiment 2

Aim: To determine whether light is essential for photosynthesis.

Method:

1. A plant is first destarched by placing it in a dark cupboard for 48 hours.
2. A pattern is cut out of aluminium foil and placed over the leaf of a plant.
3. The foil is wrapped around the leaf such that light strikes the leaf surface in the cut-out portion and no light is allowed to enter under the foil.
4. The plant, with treated leaf, is then placed in an area with adequate sunlight for 3 to 4 hours.
5. The starch test is then performed on the leaf.



Results and Conclusion

The area of the leaf that was exposed to sunlight had been photosynthesising, since it turned blue-black when subjected to the starch test, thus tested positive for starch. The area of the leaf that was not exposed to sunlight (covered in aluminium foil) had not been photosynthesising, since it turned brown when subjected to the iodine test, thus proved negative for starch.

Since only the area of the leaf that was exposed to sunlight tested positive for starch, it can be concluded that light is essential for the process of photosynthesis.

Experiment 3 (Demonstration)

Aim: To determine whether chlorophyll is essential for photosynthesis.

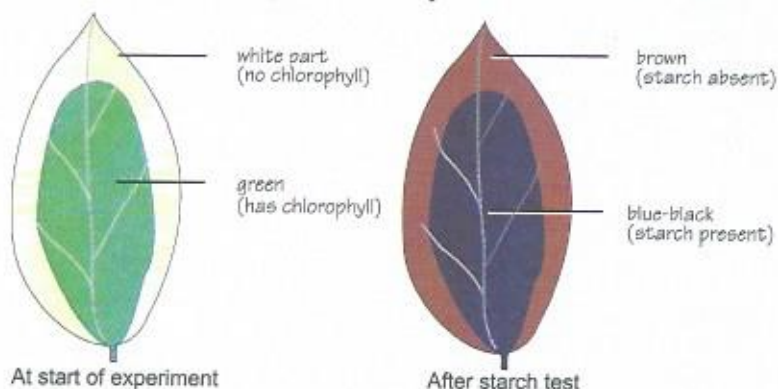
A plant with variegated leaves is chosen for this experiment. The non-green portions do not contain chlorophyll. However, the plant is first destarched so that any stored starch in the non-green areas is consumed.

The plant is left in sunlight for a few hours.

A drawing of a variegated leaf is made with the green (chlorophyll) areas clearly marked. The leaf is then subjected to the starch test.

Results and Conclusion

Since only the areas that contained chlorophyll tested positive for starch, we can conclude that chlorophyll is essential for photosynthesis.

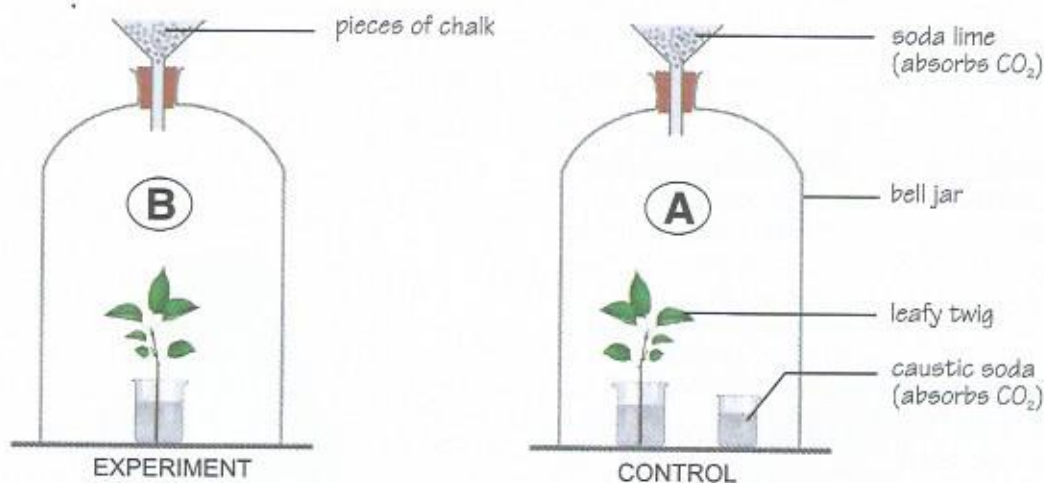


Experiment 4 (Demonstration)

Aim: To determine whether carbon dioxide is essential for photosynthesis.

Method:

1. Destarched plants are set up as in the diagram below and left in sunlight.
2. Chemicals such as soda lime or caustic soda are used to ensure that carbon dioxide is removed from the bell jar (Experiment A).
3. The bell jars are sealed with vaseline to prevent the entry of carbon dioxide.
4. A leaf from each plant is tested for starch after 24 hours.



Results and Conclusion

The leaf from bell jar A, which did not have access to CO₂, had not been photosynthesising, since it tested negative for starch. The leaf from bell jar B, which did have access to CO₂, had been photosynthesising, since it tested positive for starch.

Since the leaf from bell jar B contained starch and the leaf from bell jar A did not, it can be concluded that CO₂ is essential for photosynthesis.

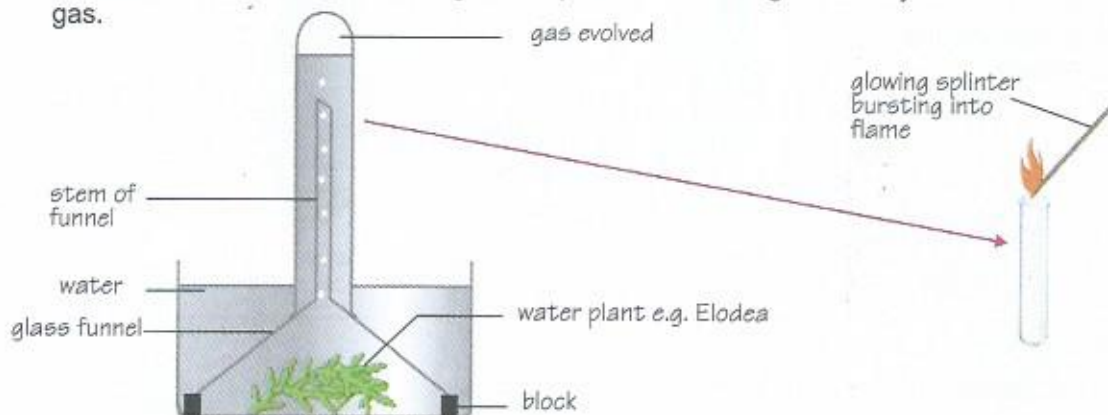
Experiment 5a (Demonstration)

Aim: To determine whether oxygen is released during photosynthesis.

Method

The apparatus is designed in such a way that any gas evolved by the plant can easily be trapped and tested. Aquatic plants serve this purpose since they continuously respire in water.

1. An aquatic plant (e.g. *Elodea*) is placed under an inverted glass funnel and then placed in a trough of water.
2. A test tube is filled with water and placed over the stem of the funnel to collect the rising gas bubbles.
3. The glass funnel is placed on coins or blocks so that water can move out of the funnel as the gas evolves.
4. The apparatus is left to stand in light for a period of time. Light intensity will increase the production of gas.



Results

Bubbles of gas were given off by the plant and were trapped at the top of the inverted test tube.

A glowing splinter is ignited spontaneously when it is held at the mouth of the test tube.

Conclusion

Since oxygen supports combustion, the gas evolved must be oxygen, proving that oxygen is liberated during photosynthesis.

Experiment 5b (Alternative Experiment) (Demonstration)

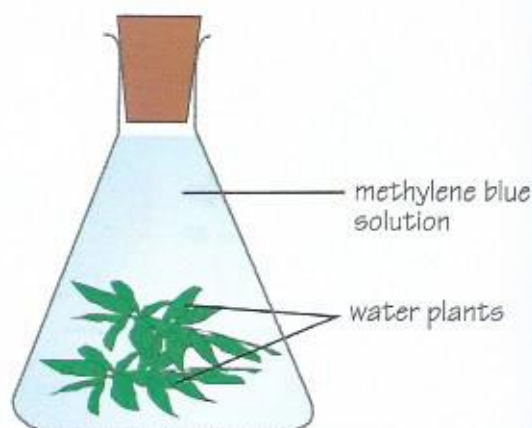
Aim: To determine whether oxygen is released during photosynthesis.

Method:

The experiment involves the use of the indicator, methylene blue, which is colourless in the absence of oxygen, but turns blue when oxygen is present.

A solution of methylene blue (initially colourless) is prepared and placed in a conical flask. A few sprigs of water plant (e.g. *Elodea*) are placed in the flask and sealed. The apparatus is then placed in bright sunlight to increase the rate of photosynthesis.

A control is set up in the same way except the water plants are removed.



Results and Conclusion

The once clear methylene blue solution became blue indicating that oxygen entered the water.

Since oxygen could have only been produced by the living plant, it can be concluded that oxygen is released during photosynthesis.

B: Animal Nutrition

Balanced Diet

A balanced diet is one that has the correct proportions of carbohydrates, proteins, fats, vitamins, minerals and fibre (roughage). The daily energy requirement of an individual changes according to the age, sex and the activity of a person. This is shown in the table below:

Person	Energy requirements per day (kJ)
8 year old	7 500
16 year old girl	9 000
16 year old boy	12 000
Woman doing light work	9 000
Woman doing strenuous work	10 500
Pregnant woman	9 800
Man doing light work	11 800
Man doing strenuous work	14 000

From the table above, it can be seen that if one eats more than what the body requires, then one will become obese (fat). Obesity often leads to heart disease, strokes and diabetes.

Nutrition - Processes

- Ingestion:** the taking in of food through the mouth.
- Digestion:** the breakdown of food, mechanically by the action of the teeth, or chemically by the action of enzymes and stomach acid. Food needs to be digested before it can be absorbed into the blood.
- Absorption and transport:** movement of digested food from the lumen (gut) into the blood vessels that surround the gut. Absorption of nutrients obtained from food is an active process, since energy is required for the process to take place. Blood transports nutrients throughout the body.
- Assimilation:** a process which occurs in the body cells, where nutrients are broken down to yield energy during cellular respiration.
- Egestion:** removal of undigested food from the alimentary canal.

Nutrition and dentition in animals

Herbivores	Carnivores	Omnivores
 Animals that only eat plant material are known as herbivores. For example, the cow's teeth consist of: • Wide sharp incisors for cutting of grass. • Molars that are used for grinding. • No canines The grass is digested in a rumen (part of alimentary canal of herbivores), with the aid of bacteria.	 Animals that only eat other animals are known as carnivores e.g. a lion. Carnivores have powerful jaws with sharp canine teeth. They have: • incisors • canines • premolars and • molars. The digestion of proteins occurs mainly within the stomach.	 Animals that eat both plants and animals are known as omnivores. E.g. humans, pigs, bears. Omnivores have: • incisors • canines • premolars and • molars Chemical digestion starts in the mouth and continues in the stomach and small intestine.

Human Nutrition

Food contains many nutrients for the body's supply of energy, as well as the building, growth and repair of tissues. Food in the form in which it is taken in cannot be utilised immediately. It must be broken down into molecules, so that it can be used in the many chemical reactions that occur within the body.

We now look at the step-wise breakdown of food, its entry into the cell and its utilisation by the body.

The importance of food

- Food is a source of energy, with carbohydrates and lipids (fats) being the main source.
- It provides proteins and minerals for the growth and repair of tissues.
- Food contains regulating substances such as minerals, water and vitamins, which assist in controlling various body functions.

Digestion

Digestion may be defined as the step-wise breakdown of large food particles into molecules, small enough to enter the body's cells.

Overview of the mechanism of nutrition

- Ingestion:** Taking in of food into the mouth (eating).
- Secretion:** Cells within the walls of the alimentary canal and accessory organs, secrete water, enzymes, and acids and alkalis.
- Mixing and Propulsion:** Alternating contraction and relaxation of the smooth muscle in the walls of the alimentary canal, mix food and secretions and push them along.
- Digestion:** The mechanical and chemical processes involved, which mix secreted fluids with ingested food and break down larger food particles into smaller particles and molecules.

Mechanical digestion involves the physical breakdown of food by teeth, the swallowing of food and the action of smooth muscles of the stomach and intestine that churn food so that it is mixed with enzymes. *Chemical digestion* involves a series of catabolic reactions where enzymes and chemicals break down carbohydrates, lipids and proteins into smaller molecules.

- Absorption:** The entry of the products of digestion into the epithelial cells lining the lumen of the small and large intestine and thereafter passing into the blood and lymph. Most drugs, as well as alcohol, are absorbed in the stomach.
- Defaecation (egestion):** The elimination of undigested food and waste material from the large intestine through the anus.

Structure of the digestive system (Refer diagram on the next page)

The digestive system of man consists of the **alimentary canal** and its **associated organs**.

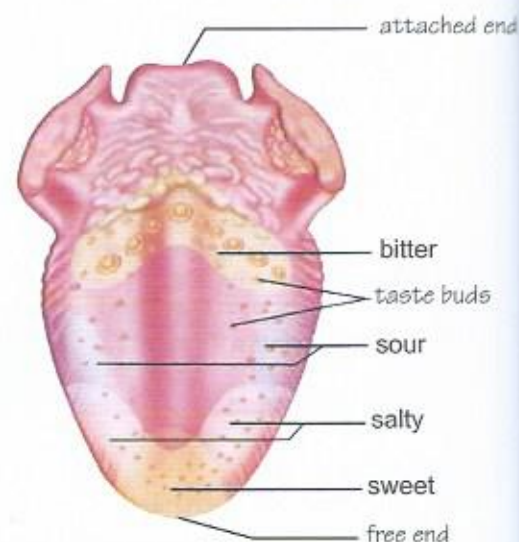
The canal starts at the mouth and ends at the anus. Some of the organs associated with the alimentary canal are the tongue, teeth, liver, pancreas and salivary glands.

The mouth

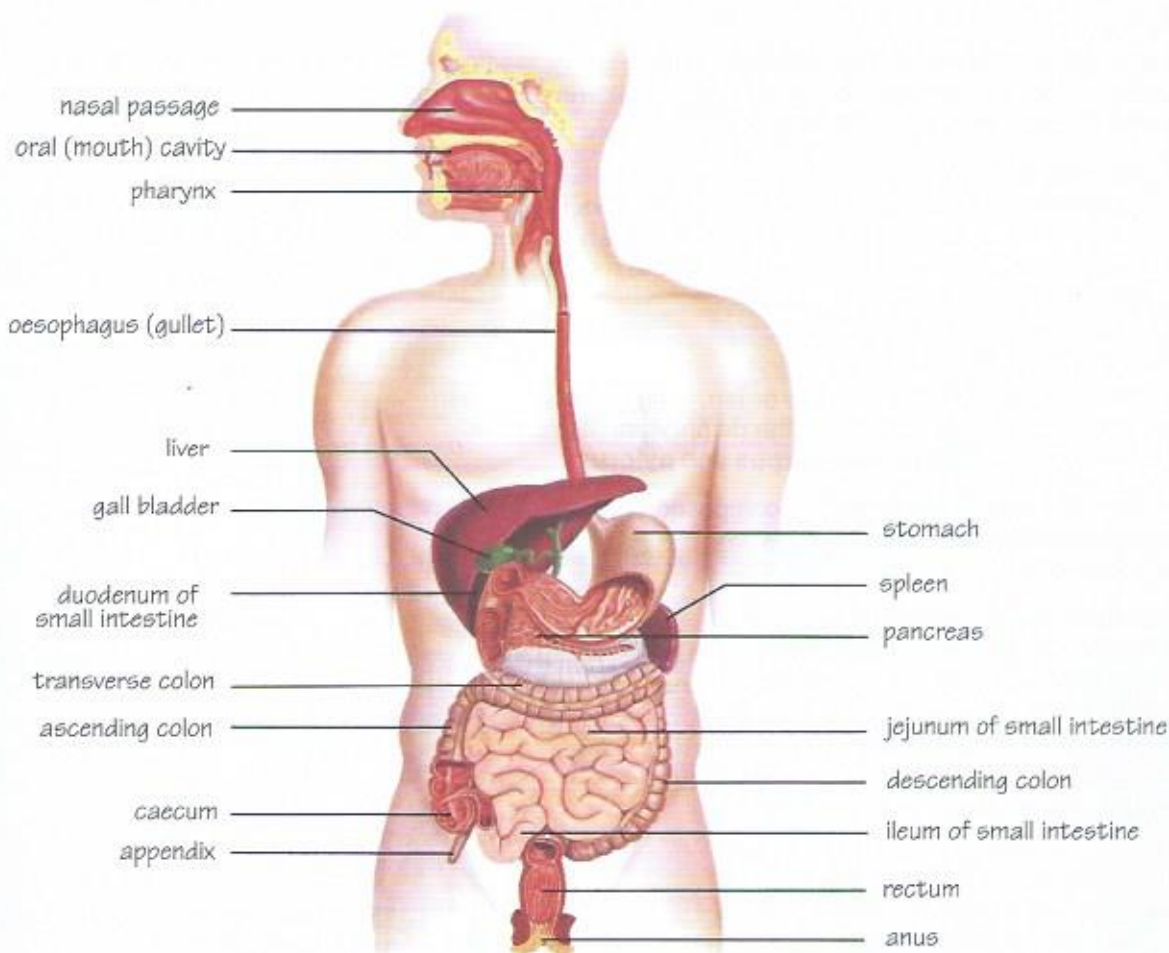
The mouth is the first part of the digestive system where food enters. The lips, cheeks and tongue serve to keep the food between the teeth, ensuring uniform chewing and proper mastication.

Tongue:

The tongue is a muscular organ attached to the floor of the mouth. It serves to move the food in the mouth and keep it between the teeth. The tongue helps shape food into a **bolus** (ball of food) and pushes it towards the back of the mouth cavity for swallowing. It is also the organ of taste (salty, sweet, sour and bitter) and stimulates the secretion of saliva.



The tongue as the organ of taste



The alimentary canal of man

Teeth

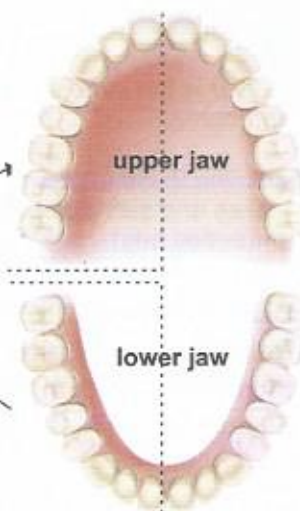
Teeth are found in sockets in the upper and lower jaws. An adult has 32 teeth. Teeth cut, tear and pulverise food into smaller particles for swallowing.

In both jaws there are:

- 8 incisors are used for biting and snipping food.
- 4 canines are used for gripping and tearing food.
- 8 premolars help in chewing food.
- 12 molars are used for chewing.

• The human dental formula is: $\frac{2.1.2.3}{2.1.2.3}$

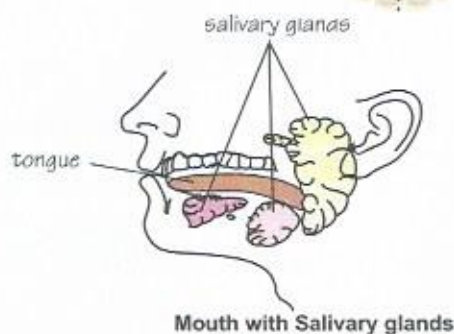
This implies that on half of the upper jaw, there are 2 incisors, 1 canine, 2 premolars and 3 molars present. The same applies to the lower jaw.



Salivary Glands

Three pairs of salivary glands are present in the mouth.

They secrete saliva which consists of water, mucin and an enzyme. Saliva serves to soften and lubricate food which facilitates chewing, mixing and swallowing.



Mouth with Salivary glands

The pharynx

The pharynx is the area at the back of the mouth cavity, leading to the oesophagus and trachea. It allows the entry of food into the oesophagus during swallowing. When food is swallowed, the epiglottis closes so that food does not enter the trachea.

The oesophagus

The oesophagus is a narrow muscular tube that links the pharynx to the stomach. It lies immediately behind the trachea. The oesophagus forces the bolus down into the stomach, by a muscular wave-like motion called **peristalsis**. Goblet cells in its wall secrete mucus, which serves to lubricate the walls for the smooth passage of the bolus.

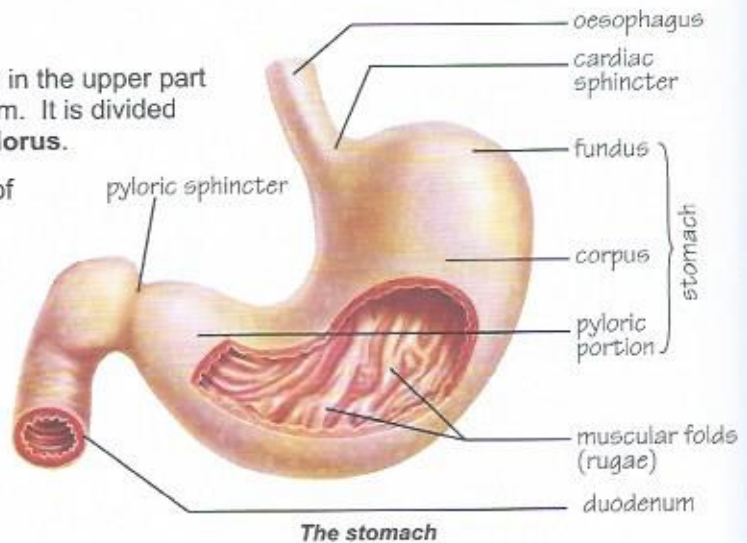
The stomach

The stomach is a muscular bag-like organ, lying in the upper part of the abdominal cavity, just below the diaphragm. It is divided into three sections: the **fundus**, **corpus** and **pylorus**.

The inner surface of the stomach is composed of many muscular folds called **rugae**, which become fewer as the stomach distends.

The stomach secretes **gastric juice** which contains enzymes and hydrochloric acid (HCl). The muscular action of the stomach mixes the food with saliva and gastric juice, forming a watery mixture called **chyme**.

The cardiac and pyloric sphincters control the entry and exit of food.



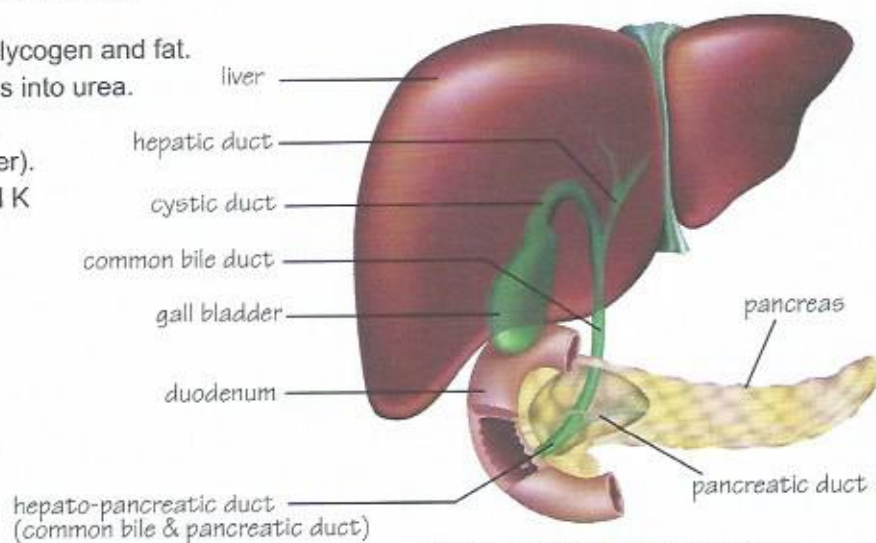
The pyloric end of the stomach narrows down to form the first part of the small intestine, the **duodenum**. The liver, gall bladder and pancreas are important organs associated with the duodenum.

Liver

The liver is the largest gland in the body, lying in the upper portion of the abdominal cavity, just below the diaphragm.

Functions of the liver:

- Makes and secretes bile (bitter fluid which emulsifies fats).
- Converts excess glucose into glycogen and fat.
- Deaminates excess amino acids into urea.
- Detoxifies harmful substances.
- Stores minerals (iron and copper).
- Stores vitamins A, B₁₂, D, E and K



Gall Bladder

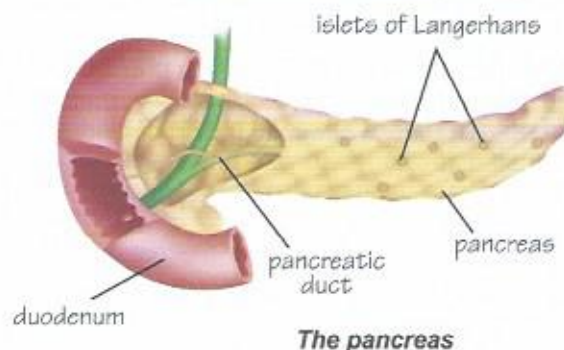
The gall bladder is a pear-shaped pouch found in the depression on the lower surface of the liver. It stores bile.

Pancreas

The pancreas is a gland lying below the greater curvature of the stomach. Ducts connect the pancreas to the duodenum.

It secretes **pancreatic juice** which contains a number of enzymes.

Special groups of endocrine cells called **islets of Langerhans** are found in the pancreas. They secrete the hormones insulin and glucagon, which control blood sugar level.



The pancreas

Small intestine

The small intestine begins at the pyloric sphincter, extends through the central part of the abdominal cavity and opens into the large intestine.

Enzymes are found on the surface of the columnar epithelial cells.

Numerous finger-like projections of the mucosa, called villi, serve to increase the surface area for the increased absorption of nutrients.

The muscles of the small intestine cause peristalsis, which move food along towards the large intestine.

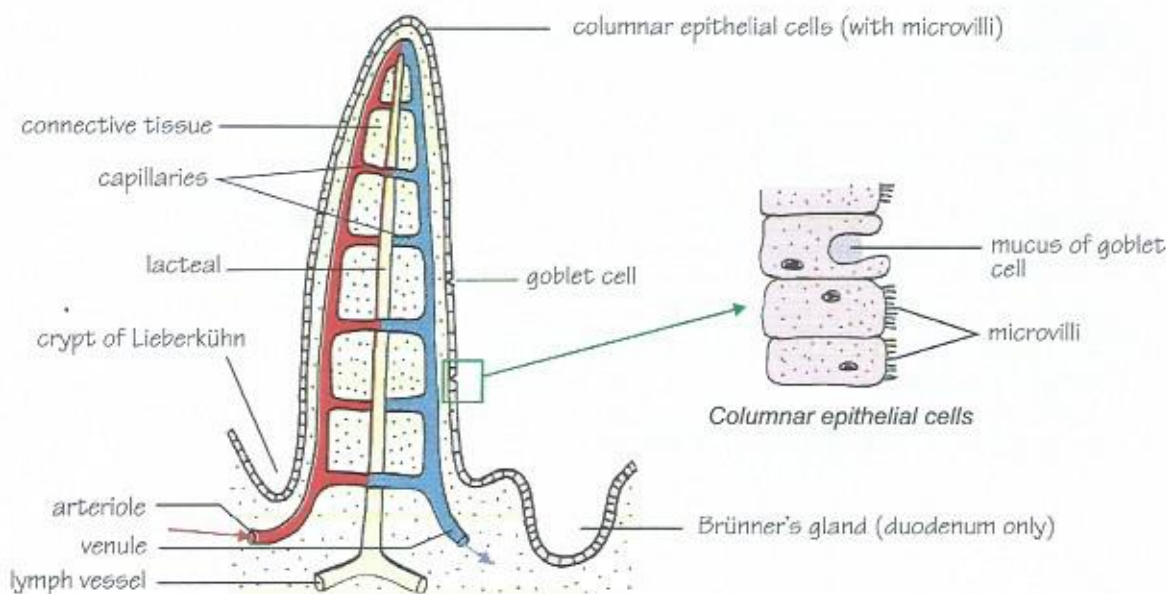


Diagram of a villus (l/s)

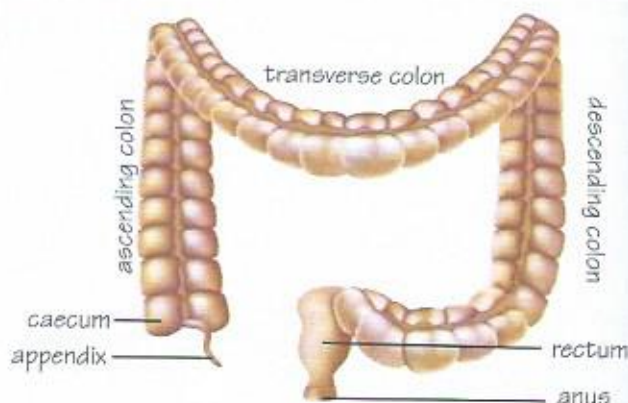
Structural Adaptations of the Villus

- Has a single layer of epithelial cells to facilitate diffusion.
- Has a lacteal to transport absorbed fats.
- Well supplied with capillaries for the transport of absorbed nutrients.
- Columnar epithelial cells of the villus have many mitochondria, which provide the energy for the active absorption of nutrients (mostly lipids).
- Goblet cells secrete mucus, which protects the villi and aids absorption.
- Brunner's glands secrete an alkaline mucus, which serves as a lubricant and protects the lining of the intestine against the acidic chyme, by neutralising it.

Large Intestine

The large intestine extends from the ileum to the anus. It is attached to the abdominal wall. It consists of the caecum, colon, rectum and anus.

The colon contains bacteria which break down undigested carbohydrates. Gases like methane and carbon dioxide are released by the bacteria during this process.



The large intestine (colon)

Digestion

The need for digestion

Food taken in consists of large molecules which are often insoluble in water. This food must be broken down into a form that can be readily absorbed by the cells of the body. The breaking down of food into smaller molecules so that it can be absorbed, is known as digestion.

a) Mechanical digestion

Mastication: Food is pulverised into smaller particles, by the grinding action of the teeth and jaws, and mixed with saliva so that it can be swallowed.

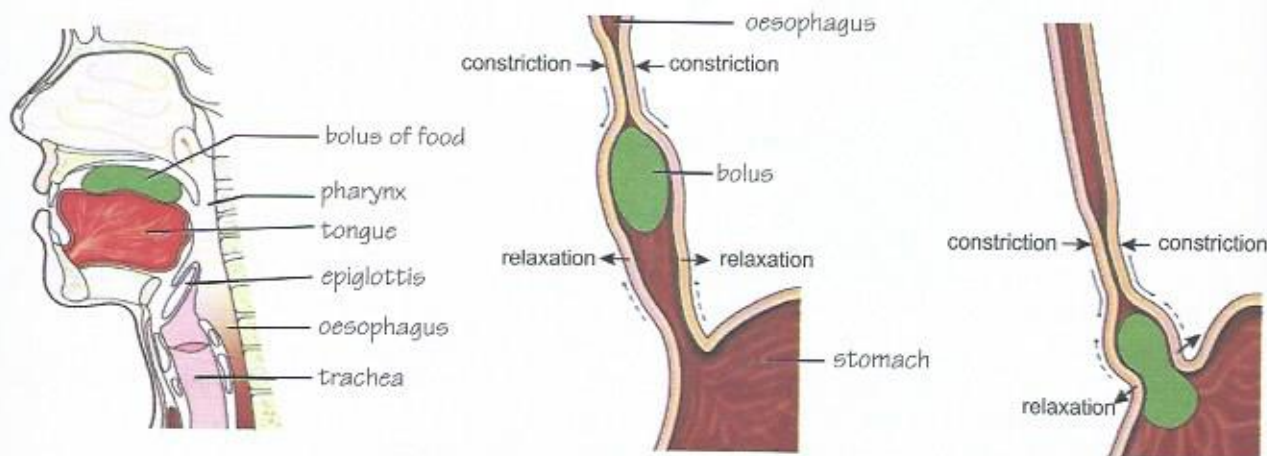
Bolus Formation: The tongue rolls the moistened food particles into a ball called a bolus, which makes it easier to swallow.

Swallowing: The movement of the bolus down the pharynx and into the oesophagus is called swallowing. The tongue pushes the bolus to the back of the mouth cavity, where the action of swallowing is triggered.

Peristalsis of the Oesophagus, Stomach and Intestine: Peristalsis is the successive muscular contractions along the wall of the alimentary canal, causing the food to move along. These muscular contractions cause the moist bolus to slide downwards until it reaches the stomach.

Peristaltic movements in the stomach are greater, causing food to be thoroughly mixed with gastric juice. Food is thus churned into fine particles in a fluid medium which is now called chyme.

Peristaltic movements within the small intestine are similar to those which occur in the oesophagus. Food is forced along the small intestine and eventually enters the large intestine. Peristalsis in the large intestine allows for the movement of food and its elimination (defaecation).



Peristalsis in the Oesophagus

The importance of roughage

Roughage promotes the efficient operation of the alimentary canal. It consists of indigestible plant cell material such as cellulose, hemicellulose, pectin and lignin.

Sources: All raw and cooked vegetables, peanuts and tree nuts. Roughage is also found in brown and whole wheat bread, as well as fresh and dried fruit.

Purpose of Roughage: Roughage gives volume to the waste material in the large intestine (colon). This increased volume results in stretching of the colon, stimulating peristalsis and movement of waste material towards the rectum for defaecation. Roughage also enables faeces to retain water, preventing constipation and piles (haemorrhoids).

The role of water in facilitating movement of food

By increasing the fluidity of food, water enables it to move freely along the alimentary canal. It also enables tissues along the alimentary canal to remain soft and pliable, ensuring free movement within the canal.

b) Chemical Digestion

Chemical digestion involves the breakdown of large food molecules into smaller molecules, with the aid of enzymes. The enzymes speed up the reactions, but are not used up the reactions. These enzymes are found in the digestive juices. There are 5 digestive juices: Saliva (mouth), Gastric juice (stomach), Pancreatic juice, Bile and Intestinal juice (intestines). The latter three are active in the small intestine.

Region	Digestive juice	End product of digestion
Mouth 	saliva	Carbohydrates, like starch, are chemically broken down (hydrolysis) in the mouth by enzymes in saliva.
Stomach 	gastric juice	Proteins are mainly broken down in the stomach by the acidic conditions and enzymes present in gastric juice.
Small Intestine 	1. pancreatic juice 2. bile (no enzymes) 3. intestinal juice	Final breakdown of carbohydrates, proteins and fats occur in the small intestine with the help of bile, pancreatic juice and intestinal juice. (N.B.: Bile has no enzymes.) The end products of digestion are: • Carbohydrates → monosaccharides (single sugars). • Proteins → amino acids. • Fats or lipids → glycerol and fatty acids.

Absorption of Digested Food

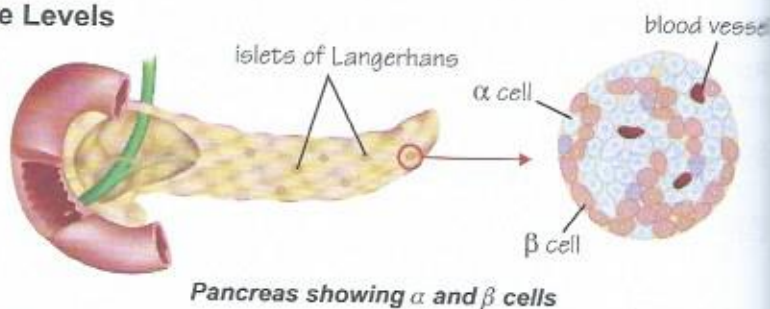
- Most foods are absorbed in the small intestine.
- The villi play an important role in the absorption of food.
- Sugars and amino acids are absorbed into the blood and are carried to the liver via the hepatic portal vein.
- Absorbed fat enters the lymphatic system via the lacteal and later joins the blood system.

Fate of Absorbed Food

- Sugars, like glucose, are stored in the liver and muscles as glycogen, or they are used up as a source of energy during cellular respiration.
- Amino acids are used to make proteins in cells and tissues. Excess amino acids are deaminated (broken down) in the liver, then filtered by the kidneys and excreted as urea in urine.
- Fats are stored under the skin or around delicate organs like the heart and kidneys. Fats serve as a reserve source of energy.

Homeostatic Control of Blood Glucose Levels

Blood glucose levels are controlled by two hormones: insulin and glucagon. These hormones are secreted by the islets of Langerhans, which are found within the pancreas.



When blood glucose levels are raised

- Insulin is secreted into the blood.
- Insulin decreases the blood glucose levels by:
 - converting excess glucose to glycogen, which is then stored in the liver and muscles.
 - promoting the absorption of glucose into body cells.

When blood glucose levels are lowered

- Glucagon is secreted into the blood.
- Glucagon increases the blood glucose level by converting stored glycogen to glucose, which is then released into the blood.

Diabetes

Diabetes mellitus is a condition where the pancreas does not secrete sufficient insulin, resulting in blood glucose level being high.

Symptoms of Diabetes

- Frequent urination.
- Blurred vision.
- Presence of glucose in the urine (urine test).
- Being thirsty.
- Wounds that will not heal.

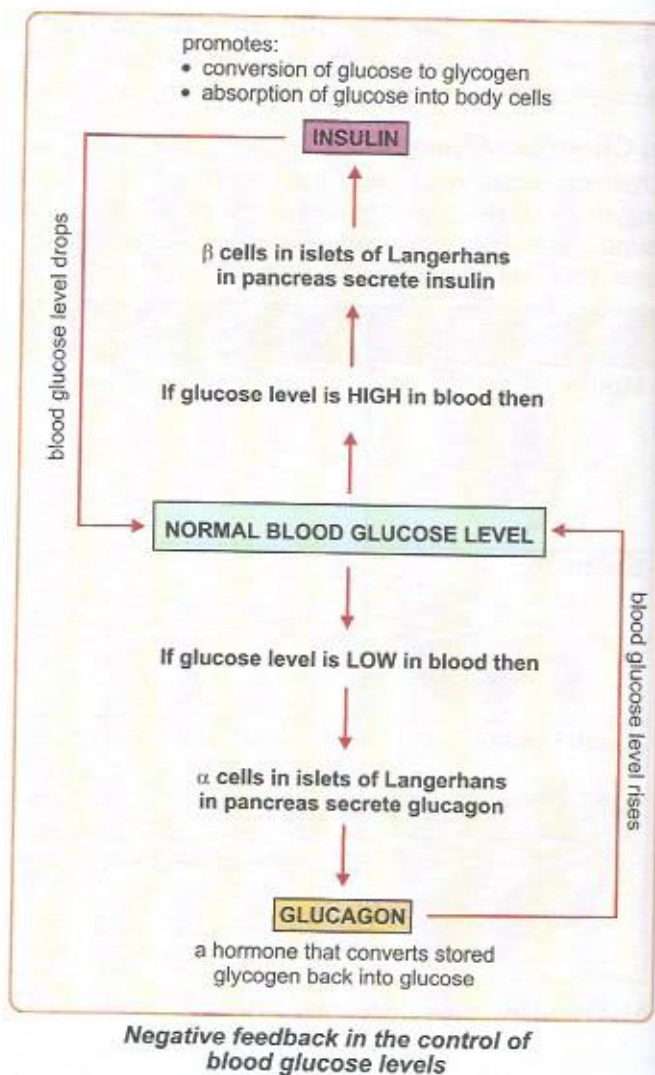
There are two types of diabetes:

Type 1 Diabetes (insulin-dependent)

- Occurs when the pancreas does not secrete insulin.
- Young children and adults up to the age of 30 are usually diagnosed with type 1 diabetes.
- They have to rely on insulin injections to survive.

Type 2 Diabetes (insulin-independent)

- Pancreas in people diagnosed with type 2 diabetes does not secrete adequate insulin.
- Common in adults who are obese and over the age of 40.
- Glucose level in these adults is usually controlled by prescribed medication.



Problems associated with nutrition

A balanced diet

A balanced diet is one which contains essential food components, in sufficient quantities, from the five major food groups. These groups are: carbohydrates, proteins, lipids, vitamins and minerals. The actual daily requirements will differ because, different populations have different dietary habits according to their life style.

On average, the approximate daily food intake should be:

- 1) 50 - 60% carbohydrates, with less than 15% from simple sugars,
- 2) less than 30% fats,
- 3) 12 - 15% proteins.

Water is very important. About 2 litres should be taken in every day, however some of this water is found in food.

Malnutrition

Malnutrition is a state of poor or bad nutrition that may be due to inadequate food intake (under nutrition), imbalance of nutrients, or over nutrition. Some of the consequences of malnutrition are:

1. Under nutrition

CONDITION (DISORDER)	CAUSE	SYMPTOMS
Kwashiorkor	Children fed on a high carbohydrate and low protein diet.	Swollen abdomen, stick-like arms and legs, retarded growth, sores on skin and swollen face.
Anorexia nervosa	Psychological - person refuses to eat.	Excessive weight loss which could lead to death. There is also a decreased resistance to diseases.
Nutritional marasmus	Children receiving too little carbohydrates, proteins and fats.	Loss of mass, tightly stretched skin, thin muscles and very little fatty tissue.
Bulimia	Exact cause is unknown. May be psychological, neurological or endocrinal. Episodes of over-eating followed by self-induced vomiting.	Guilt associated with eating, frequent weighing, low body weight, secretive behaviour, low blood pressure.

2. Over nutrition Obesity

Obesity is caused by a person eating too much carbohydrates and fats, resulting in an excessive accumulation of adipose tissue. Obese persons are more likely to suffer from cardiovascular diseases, hypertension, diabetes, certain cancers and gall bladder diseases. Recently, obesity has been linked to genetic factors related to metabolic rates.

Hormonal Control

Two hormones play a role in the digestion process in humans:

Gastrin • secreted by the stomach walls.

- stimulate glands in the stomach walls to secrete gastric juice.

Secretin • secreted by the walls of the duodenum and travels via the blood to stimulate the:

- pancreas into releasing pancreatic juice.
- liver into releasing bile which is stored in the gall bladder.

Different Diets

Humans have different diets for different reasons. It may be due to cultural practices, religious practices, health reasons or personal reasons.

Vegan	Vegetarian	Kosher	Halaal
A vegan is one that avoids eating or using any animal products. They do not eat meat, fish or eggs. They don't drink dairy products and don't use any substance that is derived from animals. They don't eat honey as well.	A vegetarian does not eat meat, fish and eggs. They eat vegetables only. Many Hindus are vegetarians due to their religious beliefs. Some eat only vegetables on certain days of the week.	Foods are said to be kosher if they meet all the criteria laid down by Jewish law. Foods that have a mixture of meat and milk are regarded as non-kosher. Foods purchased have a symbol indicating whether it is kosher.	Muslims will only eat meat that is Halaal. This implies that the animal was slaughtered according to the Muslim principles and techniques. Halaal foods purchased have a symbol or declaration on them.

Dietary Supplements

People take supplements for various reasons. Some of the reasons for taking supplements are:

- to improve one's health.
- to enhance one's performance in sport.
- to improve one's appearance (beauty).
- to have a young appearance (anti-ageing).

If a balanced diet is eaten regularly, then dietary supplements should not be taken. Dietary supplements include vitamins, mineral salts, plant and animal extracts etc. Since vitamin B₁₂ is only found in animal products, vegetarians should take a vitamin B₁₂ supplement. Calcium and vitamin D supplements will help prevent osteoporosis (brittle bones) from occurring as one gets older.

Tooth decay related to diet

Regular eating of sweets and chocolates could result in tooth decay. One must brush ones teeth regularly to reduce the chances of tooth decay. Drinking lots of milk (calcium) will help strengthen ones teeth. Fluoride exists naturally in our water and it helps prevent tooth decay by strengthening the enamel. The fluoride also prevents new cavities from forming.

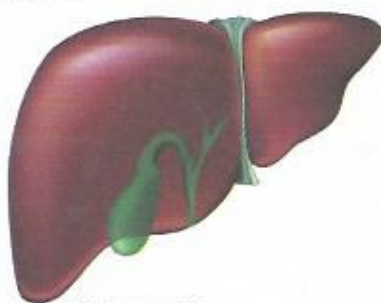
Fluoridation occurs in most countries. This process involves the addition of fluoride to drinking water. However, high dosages of fluoride in drinking water can be hazardous.

Effects of alcohol abuse

Excessive alcohol is harmful to the body and affects the body in many ways. The liver is one of the first organs to be affected by excessive alcohol consumption. A condition known as cirrhosis ("cirrhosis" means "orange") occurs where the liver becomes hard, turns orange and the cells die.

Other ways that alcohol affects humans are:

- Impaired judgement.
- Impaired speech.
- Social relationships.
- Job efficiency.
- Deficiency of certain vitamins.
- Red and white corpuscle deficiency.
- Immune system depressed, resulting in cancer of the stomach, liver, pancreas, colon and tongue.



A normal liver



Cirrhosis of the liver

Effects of drug abuse

Marijuana

Marijuana is a drug that is obtained from a plant *Cannabis sativa*. Those that smoke Marijuana experience euphoria, together with alterations in vision and judgement. Often brain damage occurs together with respiratory diseases and lung cancer.

Cocaine

Cocaine is an addictive drug that affects the human brain. Memory and concentration levels are affected. Men that take cocaine can become impotent. High doses of cocaine can lead to seizures as well as cardiac and respiratory arrest.

Heroin

Heroin is also an addictive drug. Some of the side effects of taking heroin are nausea, vomiting, respiratory and circulatory depression, leading to death.

C: Cellular Respiration

Energy in our universe remains constant. Energy is neither created nor destroyed.

Energy exists mainly in two forms.

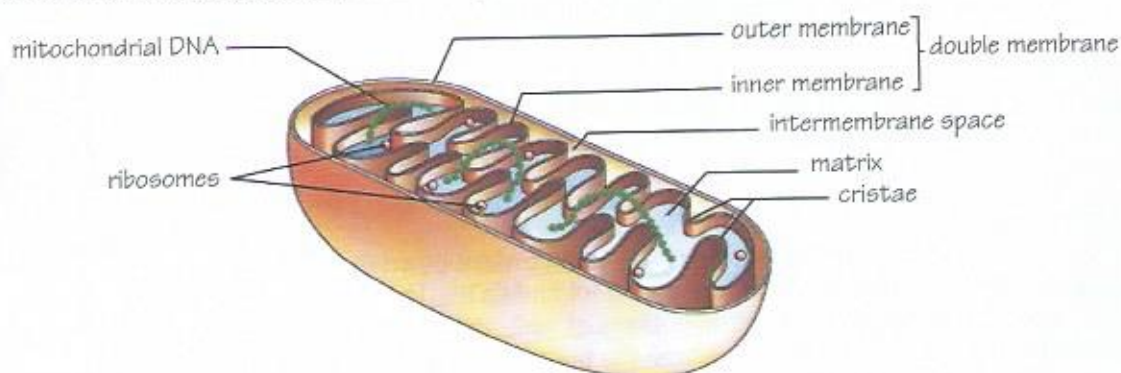
- potential energy (stored energy)
- kinetic energy (energy due to motion)

Living organisms need energy to survive. Plants are autotrophs, as they manufacture their own food. Animals are heterotrophs, since they cannot make their own food. They obtain energy by eating plants (herbivores) or other animals (carnivores)

Cellular respiration releases the energy in food, so that the organism can get the energy it requires. When oxygen is available to a cell, **aerobic** respiration takes place and lots of energy is released and stored as ATP. When oxygen is not available to a cell, **anaerobic** respiration occurs and little energy is released.

The Mitochondrion

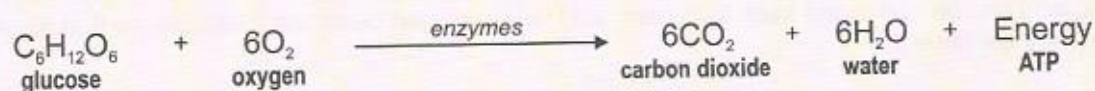
The mitochondrion is the organelle in which the process of aerobic respiration is completed.



A mitochondrion (l/s)

Aerobic Respiration

Aerobic respiration takes place in the presence of oxygen. A summary of aerobic respiration follows :

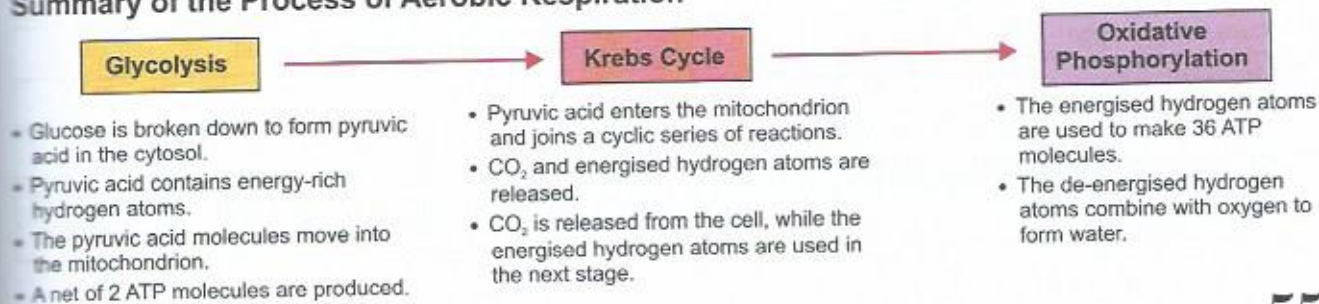


The energy released is stored in the mitochondria as adenosine triphosphate (ATP), a chemical containing an energy-rich bond. When this bond is broken, energy is released. During aerobic respiration, 1 glucose molecule will produce a net product of 38 high energy ATP molecules.

Aerobic respiration involves three stages:

1. Glycolysis (occurs in the cytosol).
2. Krebs cycle (occurs in the mitochondrion).
3. Oxidative phosphorylation (occurs in the mitochondrion).

Summary of the Process of Aerobic Respiration

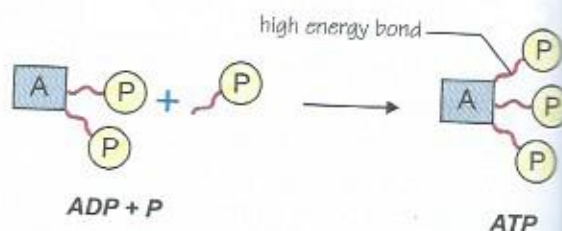


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Energy Carrier in a Cell

ATP is a carrier of energy in a cell. When energy is required, ATP breaks down to ADP + P (adenosine diphosphate and phosphate) and the energy that is released is available to the cell.

ATP is formed when $\text{ADP} + \text{P} + \text{energy}$ forms ATP.



Anaerobic Respiration

Anaerobic respiration is a catabolic (breaking down) reaction that occurs in both plant and animal cells, when oxygen is **not** available in the cell. The reaction occurs in the cytosol of the cell and the products formed in plant and animal cells are different.

In Plant Cells

In plant and yeast cells, energy-rich glucose is broken down to ethanol (alcohol). Carbon dioxide and some energy is released. The process is called **alcoholic fermentation**.

Beer Making:

Beer is made when the yeast (fungus) is allowed to ferment under anaerobic conditions (absence of oxygen) to produce alcohol.



Bread Making:

Yeast is also used in the making of bread. The yeast breaks down the sugar via anaerobic respiration to produce ethanol and CO_2 . The alcohol evaporates while the CO_2 forms pockets of "air", causing the dough to rise. The yeast is killed by the time the bread is fully baked.



In Animal Cells

In animal cells, anaerobic respiration is also known as **lactic acid fermentation**. During this process, food (e.g. glucose) is broken down to yield some energy and lactic acid. A build-up of lactic acid in muscles leads to pain and muscle cramps.

N.B. Lactic acid can be converted back to pyruvic acid when oxygen becomes available, so that aerobic respiration may continue.

Comparison between Aerobic and Anaerobic Respiration

Similarities: In both processes:

- Glucose is the source of energy.
- Energy in the form of ATP is released.
- The reactions are controlled by enzymes.

Differences between Aerobic and Anaerobic Respiration

Aerobic Respiration	Anaerobic Respiration
Occurs when oxygen is present in cell.	Occurs when oxygen is absent in cell.
Starts in the cytosol and ends in the mitochondria.	Occurs in the cytosol.
One glucose molecule releases 38 ATPs (net).	One glucose molecule releases only 2 ATPs (net).
ATP, CO_2 and water are the by-products in both plant and animal cells.	ATP, CO_2 and ethanol are the by-products in plant cells. ATP and lactic acid are the by-products in animal cells.

Differences between Photosynthesis and Respiration

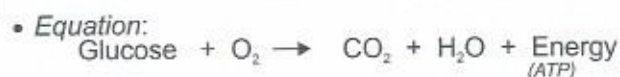
Photosynthesis

- Occurs only in chlorophyll-containing organisms, e.g. green plants.
- It is an energy storing process converting radiant energy (sunlight) into chemical energy.
- It takes place in the presence of light.
- Carbon dioxide is a raw material for the process.
- Glucose is produced.
- Oxygen is a product of the process.
- Water is required.



Respiration

- Occurs in all living organisms and is independent of chlorophyll.
- It is an energy releasing process, releasing chemical energy stored in glucose.
- It is independent of light.
- Carbon dioxide is a product of the process.
- Glucose is broken down.
- Oxygen is a requirement for aerobic respiration.
- Water is released.

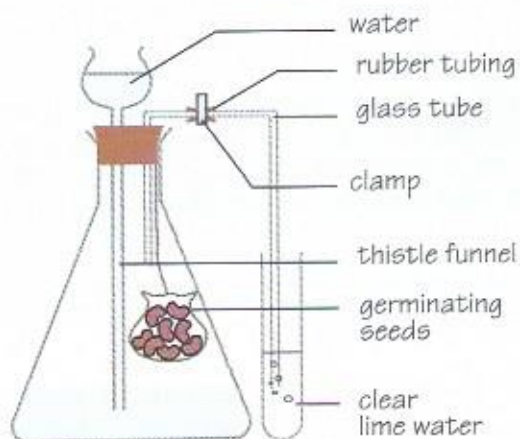


Practical Work: Respiration

Experiment 1

To determine whether carbon dioxide is given off during respiration.

- Germinating seeds are used in this experiment as they are actively respiring.
- The apparatus is designed such that any gas given off by the germinating seeds is trapped in the flask.
- When the clamp is removed and the thistle funnel is raised to just above the water level in the flask, the water from the thistle funnel will drain into the flask.
- This will cause the same volume of trapped air, together with the gas evolved during the experiment to bubble through the lime water.
- The lime water will turn milky if the gas passing through it is carbon dioxide.
- A control is set up in exactly the same way except germinating seeds are replaced by seeds that have been killed, by boiling them in water and sterilising them. Sterilisation kills any bacteria and fungi to prevent them from respiring.



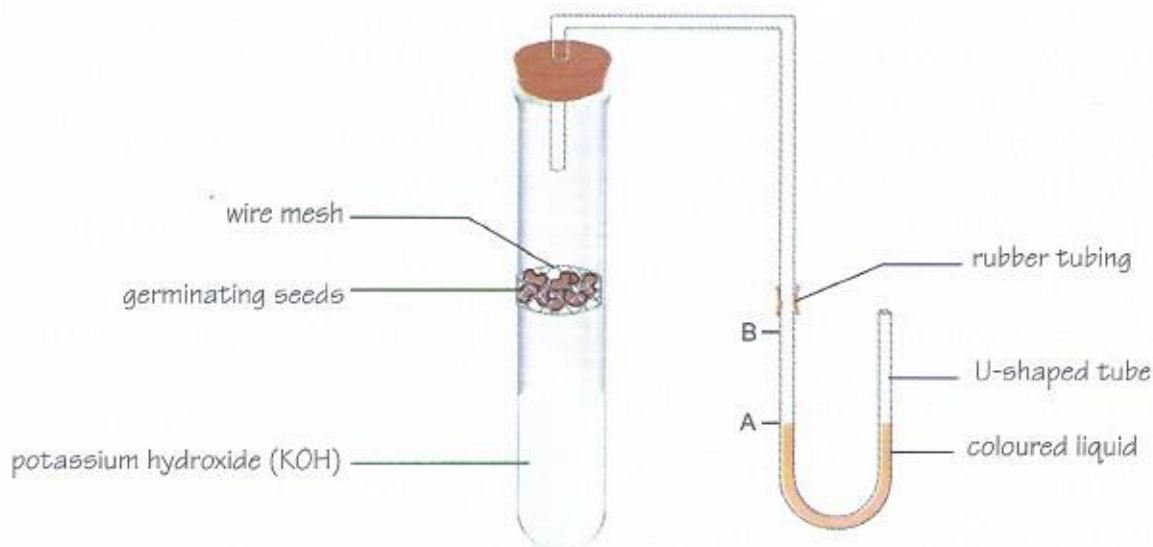
Results and Conclusion

Any gas released by the seeds has to escape through the lime water. Since the lime water turns milky, the gas liberated by respiring seeds must be carbon dioxide.

Experiment 2

Demonstration to prove that oxygen is used by respiring seeds.

The apparatus is set up as shown below.



- The germinating seeds will undergo cellular respiration rapidly, where carbon dioxide will be released and oxygen will be taken up by the respiring seeds.
- Potassium hydroxide is a chemical that absorbs carbon dioxide. The level of the coloured liquid in the capillary tube will not be affected by the any carbon dioxide released by the respiring seeds.
- However, since oxygen is taken up by the seeds during aerobic respiration, the coloured liquid will move from point A to point B.

Observations and Explanation

The level of the coloured liquid rises in the left side of the U-shaped tube (and drops on the right side). Any carbon dioxide produced will be removed when it is dissolved in the potassium hydroxide, and will not affect the volume of the gas in the test tube.

The rising of the coloured liquid indicates that a gas is being consumed in the test tube containing the bean seeds. Nitrogen gas, which makes up almost 80% of the air in the test tube, is unreactive and has no influence on the experiment. The only reactive gas in the test tube is oxygen, whose volume must be decreasing, causing the level of the coloured liquid to rise. The germinating bean seeds must then be consuming oxygen.

Setting up a Control

Another set of apparatus is set up exactly as shown above, except:

- The seeds are boiled to kill all tissues, ensuring that there are no living cells to respire and consume oxygen.
- The seeds are sterilised to kill all bacteria which may be present, again ensuring that there are no living organism capable of respiring and consuming oxygen.

At the end of the experiment one would notice that there is no change in the level of the coloured liquid in the U-shaped tube, confirming that respiring seeds consume oxygen.

D: Gaseous Exchange

All cells in the body continuously use oxygen in reactions that result in the release of energy during cellular respiration. At the same time, carbon dioxide is released. An accumulation of carbon dioxide will increase the acidity of the contents of the cell and eventually prove toxic. A living cell therefore requires a regular supply of oxygen and the constant removal of carbon dioxide. In unicellular organisms, simple diffusion suffices. However, in complex organisms like man, a system is required. The respiratory system serves this purpose. The cardio-vascular system transports these gases between the lungs and cells of the body.

Difference between Cellular Respiration, Breathing and Gas Exchange

Cellular respiration

- Occurs in living plant and animal cells
- It is a chemical process.
- Glucose is broken down to release energy (ATP) and carbon dioxide.

Breathing

- Involves inhalation and exhalation.
- It is a mechanical process.
- Inhalation is when air is taken into the lungs.
- Exhalation involves the removal of air from the lungs.

Gas exchange

- Occurs at two sites in the body, the lungs and in body tissues.
- It is a physical process involving diffusion.
- In lungs, O_2 diffuses from the air sacs into the blood, while CO_2 diffuses from the blood into the air sacs (alveoli).
- At the tissue level, O_2 diffuses from the blood capillaries into the body cells, while CO_2 diffuses from the body cells into the blood capillaries.

Requirements for an efficient gaseous exchange system

Requirements	In humans
The gas exchange surface area must be large enough to allow for the maximum intake of O_2 and sufficient release of CO_2 .	A large number of alveoli provide the large area for the exchange of gases.
The exchange surface must be kept moist for the gases to dissolve before diffusing and to prevent the drying out of the alveolar cells.	The secretions of certain cells lining the alveoli keep the surface moist.
The exchange surface must be thin to facilitate diffusion.	The squamous epithelium of the alveolus is only one cell layer thick.
An efficient transport system must be in close proximity to the exchange surface for the transport of gases.	Alveoli are richly supplied with blood capillaries.
An efficient ventilating mechanism must be present to ensure a constant intake of O_2 and removal of CO_2 .	The diaphragm and intercostal muscles between ribs provide an efficient mechanism for ventilation.
There must be adequate protection for the delicate lung-tissue exchange surface.	The thoracic cage, consisting of the ribs, sternum and vertebral column protects the lungs.

The requirements for an efficient gaseous exchange system are met in different ways by different plants and animals.

Unicellular organism (e.g. Amoeba)  - Being unicellular, it cannot have specialised breathing structures. - Process of diffusion is sufficient. - Oxygen from its environment enters by diffusion across its cell membrane. - Carbon dioxide leaves by diffusion.	Dicotyledonous Plant  - Plants get their oxygen from the air that enters the plant through the stomata. - Oxygen diffuses into the plant cells and allows aerobic respiration to take place.	An Earthworm  - Earthworms breathe through their skin. - Their skin has to be kept moist at all times, since oxygen dissolves in the moisture on the skin, before diffusing into the body of the earthworm. - The elongated body of the earthworm provides a large surface area for gaseous exchange to occur.
Insects  - Insects have a system of tubes that carry air laden with oxygen to the body cells directly. - Openings (spiracles) on the thorax and abdomen, allow air to enter and exit the tubes. - Blood plays no role in the transport of gases in insects.	Bony Fish  - Bony fish obtain oxygen from the water via their gills. - Gills are very thin, allowing oxygen to diffuse through the gills into the blood. - Gill filaments provide a large surface area for gas exchange to take place. The gills are protected by the gill rakers and by the operculum (gill cover).	Mammals  - In mammals, gas exchange occurs in the alveoli (air-sacs) of the lungs. - Alveoli are thin and sac-like which, provides a large surface area for the rapid exchange of gases. - The lungs are protected by the rib cage.

Structure of the Human Breathing System *Refer next page*

The Mechanism of Breathing

Differences in pressure, caused by changes in volume of the thoracic cavity, force air into/out of the lungs.

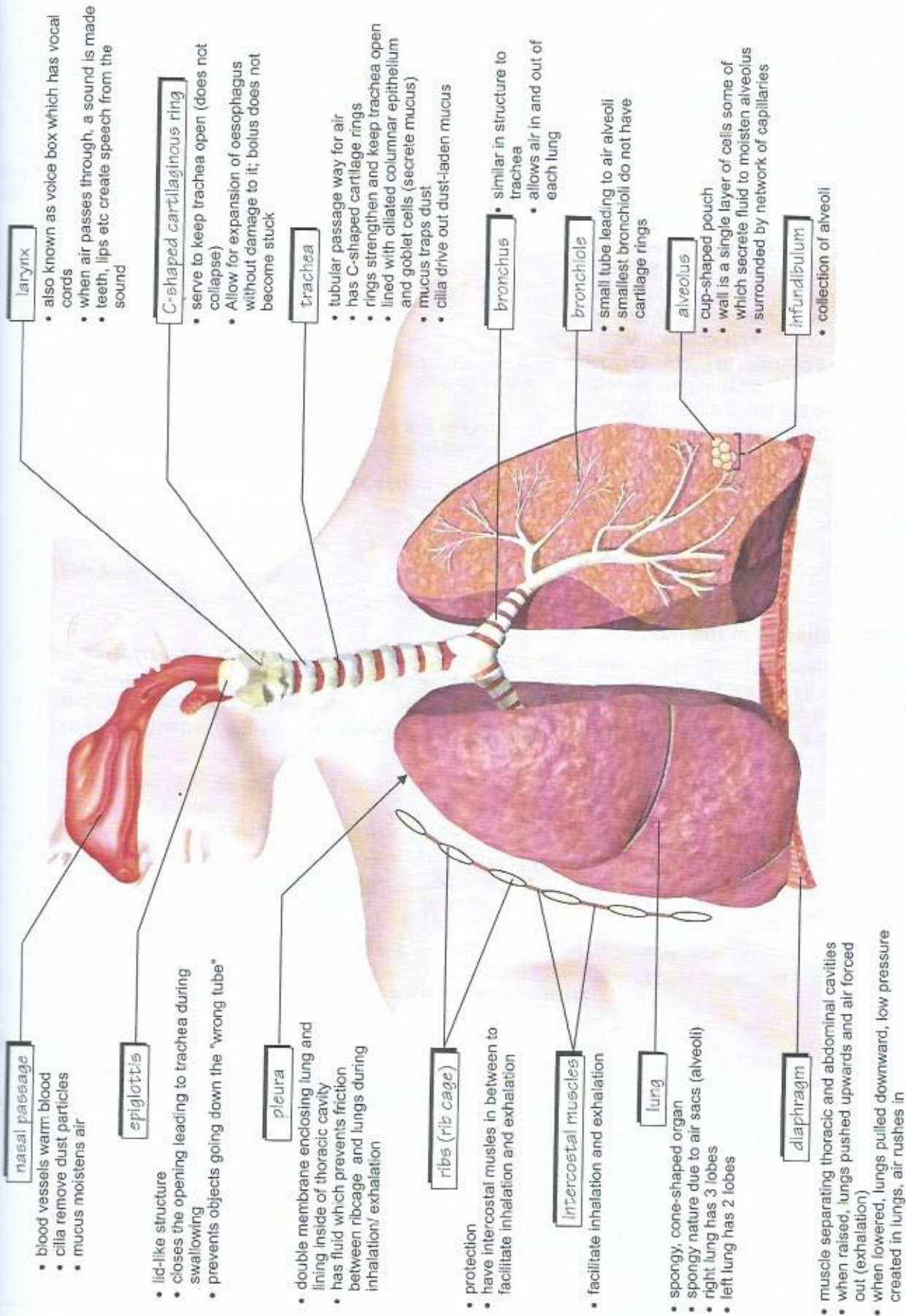
Inhalation	Exhalation
The diaphragm contracts and flattens, increasing the volume of the thorax from top to bottom.	The diaphragm relaxes and is raised, decreasing the volume of the thorax from top to bottom.
The external intercostal muscles contract, causing the ribs to be lifted upwards and outwards. The volume of the thoracic cavity increases sideways.	The external intercostal muscles relax, causing the rib cage to be lowered and become smaller. The volume of the thoracic cavity decreases sideways.
Interpleural pressure (pressure between pleura) decreases, causing a decrease in the pressure in the lungs.	Interpleural pressure (pressure between pleura) increases, causing an increase in the pressure in the lungs.
Since atmospheric pressure is now higher than pressure within the lungs, air rushes into the lungs via the nostrils.	Since pressure within the lungs is now higher than atmospheric pressure, air is forced out of the lungs via the nostrils.

Comparison between inhaled and exhaled air

From the table alongside, the following may be deduced about gas exchange in the lungs:

- Nitrogen gas is not absorbed into the blood.
- About 4% oxygen is absorbed into the blood.
- Almost 4% carbon dioxide is expelled from the lungs.
- The total volume of inhaled air equals the total volume of exhaled air.
- Far more CO₂ is exhaled than inhaled.

Name of gas	% gas in inhaled air	% gas in exhaled air
Nitrogen (N ₂)	78	78
Oxygen (O ₂)	20	16
Carbon dioxide (CO ₂)	0.03	4



The Human Breathing System

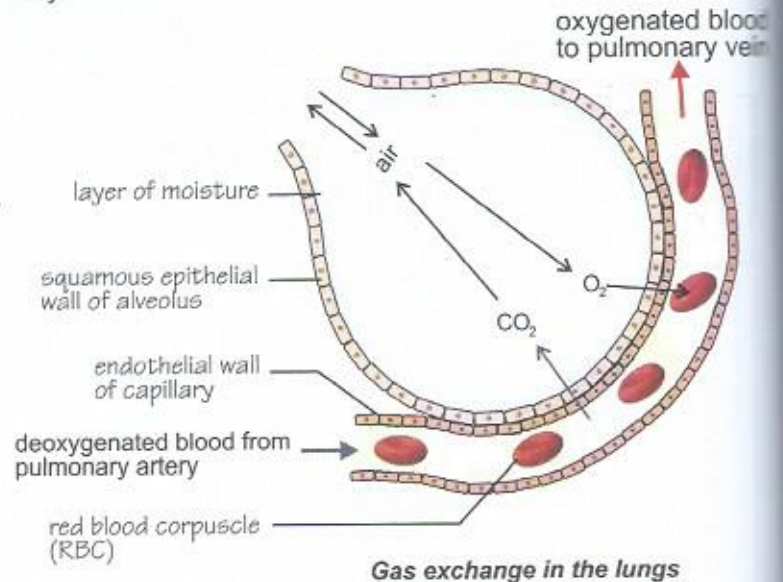
Homeostatic Control of Breathing

Modification of the breathing rate in relation to the needs of the body

Strenuous physical activity increases the body's need for energy. This in turn, demands a greater intake of oxygen, whilst producing more carbon dioxide. When CO_2 levels in blood rise, the medulla oblongata responds by increasing the heart rate and the breathing rate. Hence more blood flows to the lungs, more O_2 is taken up and more CO_2 is expired from the body.

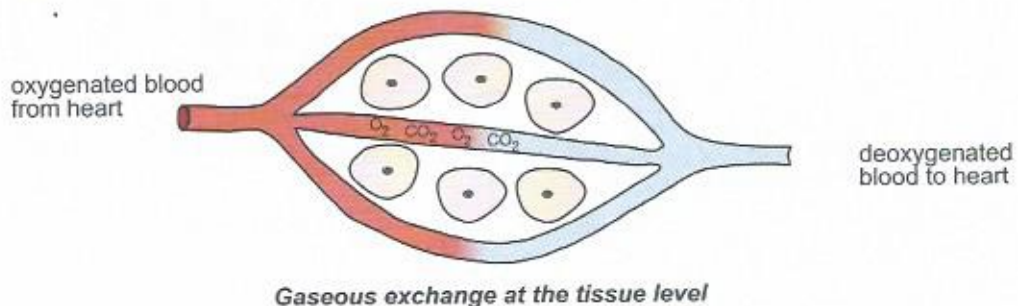
Gaseous exchange in the lungs

The capillaries surrounding an alveolus have a high concentration of CO_2 and a low concentration of oxygen. Air in the alveolus has a high concentration of oxygen and a low concentration of CO_2 . This concentration gradient causes diffusion to occur. Oxygen dissolves in the moisture lining the alveolus and diffuses into the blood stream; CO_2 diffuses out of the blood stream into the alveolus. The oxygen forms a loose combination with haemoglobin of the erythrocytes (red blood corpuscles) to form oxyhaemoglobin. A minimal amount of oxygen may dissolve in the blood plasma, where it is transported in solution form.



Gaseous exchange at the tissues

Blood in the capillaries reaching the tissues has a high concentration of O_2 and a low concentration of CO_2 . The tissue fluid has a higher concentration of CO_2 and a lower concentration of O_2 . This concentration gradient causes diffusion to occur. Oxygen diffuses into the tissue fluid, then into the cells; CO_2 diffuses out of the cells, into the tissue fluid, then into the blood. Cellular respiration causes the consumption of oxygen and production of CO_2 .



Transport of gases by the blood

Oxygen

--

Carbon dioxide

--

Tuberculosis (TB)

Tuberculosis (TB) is caused by the bacterium, *Mycobacterium tuberculosis*. It usually attacks the lungs, but can also attack any part of the body. Most people who become infected with the TB bacterium might not even need treatment, if their immune systems fight the bacterium and stop it from multiplying. Such people have a latent TB infection and cannot infect others. Globally, TB causes over three million deaths annually.

Transmission of TB

When a person coughs or sneezes, the TB bacteria get into the air. Other people breathe in the bacteria which then settles in their lungs and start to multiply. From there the bacteria can move via the blood to other parts of the body, such as the kidney, brain and spinal cord.

Symptoms

- Loss of appetite
- Weight loss
- Fever
- Chills
- Chest pains
- A bad cough that lasts for more than two weeks
- Coughing up blood or sputum

TB is confirmed by:

- X-rays,
- TB skin test,
- tissue culture of body fluids such as phlegm.

Treatment

1. Since TB is a bacterial disease, IT CAN BE CURED. There is medication available to help eliminate the bacteria from our bodies.
2. Patients have to ensure that they take their medicines daily, and must complete the course which is at least six months long.
3. Sometimes patients stop taking their medicines as soon as they start feeling better. These patients may suffer a relapse. There is also the danger that the TB bacteria may become resistant to the medication and thereafter become extremely difficult to cure.
4. The World Health Organization (WHO) now strongly advocates the use of the Directly Observed Therapy Shortcourse (DOTS) method. The WHO recommends that the patient be observed while taking medication and must be seen to swallow their medication by trained individuals, like health care workers or even members of the community who have volunteered to be trained to assist these patients. Along with the proper prescription of drugs, the WHO believes that DOTS monitoring, which ensures that patients take the prescribed medications for the appropriate periods of time, will greatly reduce drug resistant TB.

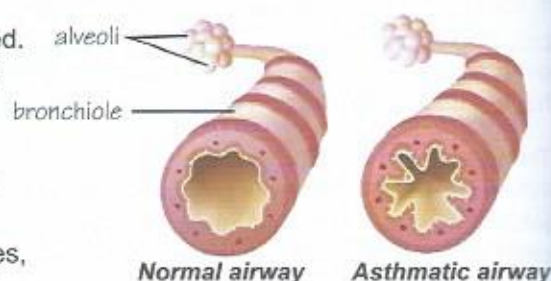
Prevention

1. The BCG vaccine, that was developed by two French scientists, Calmette and Guerin, is given to babies immediately after birth, and if no scar is visible at three months, it is then repeated.
2. People with weak immune systems, such as babies and young children, people with diabetes or HIV, organ transplant patients and drug abusers, should stay away from infected individuals.
3. A healthy diet and regular exercise keeps the immune system strong.
4. Health care workers should be educated about TB and be screened regularly for the disease.
5. Keep rooms well ventilated by opening windows and doors to prevent contamination.
6. Air in rooms can also be cleaned through air filtration.

PROBLEMS ASSOCIATED WITH BREATHING

Asthma

Asthma is caused when the bronchioles become constricted. This makes breathing difficult, since air cannot move freely into and out of the lungs. The constriction may be due to inflammation of the bronchioles and contraction of the smooth muscles around the bronchioles. Dust and pollen grains in the air result in the production of histamines in the body by leucocytes and mast cells. This causes excessive mucus to be secreted into the bronchioles, causing them to become constricted.



Hay Fever

Hay fever (allergic rhinitis) is an allergic reaction to dust and pollen in the air. It causes watery eyes and sneezing, due to inflammation of the mucous membranes of the eyes and nose.

Cancer of the Lungs

Smoking (passive and active) is one of the main causes of cancer in the lungs. The cancer presents as a tumour in the bronchi, where the cells do not appear to be normal. These cells divide abnormally and block the path of air into and out of the lungs. This causes the lungs to collapse. The lung tissue becomes infected and abscesses, possibly resulting in pneumonia.

Emphysema

Emphysema (Greek word for 'inflation') results from infected bronchi. This causes air to be trapped in the lungs. The walls of the alveoli (air sacs) rupture and large air spaces form within the lungs. Gaseous exchange is not efficient. Cigarette smoking and polluted air are thought to cause emphysema.

Bronchitis

Bronchitis is caused by exposure to infectious microbes and or polluted air, including tobacco smoke. Bronchitis is a respiratory disorder when the bronchi are inflamed and there is a build up of mucus. The air passage is then blocked and breathing is impeded. Acute bronchitis usually responds to antibiotic therapy.

Choking

This is caused by an inability to get air into and out of the lungs. Food or any object can cause the blockage in the air passages.

Symptoms of choking

- Gasping for air
- Unable to speak
- Face turning blue in colour

Action to take

- Respond to patient immediately.
- If patient cannot cough, give 4 sharp slaps between the shoulder blades with the heel of your hand.
- Remove any foreign object from the patient's mouth.
- If patient is still not breathing, stand behind the patient. Clench your fist and place over patient's stomach (upper abdomen). Grasp your fist with your other hand and pull suddenly inward and upward. The obstruction should come out. (The Heimlich Manoeuvre)
- If patient loses consciousness, open and clear the airway and begin mouth-to-mouth ventilation (see next page).



The Heimlich Manoeuvre

Effects of Smoking on Gas Exchange

Cigarette smoke has many harmful substances that reduce the amount of oxygen that gets to the body cells. Blood vessels become narrow, resulting in less oxygen getting to body cells. Cigarette smoke has tar which affects lung tissue and causes lung cancer. Toxic substances like nicotine, paralyse the cilia that line the respiratory tract. This allows harmful dust and smoke particles to accumulate along the inner walls of the air sacs (alveoli), which then impede effective gas exchange. Carbon monoxide is present in cigarette smoke. Oxygen transport is affected since the pigment haemoglobin has a greater affinity for carbon monoxide than oxygen. Cigarette smoke causes a build up of mucus in the lungs. This leads to "smoker's cough".

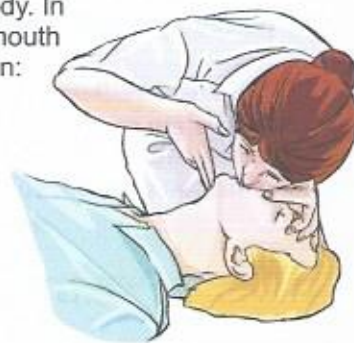
Smoking Legislation in South Africa

- Smoking has been banned in public places.
- Special designated rooms must be available in bars, restaurants and places of employment for smokers to use.
- Cigarettes may not be sold to children under the age of 18.
- Advertisements for smoking have been banned.
- Tobacco companies are not allowed to sponsor sporting events.

Artificial respiration

Artificial respiration is necessary when a person is unable to breathe on their own. Artificial respiration ensures that adequate oxygen gets to vital parts of the body. In a hospital, a ventilator is used for this purpose. Outside a hospital, mouth to mouth resuscitation needs to be done. The following procedure should be undertaken:

- Allow the person to lie on their back with their head tilted backwards.
- Block their nostrils with your thumb and finger.
- Gently blow into their mouth until their chest rises.
- Then allow the air to escape through their mouth.
- Repeat this procedure at a rate of 15 times per minute until the person starts to breathe on their own or until the paramedics arrive.



Administering artificial respiration

Oxygen Levels At High Altitude

At sea level, the air is very dense and there is more oxygen in the air. As the altitude increases, the air becomes less dense resulting in less oxygen being present in the air. Humans that live at high altitudes have more red blood corpuscles in their blood compared to those that live along the coast (low altitude). This is one of the reasons why long distance athletes that live in high altitudes perform better than athletes that live in low altitudes. The greater number of RBC's results in more oxygen being carried to the muscle cells, which enhances their performance in races.

Practical: Gas Exchange

To demonstrate the mechanism of breathing in humans.

The apparatus comprises:

- a bell jar which represents the thorax in man: the cavity within the bell jar represents the thoracic cavity.
- a Y-shaped tube which represents the trachea and bronchi.
- a rubber sheet, tied at the open end of the bell jar; which represents the diaphragm.
- balloons tied at the arms of the Y-tube represent the lungs.

Inhalation

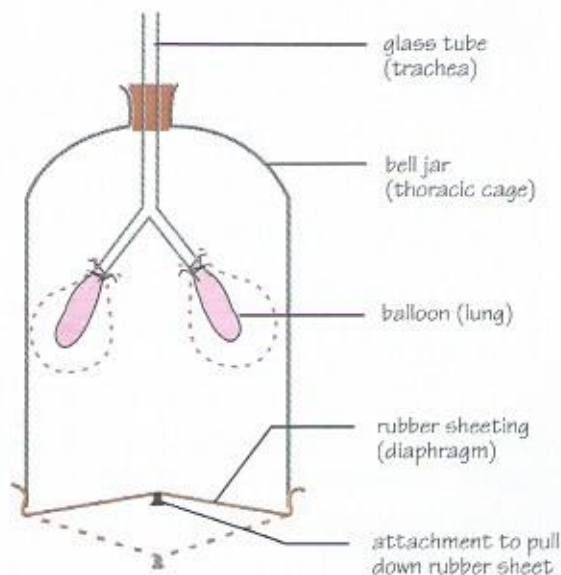
- When the rubber sheet is pulled downwards this represents the contraction of the diaphragm muscles in man.
- When the balloons inflate, this represents the inflation of the lungs in man.

Exhalation

- When the rubber sheet is raised this represents the relaxation of the diaphragm muscles in man.
- When the balloons deflate, this represents the deflation of the lungs in man.

Shortcomings of the apparatus

- The bell jar which represents the rib cage, is inflexible. In man the ribs and muscles are movable.
- There is a large space between the balloons and the glass of the bell jar. In man, the lungs lie against the inside of the thoracic cage, and occupies a larger region of the thoracic cavity.



E: Excretion

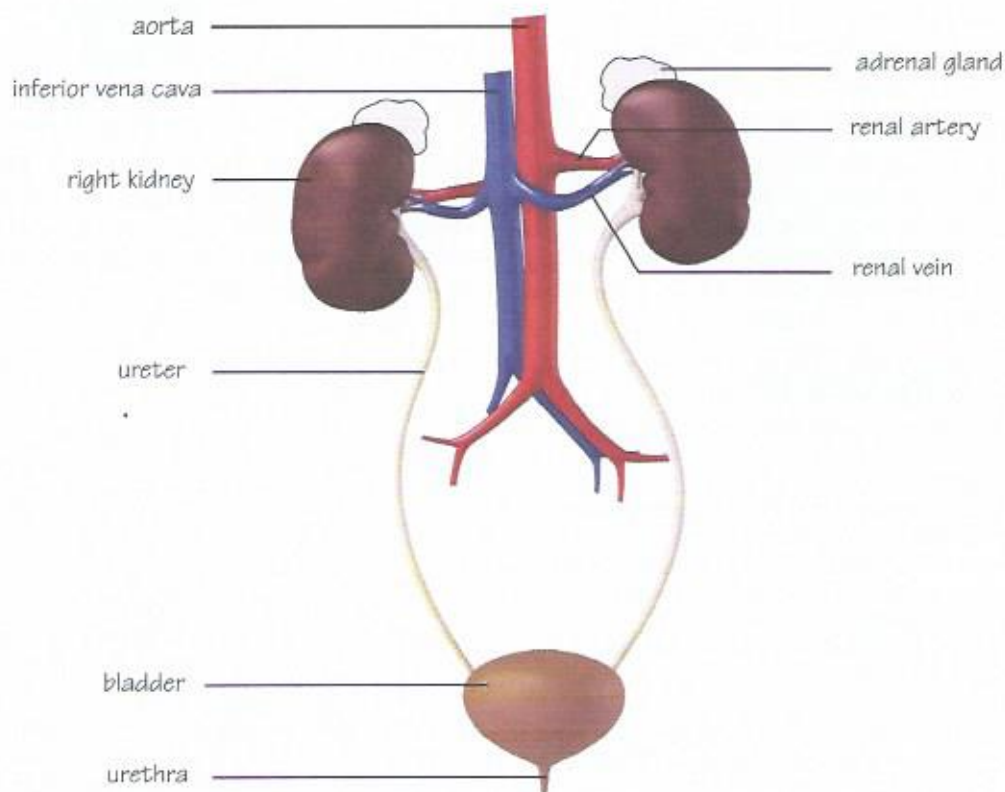
The metabolic processes that take place within the body produce a variety of waste products, such as CO_2 , ammonia, urea and uric acid. The accumulation of these waste products within a cell would have a negative impact on its normal functioning. Excretion is the removal of waste products from the body. Several organs and processes contribute to the transport and elimination of these products.

The main excretory organs are:

- Skin: produces sweat, which contains water, salts and urea.
- Lungs: removes CO_2 (released from body cells during cellular respiration) and some water.
- Kidneys: removes urea, uric acid, ammonia and water.
- Large intestine: removes heavy metals.

The Urinary System

The urinary system consists of the two kidneys, two ureters, bladder, urethra and its associated blood supply, the renal artery and renal vein. The main function of the urinary system is to maintain homeostasis by regulating the composition, volume and pressure of the blood.



The Urinary System

Ureters: Ducts that carry urine from each kidney to the bladder.

Bladder: Located in the pelvic cavity, it serves to store urine prior to urination.

Urethra: A tube leading from the bladder to the exterior through which urine (and semen males) is discharged.

The Kidneys

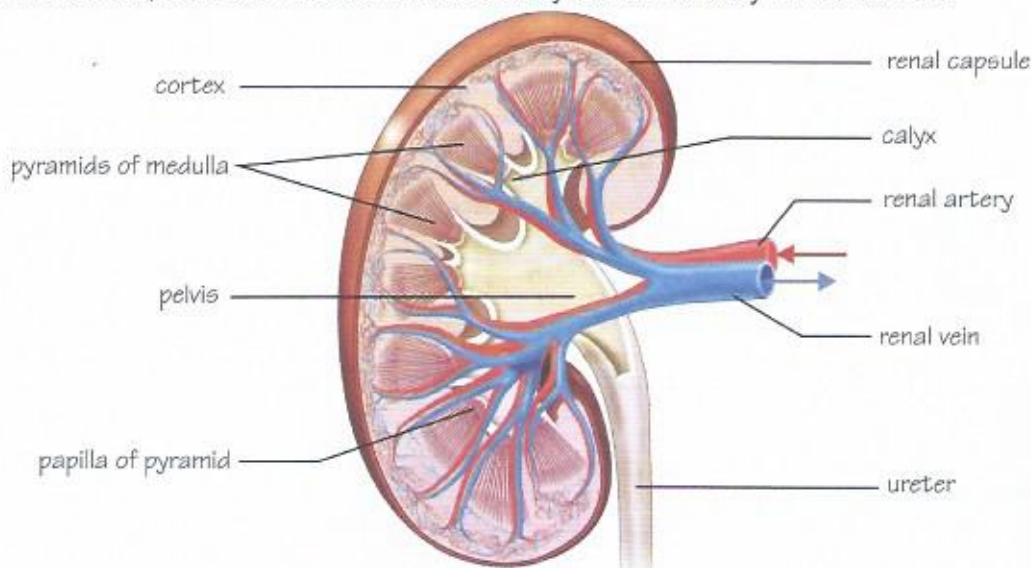
The kidneys are reddish brown bean-shaped organs, situated above the waist. The kidneys are enclosed and protected by a smooth transparent membrane, the renal capsule, which also maintains the shape of the kidneys.

Internal structure of the kidney (Macroscopic structure)

A section through the kidney shows two distinct regions: an outer reddish part called the renal cortex, and an inner reddish-brown region called the renal medulla.

The medulla consists of a number of cone-shaped structures called pyramids. The base of a pyramid faces the cortex and the apex faces the calyx.

The renal cortex and the pyramids make up the functional portion of the kidney. The functional unit of the kidney is the nephron. About 1 million nephrons are found in each kidney. Urine formed by the nephrons drains into papillary ducts, which lead into cup-shaped calyces. The urine drains into the renal pelvis, passes down the ureters, enters the bladder and eventually leaves the body via the urethra.

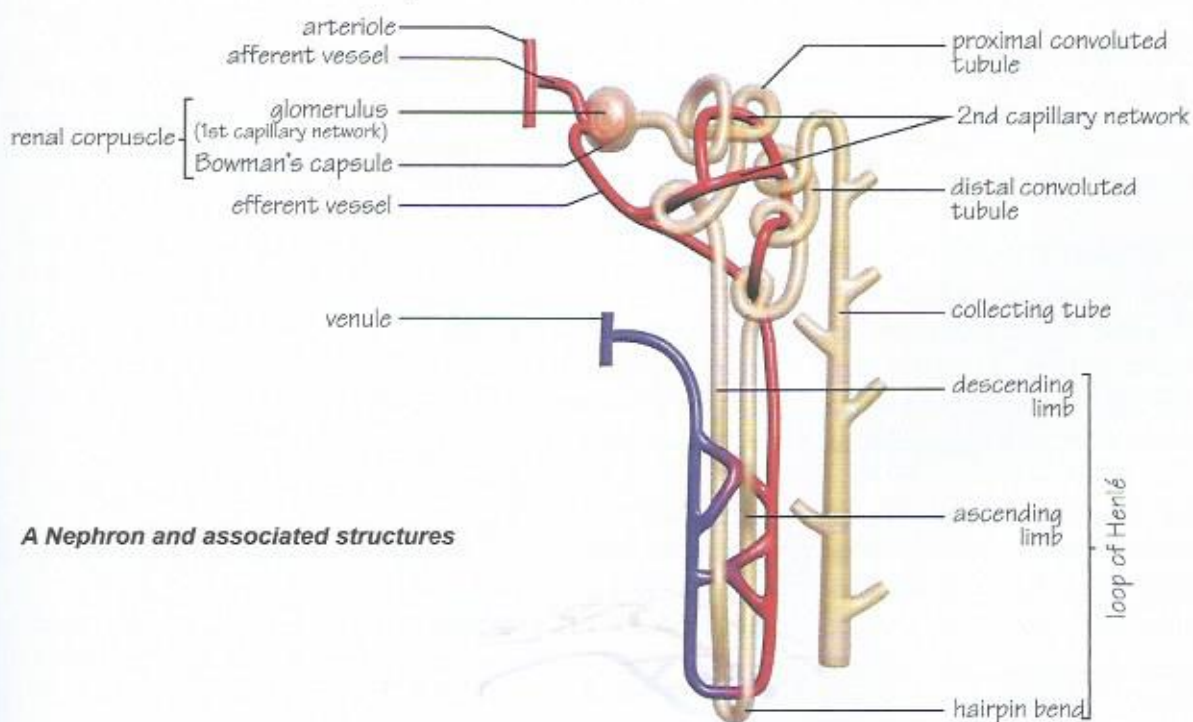


Internal structure of the kidney

Microscopic structure of the kidney (The nephron)

A nephron consists of two portions:

- a renal corpuscle (Malpighian body) where plasma is filtered and
- a renal tubule into which filtered fluid passes

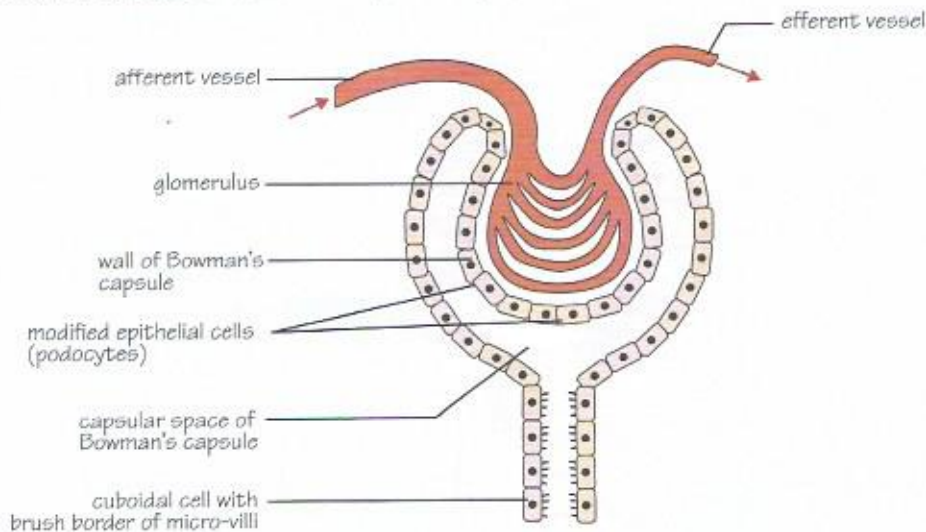


A Nephron and associated structures

a) The Renal Corpuscle (Malpighian body)

The renal corpuscle consists of two parts:

- the glomerulus: a capillary network, and
- the Bowman's capsule: a double-walled cup that surrounds the glomerulus. The outer wall of the cup has squamous epithelial cells. The inner wall consists of modified cells called podocytes, which are in close proximity to the glomerular capillaries. The podocytes and endothelial cells of the glomerular capillaries form a slit filtration membrane which acts as an ultra filter. The space between the outer and inner wall of the Bowman's capsule is called the capsular space.



A Malpighian body

b) The Renal Tubule and Ducts

The renal tubule consists of three main parts: the proximal convoluted tubule, the loop of Henlé and the distal convoluted tubule. Fluid from the capsular space passes into the renal tubules. The distal convoluted tubules of a number of nephrons empty into a single collecting duct. Collecting ducts unite to form papillary ducts which drain into calyces and then into the pelvis. From the pelvis the urine passes into the ureter, which conveys it to the bladder.

c) Blood supply of the Nephron

The renal artery, a branch of the abdominal aorta, enters the kidney and branches into small arterioles. The afferent blood vessel divides into finer capillaries to form the glomerular capillaries, which reunite to form the efferent vessel. The efferent vessel divides to form a network of capillaries around the tubules. These blood vessels eventually unite to form the renal vein which then joins the inferior vena cava.

The Functioning of the Kidney

The kidneys perform the following functions:

- Excretion of nitrogenous wastes and poisonous substances e.g. food additives in urine.
- Osmoregulation, by controlling the water content of body fluids.
- Regulation of blood pH, by ensuring that the pH is kept at about 7.4.
- Salt regulation, by extracting excess salts from the blood.

Blood in the glomerulus has the following constituents:

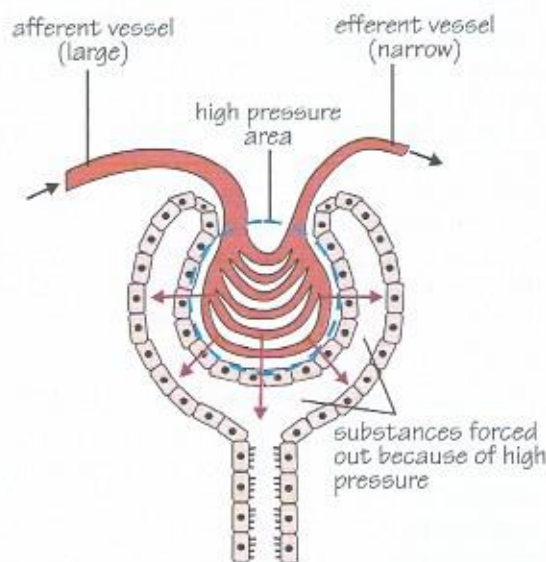
- useful substances such as water, ions, glucose, amino acids, vitamins, fatty acids and glycerol.
- waste substances, e.g. urea, uric acid and creatinine.
- normal blood constituents (blood plasma, proteins RBC and WBC).

The nephron is the functional unit of the kidney.

Functioning of the kidney

a) Glomerular Filtration (Ultra Filtration)

- Blood in the glomerulus is under pressure since the afferent vessel is larger in diameter than the efferent vessel.
- The increased pressure forces out both useful and harmful substances through the glomerulus and inner wall of the Bowman's capsule, into the capsular space.
- The tiny pores in the capillary wall of the glomerulus and the specialised cells (called podocytes) forming the wall of the inner cup of the Bowman's capsule, together form an ultra filter with slit pores, which selectively allow certain substances to pass through.
- Substances that pass through include: water, glucose, amino acids, urea and uric acid.
- Large substances like plasma proteins and blood cells do not filter through.
- The fluid, together with the dissolved substances, that enters the capsular space is called the glomerular filtrate.
- The glomerular filtrate contains both useful substances and waste products.
- The glomerular filtrate passes along the renal tubules.



Glomerular filtration

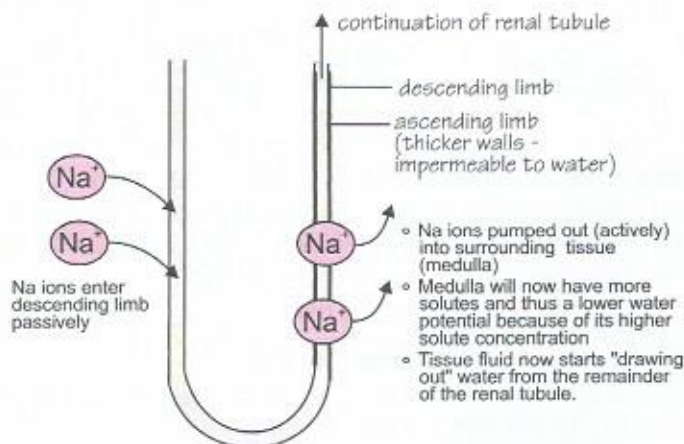
b) Tubular Reabsorption

The renal tubules consist of a single layer of cuboidal epithelial cells with brush border microvilli and numerous mitochondria. About 99% of the filtrate passing through the renal tubules is selectively reabsorbed; a process which is active (energy required), beginning at the capillary network of the proximal convoluted tubule.

- In the proximal convoluted tubule, some water and almost all the glucose and other useful substances are selectively reabsorbed by the second capillary network.
- The process of selective reabsorption is an active process requiring energy, which is obtained from the mitochondria of the cuboidal cells.
- The filtrate passes through the convoluted tubule and enters the loop of Henlé.
- The function of the loop of Henlé is to ensure that the medulla has a high concentration of sodium ions, i.e. a low water potential when compared to the tubular fluid, to ensure that the maximum amount of water is removed from the tubular fluid.
- Sodium ions diffuse passively into the tubular fluid along the descending limb of the loop of Henlé.

The Sodium Pump

- Sodium ions diffuse passively into the tubular fluid along the descending loop of Henlé, whilst water leaves the tubular loop of Henlé, via osmosis.
- In order to facilitate the reabsorption of the remaining water by osmosis, sodium ions are actively (energy involved) pumped out of the ascending limb of the loop of Henlé into the tissue fluid of the medulla.
- This sodium pump mechanism ensures that the water potential of the tubular fluid is raised.
- The concentration of solutes in the medulla is now high, causing its water potential to be low.
- Water does not leave the ascending limb as its thicker walls are impermeable to water.



The sodium pump mechanism of the loop of Henlé

- In the distal convoluted tubule and collecting ducts, water is reabsorbed by osmosis out of the tubules and into the medulla, and finally back into the blood. Water is therefore conserved.
- The remaining fluid in the collecting tubule is known as urine.
- The antidiuretic hormone (ADH) regulates the re-absorption of water from the tubules into the blood capillaries.

c) Tubular excretion

The epithelial cells of the tubules also excrete substances into the tubules. Tubular excretion is the movement of substances from the blood into the tubular fluid. Excreted substances include hydrogen ions, potassium ions, ammonium ions, creatinine and certain drugs e.g. penicillin. The excretion of these substances into the tubules is an active (energy requiring) transport mechanism.

The pH of the blood is regulated by the amount of hydrogen ions (acid) and bicarbonate ions (alkaline) present. If the blood becomes too acidic, then the tubules extract more hydrogen ions from the blood; if too alkaline, then more bicarbonate ions are extracted.

Note: Ammonia is manufactured by the epithelial cells of the tubules (kidney metabolism) and excreted into tubular fluid as ammonium ions.

The tubular fluid (urine) passes along the collecting tubule. A number of collecting tubules from other nephrons unite to eventually form a much larger tube called the duct of Bellini, which pours urine into the pelvis. The urine travels down the ureter, to the bladder, where it is temporarily stored, until it is released to the exterior via the urethra.

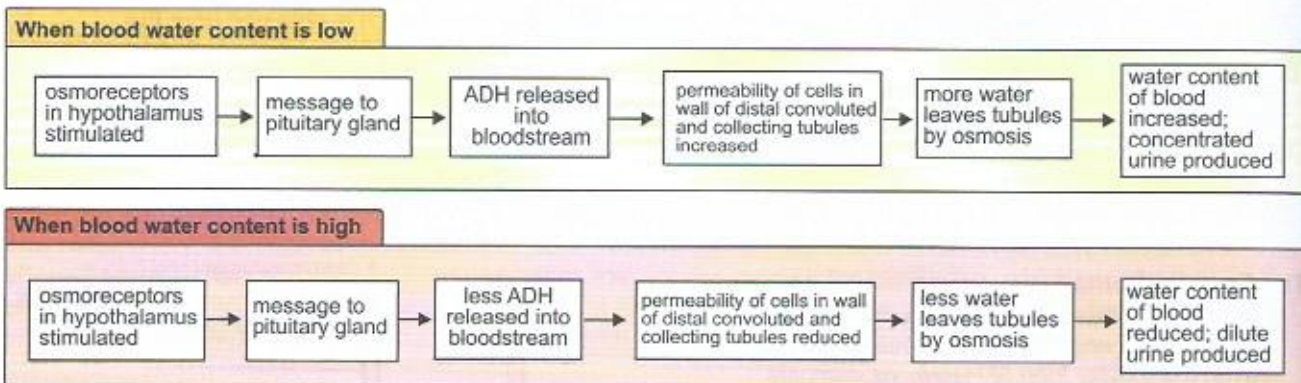
The role of antidiuretic hormone (ADH) in osmoregulation

ADH controls the amount of water re-absorbed by the blood in the capillaries within the medulla. It is produced by the hypothalamus and released into the blood stream by the pituitary gland. The release of ADH depends on negative feedback.

When the water content of blood is low, osmoreceptors in the hypothalamus are stimulated. A message is sent to the pituitary gland, which now releases ADH into the bloodstream. ADH increases the permeability of the cells in the wall of the distal convoluted tubule and the collecting tube. More water now leaves the tubule by osmosis and enters the blood in capillaries in the medulla. The water content of the blood therefore increases and the urine becomes more concentrated.

When the water content of the blood is high, osmoreceptors in the hypothalamus are stimulated. A message is sent to the pituitary gland and less ADH is released into the blood. Due to the low level of ADH in the blood, the permeability of the cells of the distal convoluted tubule and collecting tubules is reduced. Less water leaves the tubules. Dilute urine is passed out.

In summary:



The role of aldosterone in osmoregulation

Aldosterone is secreted by the adrenal glands. It controls the sodium levels of the blood in the capillaries surrounding the renal tubules. It has a direct effect on the sodium pump mechanism.

If sodium levels in the blood fall, the adrenal glands secrete aldosterone, which causes more sodium to leave the loop of Henlé and return to the blood.

Composition of "normal" urine

The composition of urine is not constant. Factors such as nature of the diet and the amount of liquid intake, amongst others, affect its composition.

Under normal conditions urine contains urea, uric acid, salts and water, and excess ions like potassium and hydrogen.

Dilute urine contains less solutes in a given volume than blood. The reabsorption of ions such as sodium, potassium and chlorine from the tubular fluid reduces the solute content of urine.

Low water intake or excessive loss of water, results in concentrated urine. The kidneys must still conserve water. This is achieved by water being reabsorbed by the blood, resulting in a small volume of concentrated urine.

The structural suitability of the kidneys in carrying out its functions

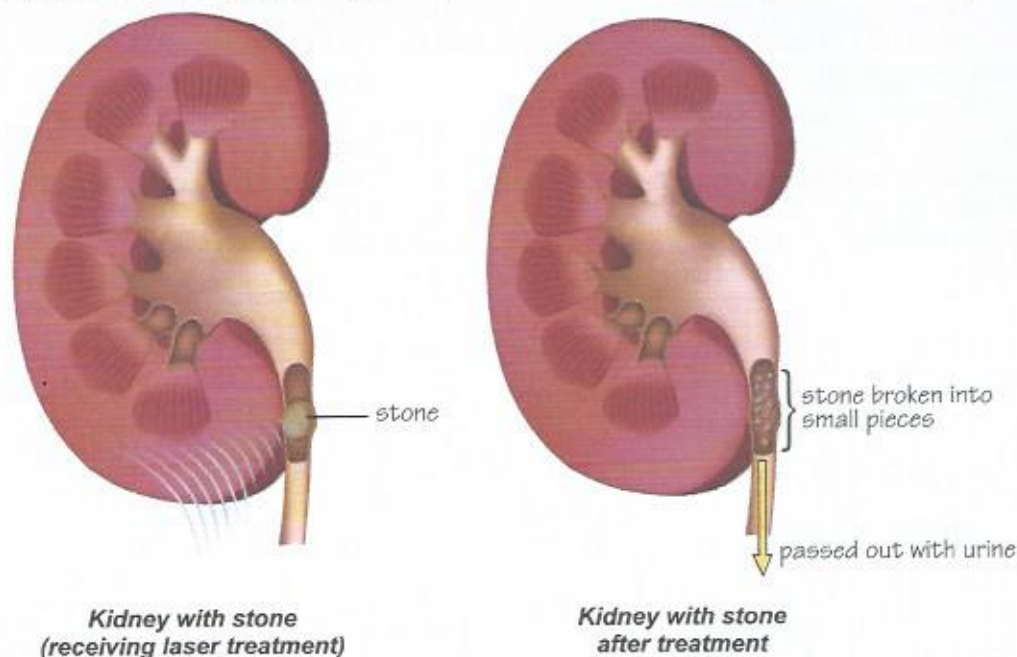
- The afferent blood vessel is wider than the efferent blood vessel. This causes a pressure build up in the glomerulus, which facilitates the filtration process.
- Podocytes of the Bowman's capsule and endothelial cells of the capillaries form an effective filtration membrane.
- The cup-shape of the Bowman's capsule allows for a close fitting of the glomerulus and a greater area for filtration.
- Cells of the tubules have brush border microvilli which provide a large surface area for selective reabsorption.
- The renal tubule is long and convoluted, allowing sufficient time for tubular reabsorption and excretion.
- A large number of mitochondria are present in the cells of the proximal convoluted tubule. This provides sufficient energy for active reabsorption to occur.

Diseases leading to kidney failure

1. Kidney Stones

A common disorder is the formation of kidney stones. They form from salts (calcium/urea) present in the urine. These crystals grow with time and can cause a blockage in the ureters. Kidney stones may be removed surgically, or they may be broken down into fine fragments using laser treatment.

To reduce the chances of developing kidney stones, one must drink at least 8 glasses of water per day.



2. Kidney Infection

Kidney infection is common in women. Bacterial infection starts in the bladder and spreads to the urinary tract. Kidney infection is treated with antibiotics. Symptoms include:

- Very high temperature.
- Back and side pain.
- Frequent urination.
- Pain while urinating.
- Blood/pus in urine.

3. Bilharzia

Bilharzia is a disease caused by a parasitic worm found in infected water, which enters the body via cuts in the skin. Once infected, the worms live in the blood vessels around the intestines and bladder. A symptom of bilharzia infection is the presence of blood in the urine. Bilharzia infection can lead to kidney damage.

Kidney failure

Kidney failure results when the kidneys fail to remove water, salts and nitrogenous wastes, like urea and uric acid, from the blood. Failure of the kidneys to function results in death. Haemodialysis or peritoneal dialysis is available to patients who are suffering from kidney failure.

1. Haemodialysis

This involves the use of a dialysis machine. The patient's blood, from an artery in the hand, is connected to the dialysis machine. The machine performs the functions of the kidney by removing impurities from the blood. These impurities diffuse into the dialysis fluid which is then discarded. The dialysis fluid has a similar composition to that of the blood plasma. The cleansed blood then returns to the patient's vein. This procedure has to be done at least three times a week in a hospital.

2. Peritoneal Dialysis

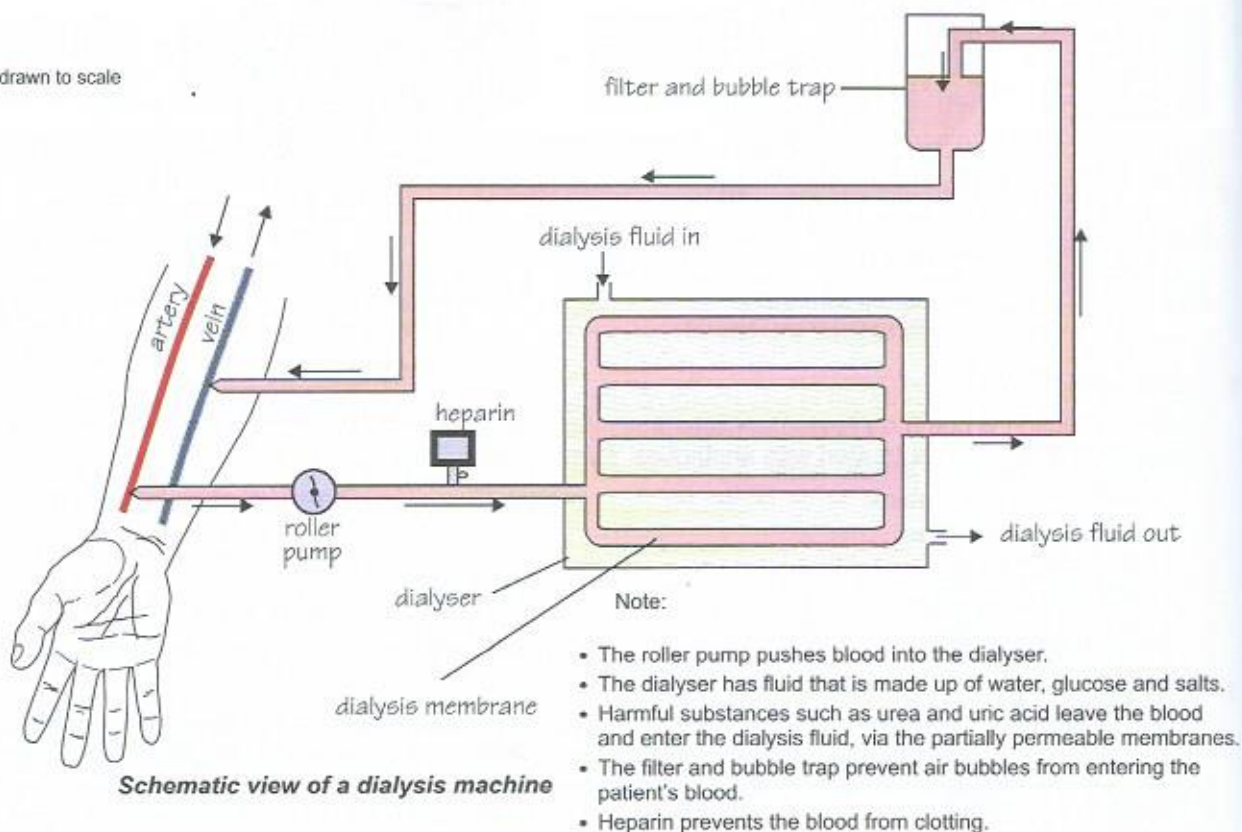
Peritoneal dialysis involves the passing of a dialysing solution into the patient's abdominal cavity. During the 4 to 6 hours of the procedure, the nitrogenous wastes and other impurities diffuse into the dialysing solution. The dialysing solution is then removed from the patient's abdominal cavity.

This draining in and draining out procedure of the dialysing solution is done at the patient's home and is very convenient. The number of times per week that the procedure has to be done depends on the extent of the kidney damage of the patient.

Advantages and disadvantages of kidney transplants vs dialysis

Kidney Transplant	Dialysis
• Once off procedure. • Operation expensive but once off. • Can lead to organ rejection. • Patient is not required to live near the hospital as the procedure is once-off. • May have difficulty finding donor. • Some religious beliefs prevent organ donation.	• Daily/every week procedure. • Relatively inexpensive but on going. • No rejection. • Procedure is time consuming, patient must live close to the hospital. • No donor is necessary. • No religion prevents dialysis procedure.

not drawn to scale



3 Environmental Studies

Section A: Population Ecology

A. POPULATION SIZE

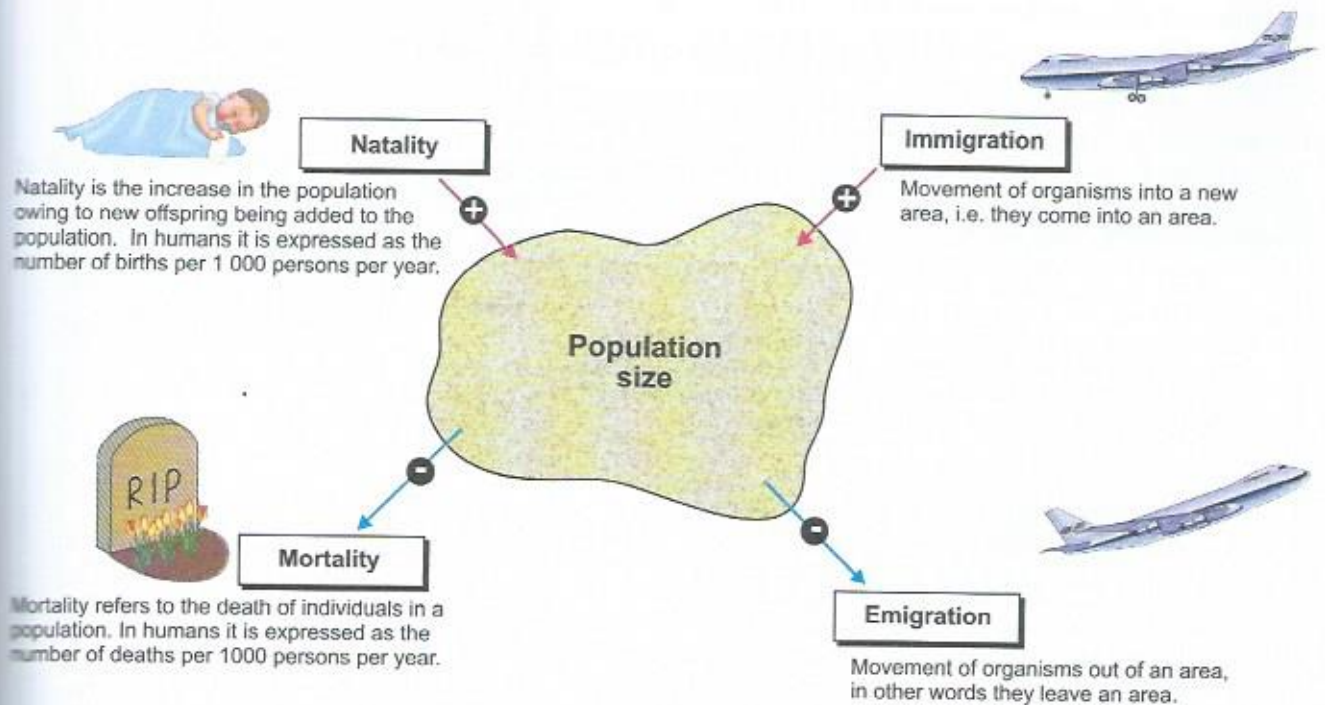
A population consists of a group of organisms of the same species which occupy the same habitat, at a particular time and are able to produce viable offspring. Example: a population of Zebra in Hluhluwe Game Reserve, a population of frogs in a pond.

Population numbers are dynamic (always changing). A population continually changes due to environmental factors and/or factors within the population.

The size of a population changes according to the season, the availability of resources, immigration, emigration, the numbers of deaths (mortality) and the number of births (natality).

The change in a population size is a balance between losses and gains in the number of individuals in that population:

- If the balance is positive, the population will grow.
- If the balance is negative, the population will decrease.



Factors that alter the size of a population, i.e. population parameters

Aspects of Population Fluctuation and Regulation

Populations will grow if the number of births and/or immigration is greater than the number of deaths and/or emigration. The maximum size a population can reach is determined by the carrying capacity of the environment.

Environmental resistance

Environmental resistance is determined by the carrying capacity of the environment, when the resources available in an ecosystem begin to limit the population's growth.

Limiting factors

There are two groups of factors that can affect a population's size:

Density independent factors

Density independent factors will affect the population size no matter how many individuals are in the population. These factors are normally abiotic, examples being, natural disasters such as earthquakes, droughts, floods and extreme temperature variations.

Density dependent factors

Density dependent factors will affect the size of a population when the population reaches a certain number or density i.e. when the population is large there will be more stress placed on resources such as food, water and space. Individuals will die because there will be competition for the limited resources.

Predation is also a density dependent factor. The density dependent factors are listed below.

- Food
- Space
- Disease
- Shelter
- Predation
- Competition
- Accumulation of waste products
- Seasonal fluctuations
- Territorial behaviour

Population Growth

The characteristic pattern of increase in the population is called its growth form. There are two main population growth forms, geometric and logistic.

1. Geometric or Exponential growth form.

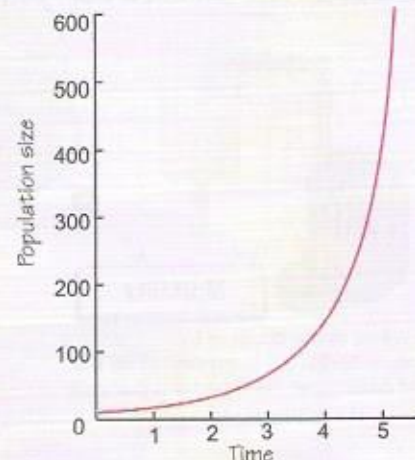
In a simple situation, in which the growth rate of a population can be easily measured and the growth of that population is unlimited, the graph of population size versus time will show that the geometric or exponential growth will have a characteristic J-shape.

Example:

The number of yeast cells in a petri dish was counted over 5 consecutive time periods of equal length and recorded as shown below. A graph of the number of yeast cells was plotted against the time period. The graph is shown alongside.

Period No.	1	2	3	4	5
No. of yeast cells	20	45	83	140	395

In reality, population growth that is exponential and unchecked leads to an unstable environment. The increased population will eventually exhaust the supply of natural resources, such as food. The environment, because it cannot supply enough resources, resists the increase in numbers i.e. environmental resistance occurs and the population will stop growing exponentially.



Geometric or Exponential growth form

2. Logistic growth form

The logistic growth form of a population can be represented by an **S-shape** graph (next page).

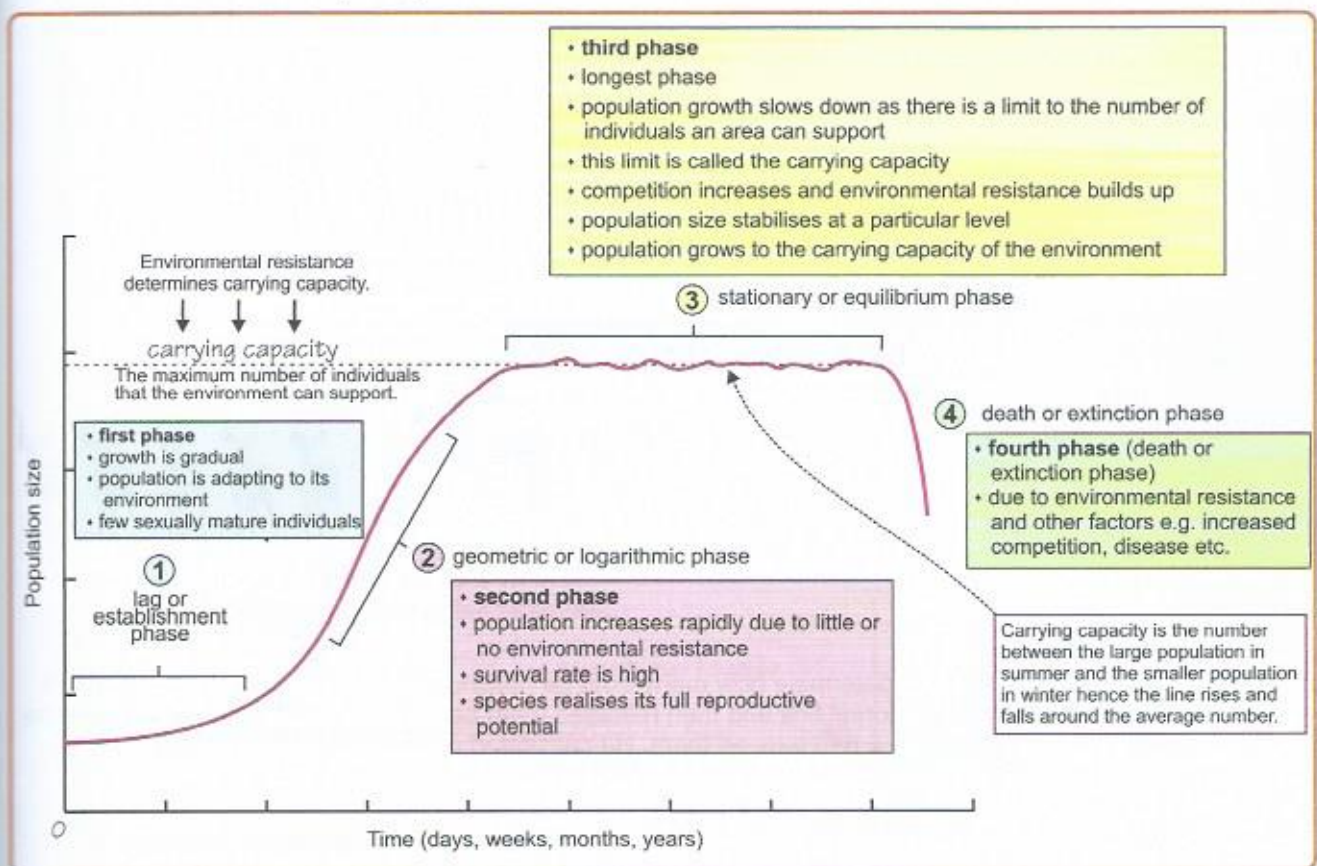
If, for example three zebra, one male and two females are introduced into a new area, it will take some time before the animals settle down into their new habitat. The animals need time to mature and then reproduce. A few years later, two zebra foals are born. The population number has now increased to five. The offspring have to grow and mature before they are able to reproduce. The population slowly begins to increase. This period of time is known as the **lag phase** (labelled 1 on the graph).

In the early stages, the population is not affected by limiting factors such as food and space, and growth therefore becomes exponential. This growth phase is known as the **geometric or logarithmic phase** (labelled 2 on the graph).

When the population becomes too large for available resources, especially in the winter months when food and water are in short supply, the resources can no longer hold the whole population. The weak, sick and old individuals will be the first to die. This will decrease the population so leaving the available resources for the stronger individuals. In the spring, offspring will be born, so increasing the population size. The population size changes between small numbers in winter, to larger numbers in summer. The **average number** of these two population sizes is known as the **carrying capacity** of the habitat i.e. the maximum number of individuals that the habitat can support or "carry" on a sustainable basis.

The environment resists an increase in the population numbers as it does not have the resources to support an ever-increasing population i.e. environmental resistance occurs. The population numbers eventually level out and stabilise at the carrying capacity. This phase is known as the stationary or **equilibrium phase**. (labelled 3 on the graph).

These populations can be adversely affected by drought or disease and the environment can no longer support the population. The population will then decrease and this phase is known as the death or extinction phase (labelled 4 on the graph). As this phase can affect the population at any stage in its growth, these factors are known as density independent factors.



A logistic growth form

Determining Population Size

When working with populations, an ecologist must establish the number of individuals in a population. Depending on the species and habitat, some populations can be counted directly. It is not always possible to obtain an exact number of a population, so an estimated number may be taken. A sample of the population is then used to estimate the size of the total population.

Some commonly used counting methods are:

a) Direct method

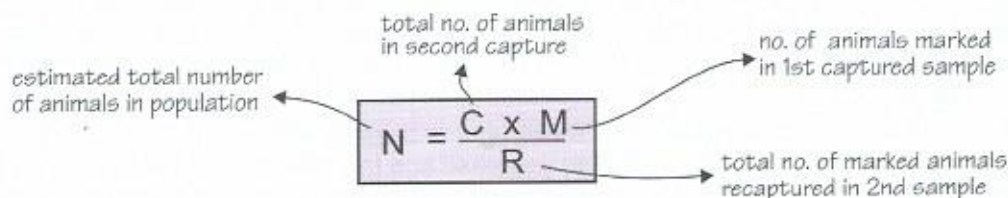
Total counts (census)

Total count (census) involves the counting of every individual in the population. It can only be used on very large animals such as elephants, people and sedentary (stationary) animals such as barnacles in a rock pool.

b) Indirect Methods

i) Mark-recapture method

The mark-recapture method involves the capturing of a small sample of the animal population. The animals in the first sample are **Marked (M)**, either by tags or non-toxic paint and then released back into the population. The animals are then allowed to mix with the rest of the population before a second **Capture (C)** is made. The number of previously marked animals **Recaptured (R)** in this sample is counted. The size of the population can be estimated by using these figures in the **Petersen Index**.



The animals captured in the second sample are then released to remix with the rest of the population and after another period of time another capture is undertaken. This procedure is carried out a number of times and the average of all the captures determined.

Example 1: In a game park, 5 kudu were trapped and marked with a tag and then released. After a period of time a second capture of 10 kudu was made. Two of those kudu had tags. Estimate the total kudu population of this game park.

Solution:

$$\begin{aligned} N &= \frac{C \times M}{R} \\ &= \frac{10 \times 5}{2} \\ &= 25 \text{ kudu} \end{aligned}$$



These 5 were released ...

... and second capture made after a period of time



Example 2: A trout farmer wants to determine how many trout he has in a dam. He caught 40 trout, tagged them carefully on their dorsal fins and then released them back into the dam. A few days later he caught 20 trout of which 8 had tags on them. He calculated an estimate of the total number of trout in the dam as follows:.

Solution:

$$\begin{aligned} C &= 20 \\ M &= 40 \\ R &= 8 \end{aligned}$$

$$\begin{aligned} N &= \frac{C \times M}{R} \\ &= \frac{20 \times 40}{8} \\ &= 100 \text{ trout} \end{aligned}$$

The following precautions will ensure a greater accuracy when using this method:

- The mark must not harm nor affect the animals' behaviour, movement or acceptance within the population.
- The mark must last for the entire period of the investigation.
- The population must be a closed population i.e. no immigration or emigration must take place during sampling and the count must not be undertaken during the breeding season.
- Sufficient time must be allowed for the marked animals to mix with the population before the 2nd capture is made.
- The chances of animals being captured must not be affected by the method of capture i.e. they should not be able to avoid capture because of previous experience and they must not be attracted to the trap either by food or shelter.
- A number of samples should be taken and an average result calculated to reliably estimate the total population size.

ii) The Quadrat Method

The quadrat method can be used for plants, slow-moving animals such as snails or sedentary animals such as oysters on rocks. A quadrat is a square-shaped sampling frame. A metal or wooden frame 50 cm x 50 cm ($0.5 \text{ m} \times 0.5 \text{ m} = 0.25 \text{ m}^2$) in size is used.

The use of the quadrat method is explained in the following example:

The number of weeds in a school hockey field were to be counted. The field measured 100 m by 20 m ($100 \text{ m} \times 20 \text{ m} = 2000 \text{ m}^2$). In order to estimate the weed population, a person walked over the field dropping the quadrat frame randomly behind him. This would ensure that he would not consciously choose an area where weeds were or were not growing. The numbers of weeds growing in the area within the frame were counted. This was repeated ten times and the results are shown in the table below. Once the average number of weeds per quadrat was calculated, the formula given below could be used.

A generalised formula is:

$$\text{Estimated total number in population} = \frac{\text{Average no. of individuals per quadrat} \times \text{total area}}{\text{quadrat area}}$$

Sample no.	No. of weeds in sample quadrat
1	25
2	13
3	60
4	35
5	93
6	45
7	19
8	89
9	123
10	48
Total	550

quadrat area

1. Find the average number of weeds per quadrat:

$$\text{Average} = \frac{550 \text{ weeds}}{10 \text{ quadrats}} = 55 \text{ weeds per quadrat}$$

2. Determine the area of the quadrat: (note 50 cm = 0.5 m) given

$$\text{Area of quadrat} = 0.5 \text{ m} \times 0.5 \text{ m} = 0.25 \text{ m}^2$$

3. Determine the area of the field: 2 000 m² (given)

4. Determine how many quadrats will fit in the field:

$$\begin{aligned} \text{No. of quadrats} &= \text{field area} \div \text{area of quadrat} \\ &= 2\,000 \div 0.25 \\ &= 8\,000 \text{ quadrats} \end{aligned}$$

5. Determine the total number of weeds:

$$\begin{aligned} \text{No. of weeds} &= \text{av. no. of weeds per quadrat} \times \text{no. of quadrats} \\ &= 55 \times 8\,000 \\ &= 440\,000 \text{ weeds} \end{aligned}$$

Or simply ...

$$\text{Av. no. per quadrat} = \frac{550}{10} = 55 \text{ weeds}$$

$$\text{Estimated total no.} = \frac{55 \times 2000}{0.25}$$

$$= 440\,000 \text{ weeds}$$

Practical Work

Experiment 1

The simulation of simple sampling

This experiment is simulated using 50 g of small coloured beads in 500g of sawdust. The coloured beads represent the organism and the sawdust the habitat.

The beads and sawdust are placed in a container and shaken well. A sample is then removed from the container, e.g. 5g (1% of the habitat) and placed in a petri dish. The number of beads (organisms) are then counted and noted. The whole sample is then returned to the container.

The above procedure is repeated several times. The total number of beads for each sample is then determined by the formula below.

$$\text{Total No. of beads} = \frac{\text{total mass of beads+sawdust}}{\text{mass of sample}} \times \text{No. of beads in sample}$$

$$\text{Example: } \frac{50\text{g} + 500\text{g}}{5\text{g}} \times \frac{3}{1} = 330 \text{ beads}$$

Results and Calculation

Sample No	No. of Beads in sample	Est. of Tot No. of beads
1	3	330
2	2	220
3	2	220
4	1	110
5	4	440
Average		264

Discussion

- By repeating the experiment and taking more samples the reliability of our estimate is increased.
- The randomness of the sample is dependent on the investigator: how well the beads and sawdust are mixed and from which section of the mixture the sample is taken.
- Heavy beads will tend to settle at the bottom of the beads-sawdust mixture, affecting the bead distribution in the sample.

Experiment 2

The simulation of the Mark-Recapture Technique

This experiment simulates the procedure used to estimate the total population by the mark-recapture technique. This technique is used for animal populations.

A jar is filled with kidney beans. Forty beans are removed from the jar and marked with a felt-tipped pen (N). The beans are then placed back into the container and shaken well to ensure adequate mixing. A sample of beans is then removed by hand from the jar.

The total number of beans are first counted and noted (C), then the number of marked beans are counted and noted (R). The sample is then put back in the jar and shaken well.

The total number of beans is then estimated using the Petersen-Lincoln index:

$$N = \frac{C \times M}{R}$$

N = Estimated number
C = No. caught in sample
M = No. originally marked
R = No. marked in sample

The procedure mentioned is repeated several times.

Results and Calculations

you calculate and fill in this column

Sample #	No. in Sample (C)	No. marked in sample (R)	Estimate of the total no. of beans
1	15	5	120
2	12	3	160
3	14	3	187
4	10	1	400
5	16	4	160
Average			205

$$\begin{aligned} \text{Example: } N &= \frac{C \times M}{R} \\ &= \frac{15 \times 40}{5} \\ &= 120 \end{aligned}$$

Discussion

- A number of samples are taken to increase the reliability of the estimate.
- The average is also taken for increased reliability.
- The results of a single sample cannot represent the actual number of animals in a habitat. A number of factors determine the number of animals at a given location at a given time, e.g. availability of food and water.

B. Interactions in the Environment

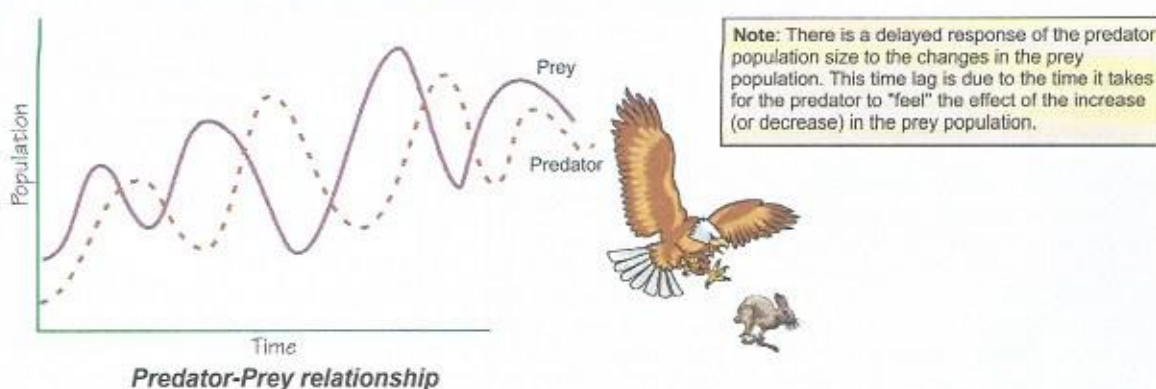
1. Predation

In each ecosystem there are interactions between predators and prey. A **predator** is an animal that hunts down living prey, kills it and eats it; **prey** is the animal that is killed and eaten.

As predators are dependent on their prey for survival, the predator population must not be too large, as over-predation will lead to elimination of the prey species. The graph below shows the typical rise and fall in population numbers in a predator-prey relationship.

In the graph it can be seen that there is a delayed response to the change in the prey population. This time lag is due to the time it takes for the predator to react to the effect of the increase or decrease in the prey population.

During a season with abundant grazing, the prey species, for example, springbok, may increase in number. As a result there is more food for the predators, the lions, and the predator population will then increase as the stronger, healthier lions produce more lion cubs. Increased predation results and the springbok population decreases. The predators now struggle to find sufficient food and as a result starvation kills off some of the weaker predators and survival will decrease. The predator population is thus stabilised or at a level that can be supported by the prey population.



The Martial eagle is a very large eagle found in South Africa. It preys on other birds such as storks and guinea fowl. In some cases it kills young impala, baboons and mongooses. It usually circles high above its prey then swoops down suddenly catching its prey by surprise. The graph above can also be applied to the martial eagle and its prey, showing a similar lag as depicted in the graph.

2. Competition

All living organisms have to compete with other organisms for food, shelter, space, breeding mates and even sunlight in the case of plants. In order for a population to survive and thrive, it must reproduce faster than the minimal rate of mortality, in other words there must be a higher birth rate than death rate in a given time period. Overcrowding of a particular habitat may result in emigration. Competition for limited resources can result in an increased risk of exposure to predators, disease and starvation, all of which will increase the death rate in the weaker organisms.

Intraspecific competition

Individuals of the same species competing for a resource. For example white rhinos will compete amongst themselves for water during a drought. Intraspecific competition may encourage aggressive behaviour in animals and plays an important role in establishing dominant hierarchies in populations.

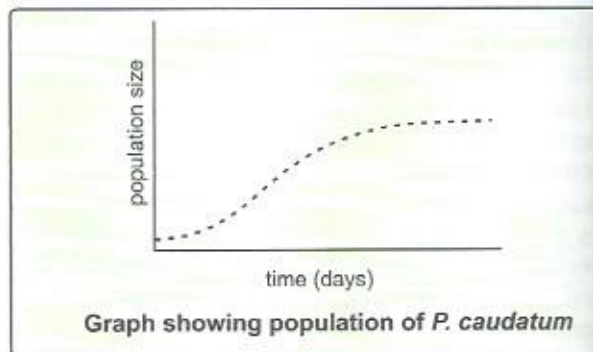
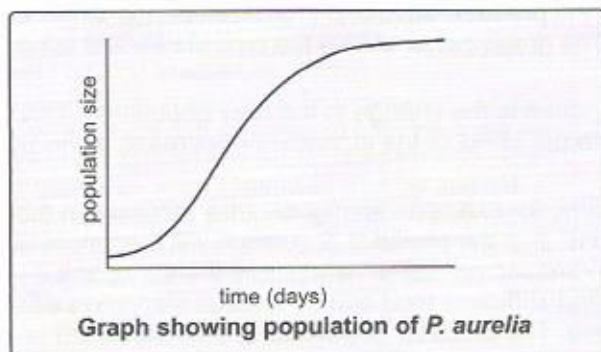


Interspecific competition

Individuals from different species competing for the same resources. For example zebra and white rhino would compete for space and grazing in a particular habitat. Interspecific competition between two different species inhabiting the same area, can result in the decline and eventual extinction of one of the species.

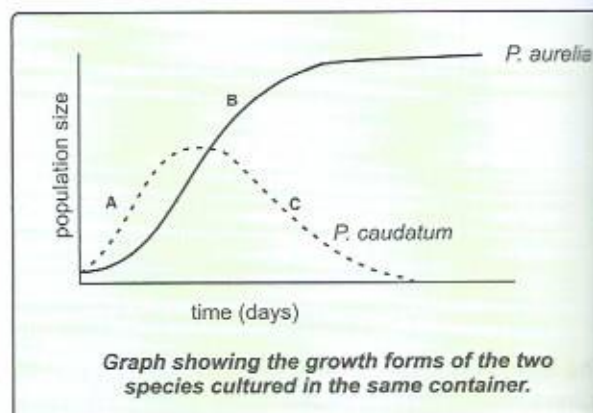


An experiment to illustrate interspecific competition was carried out by Guase, a Russian ecologist, using two different species of *Paramecium*. He placed *Paramecium aurelia* in one container with a bacterial broth to provide nutrients and *Paramecium caudatum* in a second container also with bacterial broth. Waste products from the containers were constantly removed during the experiment so that they did not affect the growth of the organisms. The two different growth forms which resulted are shown below.



Guase then placed both species into the same container (environment) and allowed them time to reproduce. The results of this experiment are shown in the graph below.

The results of the first experiment show that when the two species were cultured (grown) in their own containers (environments), each species survived and increased in size, but *P. aurelia* had a greater overall growth rate. When the two species were placed in the same environment in the second experiment, *P. caudatum* initially thrives (see graph at A) but at B on the graph, *P. aurelia* experiences exponential growth and out-competes *P. caudatum* until *P. caudatum* begins to die out as shown at C on the graph. *P. aurelia* is possibly a stronger paramecium and survives better in a restricted environment and reproduces well, therefore there are more of that particular species to make use of the limited resources such as food and space. The principle explained above is known as the:



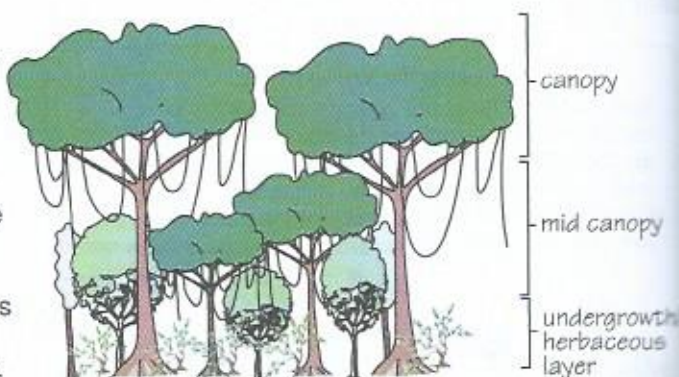
Competitive Exclusion Principle which states that two organisms cannot use the same resources in the same ecological niche and coexist indefinitely.

Resource partitioning

Resource partitioning involves different species living in the same habitat, but using different resources. In this way species live in harmony or co-exist so that they all can survive.

i) Stratification in forest ecosystems

In a forest, plants compete for light, water and space. This results in a layering or "stratification", of the plants. The tallest plants in the canopy, usually trees, require a lot of light for photosynthesis. The shorter plants (herbaceous layer/undergrowth) growing close to the ground under the trees are shade-loving plants and are able to photosynthesise at a lower light intensity. There are also other plant species (mid-canopy) found in between these two layers, which have moderate light requirements. This is a clear example of resource partitioning, as the plants have evolved to use the same resource, light, but at different intensities.



Stratification in a forest

ii) Coexistence of the large predators: lions and leopards

Lions and leopards live in similar habitats and are both predators. If they both relied on identical prey it would lead to interspecific competition. Lions prey on medium to large mammals including zebra, buffalo, giraffe and antelope. Leopards prey on a wider range of animals. Their diet includes insects, reptiles, fish and birds but their main prey is antelope. These two predators have evolved temporal partitioning. Lions tend to hunt during the day while leopards hunt at night. By preying on different animals, at different times of the day, lions and leopards can co-exist in the same area and not be in direct competition with each other.



Lions feeding on a hippo



Leopard with its kill

3. Symbiosis (means "living together")

Symbiosis is the relationship between two different species of organisms that are interdependent. One member of the relationship will always benefit and the other member may benefit (mutualism), may not be affected (commensalism), or may be harmed (parasitism).

i) Mutualism

This is a relationship in which **both organisms benefit**.

Example 1: Oxpecker and buffalo

Oxpeckers are birds that sit on the back of large animals such as buffalo and oxen. The oxpecker removes ticks from the skin of the animal so providing food for itself and benefitting the buffalo/ oxen by removing harmful ticks.

Example 2: Fungi are not capable of photosynthesising as they do not contain chlorophyll. Algae do contain chlorophyll and can photosynthesise. Lichen is a composite organism consisting of a fungus growing in close association with algae. It can be found growing on trees and rocks and appears as a blue, orange or grey growth. The two separate organisms cannot be seen with the naked eye, but under a microscope it is evident that there are two organisms living together, each providing the other with benefits: the algae photosynthesise and provide food for the fungus and the fungus traps moisture from the air to be used by the algae.

Another example would be Nitrogen-fixing bacteria in the root nodules of legumes (refer Chapter 1).



An oxpecker looking for ticks

ii) Commensalism

In this relationship **one partner benefits** and the **other is not affected**.



Example 1: Egrets and cattle.

An example of commensalism is the relationship between cattle egrets and the bovine family (cattle, buffalo). Cattle egrets are white birds that stay close to the cattle. When cattle eat, they disturb the vegetation in which the egret's prey lives, making the prey easier to catch because the insects, worms and frogs are flushed out of the grass by the herbivore.

Example 2: Remora fish and sharks

The remora is a sucker-fish that lives in close association with sharks or other larger fish. The top or dorsal fin of the sucker-fish is modified to form a sucker. This sucker is used to attach the remora to the shark. The sucker-fish is small and does not harm or benefit the shark, but it is protected from predators and lives on the bits of leftover food generated when the shark eats its prey.



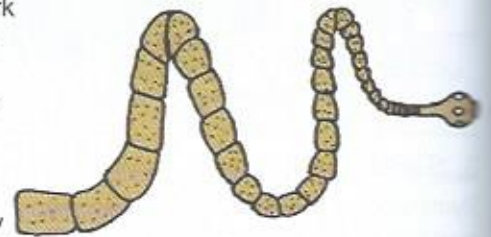
Remora fish attached to a shark

iii) Parasitism

Parasitism is a relationship in which one organism benefits and the other is harmed.

Example 1: Tapeworm (endoparasite)

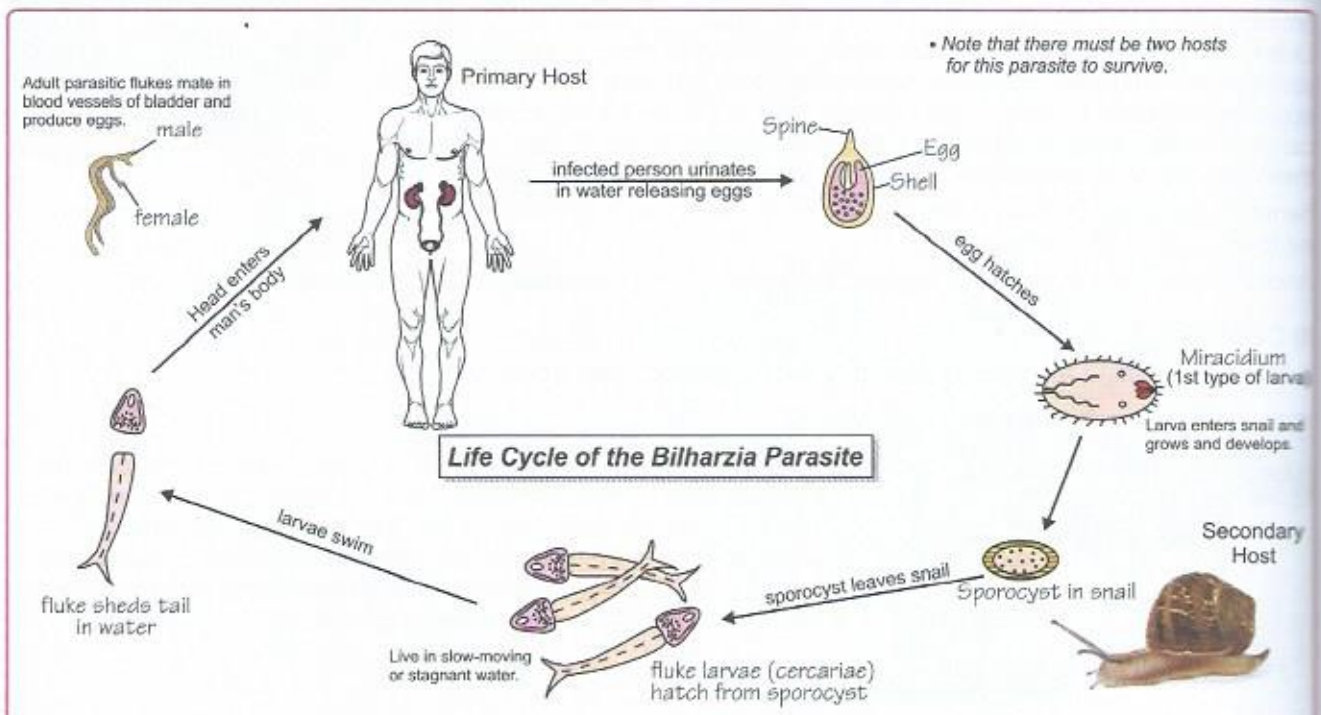
Tapeworm infection occurs in the human intestine. People acquire tapeworms (*Taenia solium*) by eating undercooked meat such as pork or from freshwater fish that contain tapeworm cysts. The cysts hatch into larvae and then develop into adult worms which latch on to the intestinal wall in order to obtain nutrients from the person. Tapeworm infestations may cause abdominal discomfort, diarrhoea or loss of appetite. If the larval cysts are found in the brain, symptoms can include headaches and seizures. Infected people pass out the tapeworm egg-bearing segments in their faeces and these eggs may be eaten by pigs or cattle completing the tapeworm life-cycle. One dose of Biltricide is usually sufficient to cure a mild infestation.



Portion of tapeworm
(can be up to 5 m long)

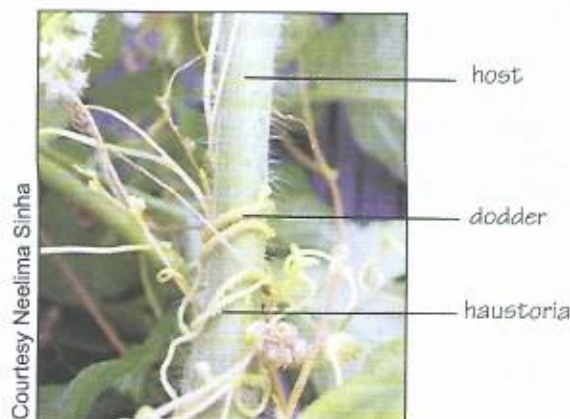
Example 2: Bilharzia (endoparasite)

Bilharzia (*Schistosoma* genus) is caused by a type of flatworm, or parasitic fluke. Fluke larvae are released by freshwater snails. When people swim in snail-infested water, these larvae penetrate the human skin and mature into adults in the human bladder. Symptoms of bilharzia include muscle pain, headache, diarrhoea, fever, vomiting, coughing, a burning sensation when passing urine, passing urine more frequently and blood in the urine. The bilharzia parasite benefits by reproducing in the human but the human is harmed by the presence of the bilharzia parasite. Untreated, bilharzia may be life-threatening.



Example 3: Dodder (Plant parasite)

Dodder is a leafless, twining, parasitic plant. Dodder contains no chlorophyll, so needs to absorb food through root-like organs called haustoria. Haustoria penetrate the stems of a host plant, and absorb nutrients from the host, sometimes killing it. The stems of the dodder may be yellow, orange, pink, or brown in colour.



Dodder on host

SOCIAL ORGANISATION

Social organisation is when members of a population live and work together to benefit the whole group. Social organisation improves the chances of survival of a species. When animals group together they experience the following advantages:

- Protection against predation. A few individuals in the group watch out for predators and give a warning signal if one does approach. This gives other individuals time to forage unhindered.
- Division of labour, so relieving some individuals to concentrate on only one task such as hunting for food.
- When a group of animals lives together they tend to come into their reproductive cycles at the same time so that they all give birth to their young around the same time
- The young offspring have a greater chance of survival, as there are many adult animals in the group to care for them and to protect them from predators.

Examples:

1. Benefits of **herds** or **flocks** as a predator avoidance strategy (safety in numbers)

Herds e.g. buffalo

When buffalo (*Syncerus caffer*) are threatened, the herd bunches together with the male adults on the outside and the females and calves in the middle of the circle. The outer animals toss their heads to threaten approaching predators.

Flocks e.g. cattle egrets (*Bubulcus ibis*)

Foraging in flocks disturbs the prey species in the grass or soil. This makes it easier to catch the prey as it leaps or flies upwards. The more birds there are the more prey will be disturbed and more food will be made available.

2. **Packs** as a successful hunting strategy e.g. wild dogs.

The African Wild Dog (*Lycaon pictus*) hunts in packs. The African Wild Dog's main prey is impala, Thomson's gazelle, springbok, kudu, reedbuck, wildebeest calves, zebras and warthogs. The dogs chase the prey in a long, open chase. Co-operation between the dogs means that only some dogs chase the prey at any one time allowing others to rest. Hunting larger prey requires a closely coordinated attack, beginning with a rapid charge to confuse the prey. One dog will take hold of the victim's tail, while another attacks the upper lip or nose, and the remainder of the dogs disembowel the animal while it is being held down. Members of a pack use yelps, squeaks and a characteristic chirping sound to help co-ordinate their movements.

After a successful hunt, hunters regurgitate (vomit up) meat for the dogs that were not present during the hunt, such as the dominant female and the pups. They will also feed other pack members, such as the sick, injured and the very old that cannot keep up, or those who stayed back to watch the pups.



Wild dogs attacking a spotted hyena

3. Animals with a **dominant breeding pair** e.g. meerkats.

In a group or gang of meerkats (*Suricata suricatta*), there is only one breeding pair, known as the dominant breeding pair, or the alpha breeding pair. The dominant female will successfully raise a litter of pups and if another female gives birth to pups, the alpha female may kill them, adopt them as her own, or allow the mother to raise them. Having a dominant breeding pair ensures that not too many offspring are produced and keeps the population size within the carrying capacity.



Meerkats

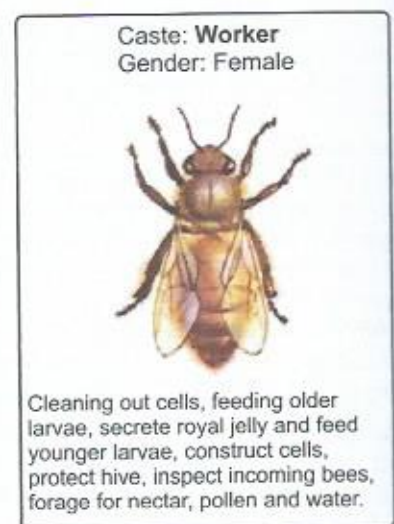
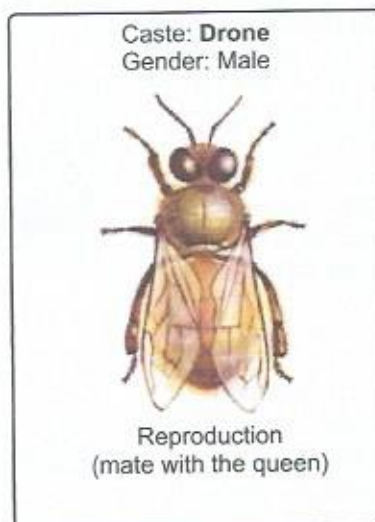
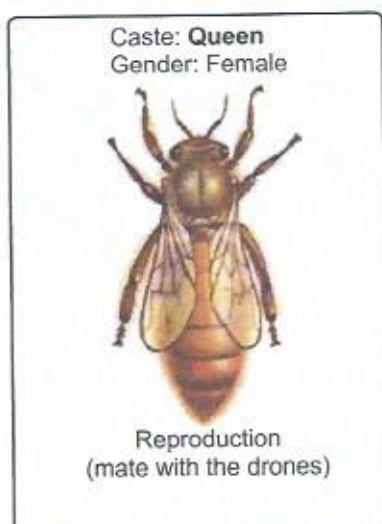
4. **Division of labour** among castes – naked mole rats, termite colonies, bees.

Division of labour allows individuals of a group to use their energy only on specific tasks. An individual performs one important task in the colony.

Bees:

Social insects live together in well organised communities or colonies. The individuals are dependent on each other for their survival.

Groups of individuals perform different tasks within the colony, specialising in a particular task. This division of labour ensures the harmonious functioning of the colony.



Courtesy Canadian Honey Council

C: Community Change Over Time

Ecological succession

The gradual process of change in the structure and function of communities over time is known as **ecological succession**, or **community development**. A community, especially vegetation, changes in response to climatic changes. As the plants change, so will the shelter and the food supply for the animals change.

There are two types of succession :

1. Primary succession

Primary succession involves the development of biotic components of a community in a new habitat, for example a bare rock, or an area of soil that has been completely cleared of all vegetation. Other examples are a newly formed sand dune at the beach, or surface mines from which all the top soil has been removed. Primary succession is a slow process as it takes a long time for topsoil to be formed.

The first species to move into or colonise a barren area are known as **pioneer species**. These species are usually blown in by the wind, such as moss and lichen spores. These plants grow close to the ground and reproduce rapidly, so establishing large populations quickly. Some secrete acids which slowly break down the rock. These low-lying plants trap soil particles that are blown in the wind and loose fragments or grains that have been worn away from rock. When small pockets of soil have developed, other seeds from grasses and small shrubs can germinate and succeed the pioneer species. This process continues over a length of time until taller plants such as trees are established and these are known as the **climax species**.

A climax community consists of all the plant and animal climax communities. It is very stable and will remain unchanged unless climatic conditions change.

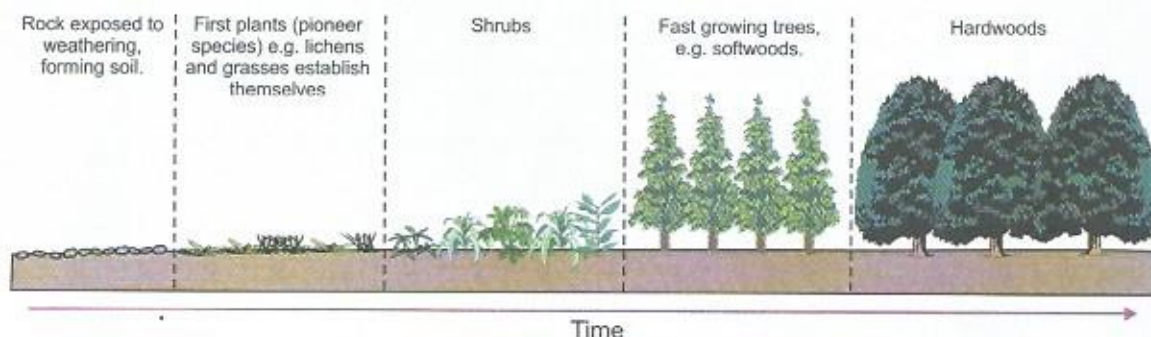


Diagram showing primary succession

2. Secondary succession

Secondary succession involves the colonisation of an area that was covered in vegetation but for some reason was cleared. Examples are landslides, abandoned farmlands, building sites, burned or cut forests, heavily polluted streams and land that was dammed or flooded to produce a shallow body of water. Secondary succession proceeds at a faster rate than primary succession because there is usually some form of topsoil remaining. The pioneer species are normally alien plants such as bug weed and lantana. These pioneers establish themselves quickly and it takes time for them to be replaced by indigenous plants.

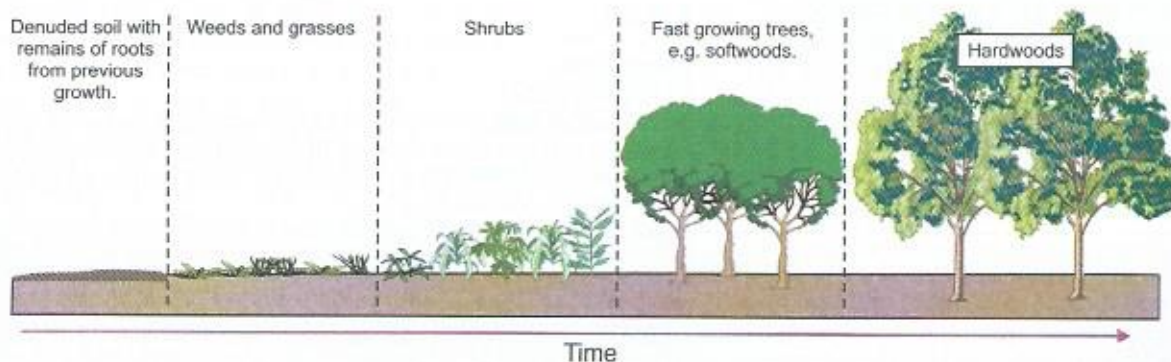


Diagram showing secondary succession

HUMAN POPULATION

The factors discussed previously can all apply to human population numbers as well. However, humans with their intelligence, have been able to manipulate and change their environment to suit their needs. If they run out of food, instead of moving to a new area, humans plant more crops, or genetically modified existing species to increase yields. If they run out of living space, they start to make use of unsuitable living areas such as reclaimed wetlands. The environment will only stand so much intervention by people and already the unlimited population growth of humans is having negative effects in such areas as climate change, extinction of some species and pollution.

Trends in Human Population Growth

Pre 1650

Determining the size of the world's population before 2 000 years ago is difficult, as no accurate records exist. The Roman's were one of the first societies to undertake a census. Using their records, plus other information, demographers estimate that around 2 000 years ago, the world's population was 250 million ($\frac{1}{4}$ of a billion) people.

Around 10 000 years ago, people started settling in communities and practicing agriculture. People began to domesticate animals and grow edible plants. The world's population 10 000 years ago was approximately 5 million people. For the next 8 000 years, the global population slowly increased to 250 million. During this time, people were at the mercy of their environment. Droughts and pests caused famines, diseases destroyed entire communities, malnutrition was extremely common and infant mortality remained very high.

Post 1650

Farming practices continually improved and by 1850 the Agricultural and Industrial Revolutions in Europe changed human populations forever. With the creation of factories, better agricultural machinery could be produced. Farming practices improved and people became better nourished. Mortality rates started declining and life expectancy increased. The world's population started growing exponentially. The table below lists some of the factors which contributed to this exponential growth.

In just 200 years, from 1650-1850, the world's population doubled and reached 1 billion.

Eighty years later, in 1930, it doubled again, reaching 2 billion people.

Forty four years later, in 1974 it reached 4 billion.

Factors causing rapid population growth from 1850

1. Improved agriculture - better yields and thus better nourishment.
2. Industrialization - better agricultural machinery, more efficient transport of goods, greater variety of food being manufactured.
3. Improved transportation - food rapidly moved from rural areas to cities.
4. Improved sanitation - development of better water supplies, water purification and sewerage disposal.
5. Better personal hygiene - soap readily available and people educated about hygiene.
6. Discovery of immunology - people vaccinated reducing the spread of diseases.

By: 1650 - 500 million

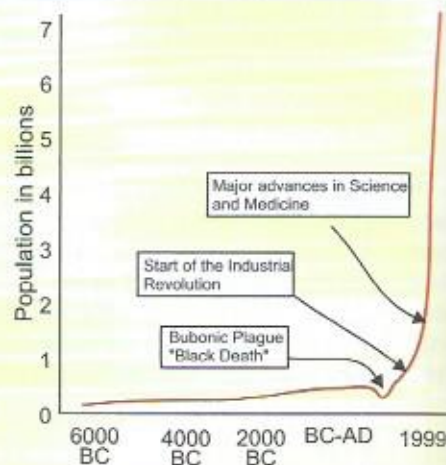
1850 - 1 billion (200 yrs later)

1930 - 2 billion (80 yrs later)

1975 - 4 billion (45 yrs later)

1999 - 6 billion (24 yrs later)

2010 - 6.9 billion (35 yrs later)



Human population size

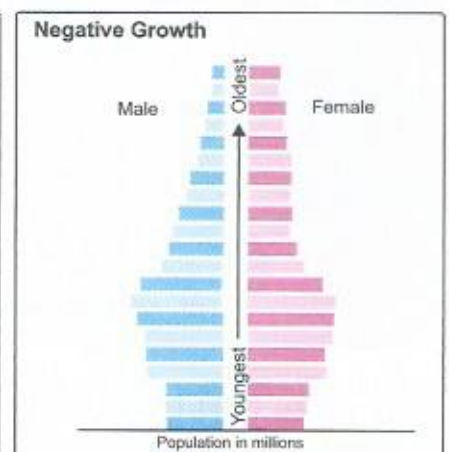
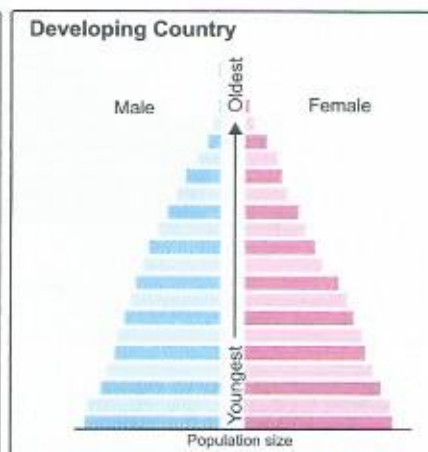
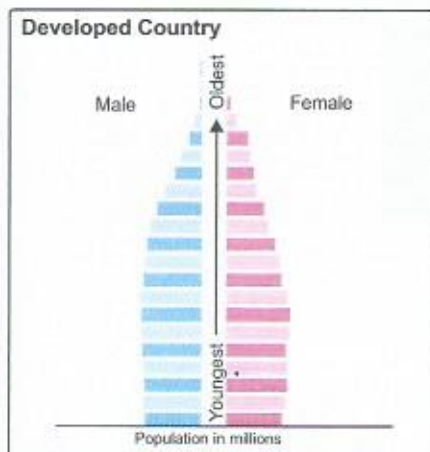
The rate of human population growth for the world has been estimated at 1,6% annually. Using this percentage, the world population for 2025 can be estimated at 8.4 billion. On 31 October 2011, the world's population stood at 7 billion (and counting).

In 2011, the world's population reached 7 billion people. Nearly 1 billion of the people living today do not receive sufficient food. Most of these people live in Africa. There are huge differences between the standards of living between people who live in developed countries and those who live in developing countries. The effects on population growth on differences in standards of living or levels of economic development can be depicted using population pyramids.

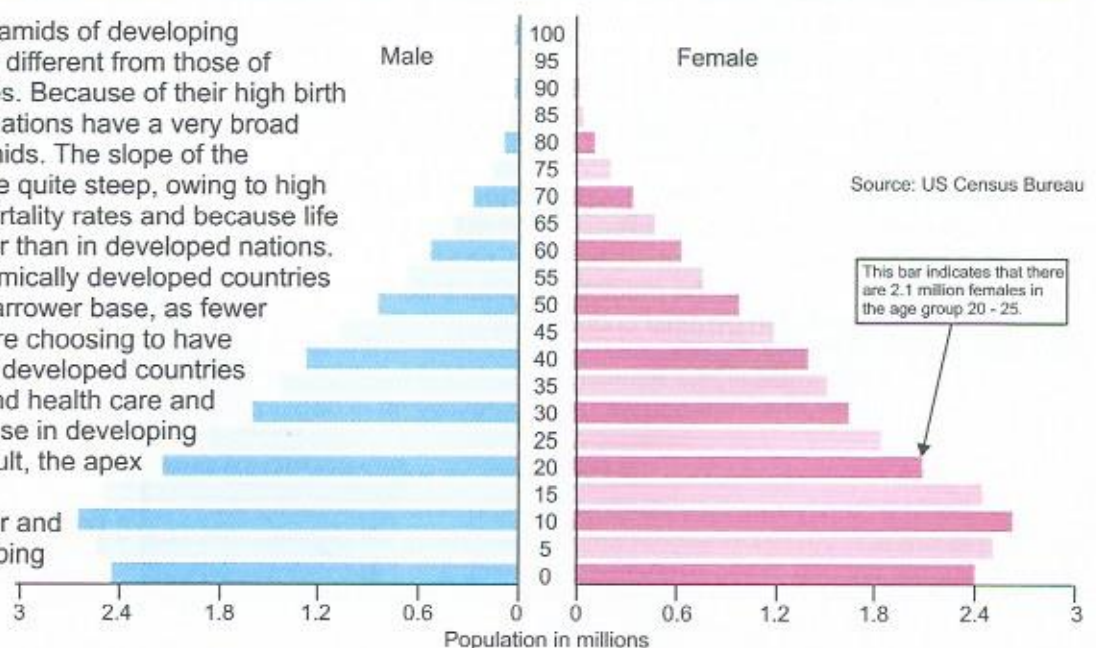
Population pyramids and economic development status

In 2011, the world's population reached 7 billion. Nearly all population growth now happens in developing nations because many developed countries have negative growth rates. Over 80% of the global population lives in developing nations, where the quality of life is low and levels of poverty are high. Most countries in Africa, South America and Asia are classified as developing. South Africa has components of both a developed and a developing nation. The table below compares some of the characteristics of developed and developing nations.

Characteristics	Developed countries	Developing countries
1. Birth rate	Low	High
2. Infant mortality rate	Low	High
3. Life expectancy	High	Low
4. Population growth rate	Low	High
5. Food availability	Very good	Poor
6. Access to clean water	Very good	Poor
7. Standard of living	Very high	Very low
8. Access to technology	Very high	Low
9. Access to good medical facilities	High	Low
Examples of countries	USA, UK, France, Japan, Australia	Brazil, Zambia, India



The population pyramids of developing countries look very different from those of developed countries. Because of their high birth rates, developing nations have a very broad base to their pyramids. The slope of the pyramid tends to be quite steep, owing to high infant and child mortality rates and because life expectancy is lower than in developed nations. By contrast, economically developed countries have a relatively narrower base, as fewer educated people are choosing to have children. People in developed countries have better food and health care and live longer than those in developing countries. As a result, the apex of their population pyramids is broader and higher than developing nations.



Some developed nations have a negative growth rate. This means that less children are being born, than elderly people are dying. The populations of those countries are aging. Problems arise when large numbers of retired people have to be supported by fewer income-generating younger people. Switzerland and Germany have negative population growth rates.

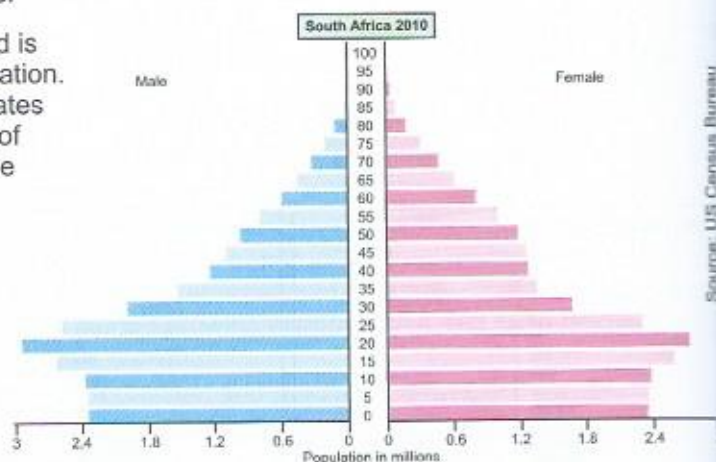
South Africa's population

The 2001 South African pyramid is typical of a developing country. There is a large percentage of the population (32%) below the age of 15 years and a very small percentage in the 65+ group. The largest group is the 10 – 14 year olds. The fact that there is a decline in the 0 – 9 year old category is an indication either of a decline in fertility or an increase in infant and child mortality.

Forecasts for South Africa's population growth in the next 20 years

In 2010, South Africa's population was 49,1 million. By 2011, the population had grown to 50,5 million. One third of the current population is younger than 15 and 39% of the population is between 15-35 years old. The life expectancy of men is 55 and women 59 years.

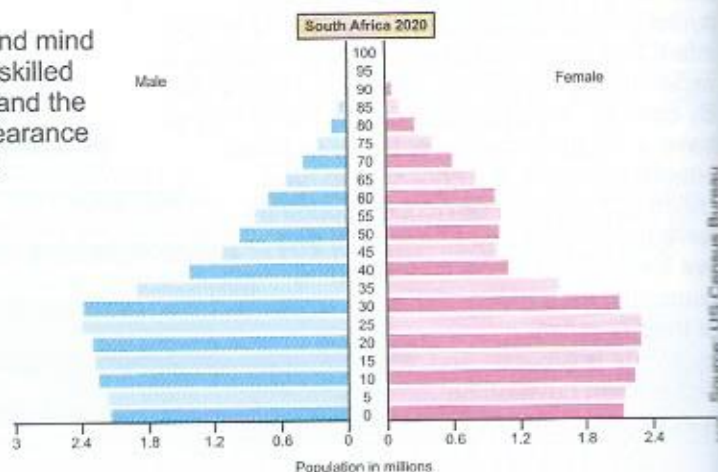
The negative growth rate depicted on the pyramid is not because South Africa is a highly developed nation. Rather, it reflects high infant and child mortality rates and lower fertility rates, possibly a consequence of more people being infected with HIV. 10,6% of the population (5,38 million people) is HIV positive.



Statistics South Africa predicts that the proportion of young people (15 – 35 years old) will increase in the future. Catering for this large number of young people is a huge challenge for the government and places a lot of pressure on education and health facilities. If good facilities are developed and the youth are provided with high standards of education, the future of South Africa will be positive, with a highly skilled workforce able to contribute positively to the economy. In this situation, the population pyramid of South Africa will look more like that of a developed nation.

A great deal more environmental and economic resources are going to be required in the future. It is more important than ever for every South African to contribute towards the economy and to concentrate on ways of using natural resources in a sustainable way.

If the necessary infrastructure is not developed and mind set not changed, there will be an increase in low skilled workers. Long-term unemployment will increase and the cycle of poverty will continue. The predicted appearance of South Africa's population pyramid under these circumstances is shown alongside.



Section B: Human Impact on the Environment

South Africa is considered to be one of the five most diverse countries in the world. It has almost 10% of the world's known bird, fish and plant species and over 6% of the world's mammal and reptile species which are contained on a land surface of only 1,1 million square kilometres (about 1% of the Earth's total land area).

However, South Africa's increasing population growth, habitat destruction, overexploitation of resources, pollution and the growth of invasive alien species are all placing increasing pressure on our natural systems.

Current crises for Human survival: Problems to be solved within the next generation

Human Impact on the Environment can be divided into five main areas of concern:

- the atmosphere and climate change
- water, the issues of its availability and water quality
- food security
- loss of biodiversity
- solid waste disposal

1. The Atmosphere and Climate Change

The atmosphere is made up of a mixture of gases:

- Nitrogen (N_2) 78%
- Oxygen (O_2) 21%
- Water vapour (H_2O)
- Smaller amounts of other gases are:
 - Carbon dioxide (CO_2) 0.003%
 - Methane (CH_4)
 - Nitrous oxide (N_2O)
 - Ozone (O_3)
 - Chlorofluorocarbons (CFCs)
 - The inert gases: Helium (He), Neon (Ne), Argon (Ar), Xenon (Xe), Krypton (Kr)

Greenhouse gases and their sources

Carbon dioxide (50%): is the principal greenhouse gas, reached a level of 390,9 parts per million (ppm). This is primarily from burning fossil fuels, but also from deforestation, land-use patterns, and modern large-scale agricultural practices. About half of this carbon released since then remains in the atmosphere - much of it remains for centuries. The impact of the accelerating emissions currently measured won't be seen for years or decades, and the growing signs of global climate warming we are now experiencing are the consequence of emissions from years and decades ago. While forests and oceans have historically acted as a carbon sink, sponging up a large amount of this added carbon and helping keep the atmosphere in balance, there are growing signs that these natural carbon sinks are now increasingly unable to act effectively.

Methane (25%): is on the increase and comes mainly from cattle, sheep, rice paddies and other wetlands and leaks from gas and coal industries.

Nitrous oxide (6,25%): is caused by burning of fossil fuels, the use of fertilisers, deforestation.

Ozone (O_3) (6,25%): at low altitudes is formed from the action of sunlight on air pollutants from car exhausts and industries.

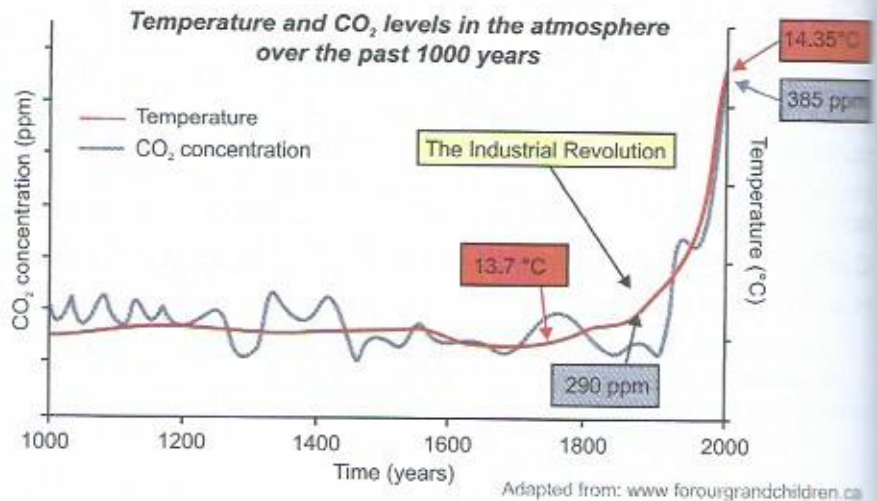
CFC's (12,5%): a gas used in refrigerators, foam products and fire extinguishers.

Greenhouse gases have the ability to trap heat in the earth's atmosphere, preventing the heat from escaping into space. The biological importance of trapping heat is to create a climate that is warm enough to sustain life on the Earth. Without the heat being trapped in an insulating layer around the Earth, life would not be able to exist.

In nature, natural emissions of greenhouse gases occur as a result of biochemical activities in living bodies of all organisms and as a part of the nutrient cycles that exist in all ecosystems. However, as a result of the industrial activities of man, the level of these specific gases being released has increased dramatically since the Industrial Revolution. The emissions of increased quantities of greenhouse gases into the atmosphere have caused an increase in the heat being trapped in the atmosphere and therefore an increase in the overall global temperature.

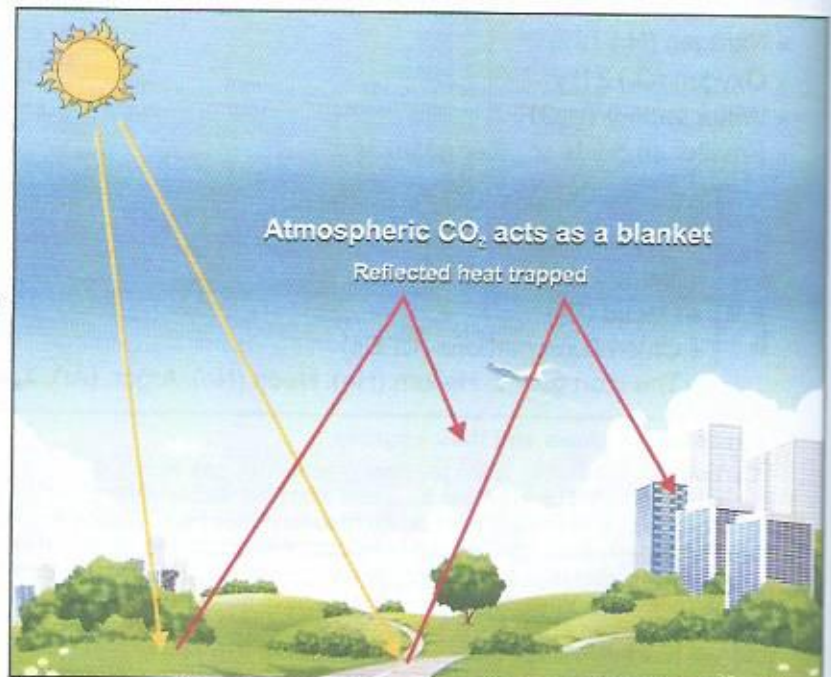
Carbon dioxide emissions

Since the Industrial Revolution (around 1850), the amount of CO_2 in the atmosphere has steadily risen owing to the increase in fossil fuel combustion. As atmospheric CO_2 levels have increased, there has been a corresponding increase in the average atmospheric temperature. The graph below depicts the relationship between CO_2 and atmospheric temperature over the past 1000 years.



The Greenhouse Effect and Global Warming

Greenhouse gases form a barrier layer above the earth's surface and prevent the heat from escaping back into the atmosphere. The warming of the Earth's surface has led to global warming. Global warming has arisen because the greenhouse gases have formed a dense blanket that is too thick and traps too much warmth. This blanket of gases prevents the escape of heat from the earth, causing the earth's temperature to rise.



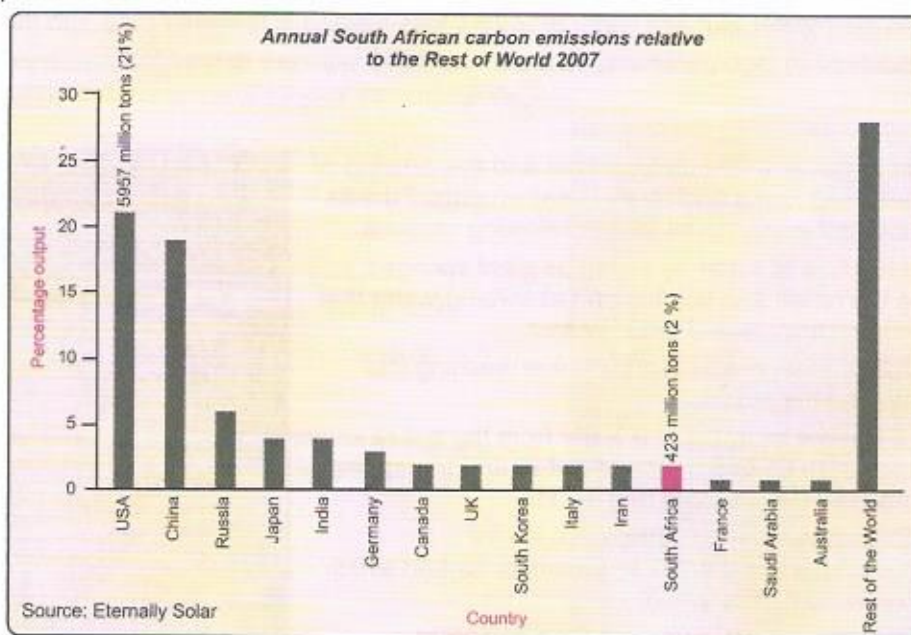
The Greenhouse Effect

Effects of global warming

- Changes in weather patterns such as an increase in rainfall in some areas and in drought in others.
- An increase in the number and intensity of extreme weather events, for example: cyclones, high winds and hail storms.
- Changes in food production due to temperature changes in areas.
- Reduction in availability of water supplies.
- Increase in evaporation from water surfaces such as oceans, lakes, dams and rivers.
- Changes in the composition and location of forests.
- Reduction in biodiversity.
- Rise in sea levels. Polar ice is melting and will cause sea levels to rise, flooding low lying coastal towns such as Cape Town and parts of Durban.
- Threats to human health.

The Carbon Footprint

A carbon footprint refers to the amount of carbon dioxide generated through human activities. These activities include such things as transportation (driving, flying, riding a bus, etc.) and energy use (lights, electricity, etc.). It can also include indirect activities like going to a restaurant, throwing trash away, or even eating food. When you go to a restaurant your presence there is causing more energy to be used and therefore, more carbon dioxide is generated. Much CO_2 is also created by the manufacture of consumer products that a person uses in their lifetime.



Every type of industry, each country and continent, also has a carbon footprint. The carbon footprint reflects the amount of CO_2 generated by their specific activities and will vary depending on whether it is a first or third world country or the particular products that are being produced.

Compared to the rest of the world, South Africa's carbon footprint appears insignificant. However, the more goods and services that are imported from countries that have a large carbon footprint, the larger South Africa's carbon footprint becomes.

Methane emissions

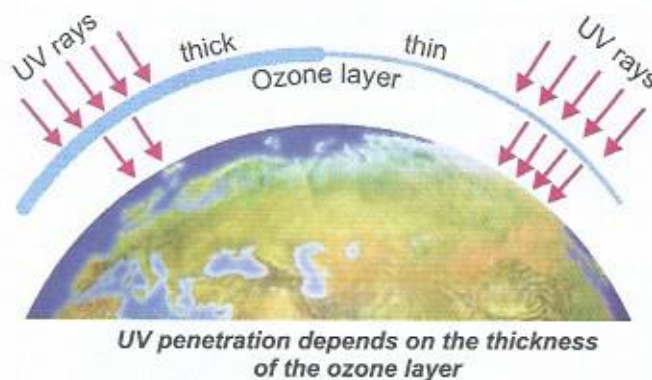
Methane (CH_4) is an odourless, colourless gas that is released by the fermentation and decay of organic materials. Methane is part of the natural carbon cycle, however it becomes a potential greenhouse gas when released in vast amounts. This may occur from the large scale decomposition taking place on municipal land sites, from gas released by grazing herbivores and natural gas leaks. In KwaZulu-Natal, the Marianhill landfill site has technology in place to trap and then use the methane gas produced by the landfill to produce electricity. It is also a conservancy site, showing how a potential problem can become a positive feature of the area in which it is found.

Ozone depletion

The ozone layer in the stratosphere filters and protects the Earth from harmful ultra-violet (UV) rays of the sun. It is composed of molecular oxygen (O_3). Ozone at ground level is a pollutant that helps form photochemical smog and acid rain. It is a poisonous gas. The ozone layer is destroyed by CFC's.

In 1987, the Montreal Protocol was drawn up to encourage all countries to decrease the production and consumption of ozone-depleting substances such as CFC's.

The global consumption of ozone-depleting substances declined dramatically. It is predicted that the ozone layer in the non-polar regions should achieve complete recovery by 2050.

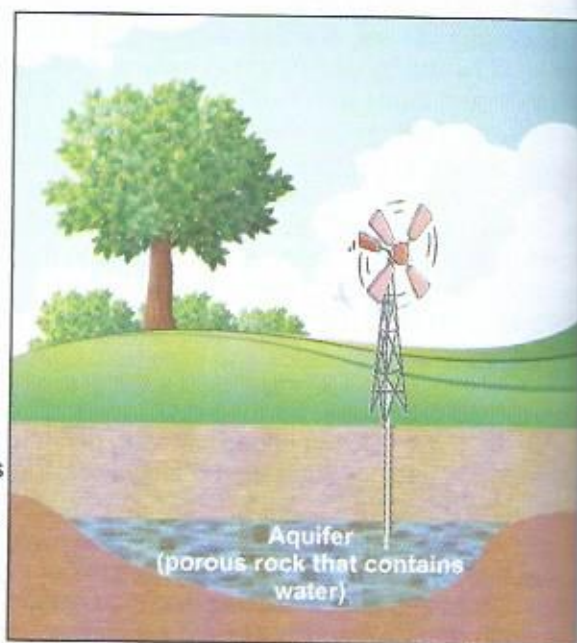


Boreholes and their effects on aquifers

Historically, water resources management in South Africa has focused on surface water, resulting in an extensive network of dams, inter-basin transfers and pipelines. However, recent work has revealed significant reserves of groundwater that are not being fully utilized. Since most water stored in catchments is stored in aquifers underground, groundwater can provide an important buffer against an increasingly uncertain rainfall future.

The potential for underground storage and increased use of groundwater heightens the importance of minimizing water contamination, from mining, industrial, agricultural and domestic sources.

Rain water that soaks through the ground collects in aquifers. The downward flow filters the water to a high standard. Bore holes are drilled through rocks to the aquifers in order to extract the water. Because of the filtering effects of the ground, much of the aquifer water can be consumed immediately without any chemical additives. The reason ground water is so clean is because most life needs light, oxygen and warmth. Underground there is no light, very little oxygen and the temperature is around 6°C.



Borehole to extract water from an aquifer

Water wastage

Water conservation and water demand management strategies are becoming a fundamental part of life. These require changes in behaviour at the municipal, household and personal level and include actions such as: leakage detection and repair, use of water efficient fittings, and user education. Ways of reducing water wastage include: recycling and re-use, desalination and rainwater harvesting.

Cost of water

All South Africans receive the first six kilolitres of water they use each month, free. To discourage water wastage, municipalities charge for water on a sliding scale. The greater the volume of water used, the higher the charge for that month. Effective monitoring of the state of the country's water resources, water use, water infrastructure and institutional performance, is becoming increasingly important to inform decision making on the availability, allocation and pricing of water.

Costs of water can also be reduced by installing rainwater tanks, using grey water (water which has been used for bathing and washing) for gardens and using boreholes. South Africa is reportedly in danger of having a 17% gap between supply and demand for water by 2030.

The impact of different land uses on water quality

Domestic water consumption

If human waste as well as soaps and detergents from toilets, baths, basins, showers and dish washing water are not correctly disposed of, they can enter water systems and cause the BOD (Biological Oxygen Demand) to increase. The BOD refers to the amount of oxygen that saprophytic micro-organisms require in order to decompose organic matter. The BOD is usually defined for a particular volume of water, over a given period of time. The higher the BOD, the more polluted the water and the more methane gas that is released as a by-product of decomposition.

Waterborne diseases

In the developing world, waterborne diseases are common. Informal settlements in urban areas and most rural communities do not have access to clean water sources, or to water-borne sewerage systems. Many rural communities share their water with domestic animals and wash clothes in the same rivers from which they draw their drinking water. As a result, 90 – 95% of all sewage is deposited untreated in water systems. Water contaminated with human waste causes diseases. Outbreaks of diarrhoea and vomiting, caused mainly by *Escherichia coli*, intestinal bacteria found in human faeces, are common. Other pathogenic micro-organisms found in human faeces are responsible for: cholera, hepatitis A, dysentery, gastroenteritis and typhoid fever.

In South Africa, gastro-intestinal deaths, caused by waterborne diseases are the third highest cause of death amongst children under 5 years old, with over 10,000 deaths occurring annually. All these deaths could be prevented if communities had access to clean water.

Industry, agriculture and mining

Water-soluble inorganic chemicals such as acids from factories and mines, salts, mercury and lead compounds can affect aquatic life, make the water unfit to drink and can harm crops which are irrigated with this water.

Many factories and power generators release hot water into rivers which results in plants and animals being killed. This thermal pollution also lowers the dissolved oxygen content in the water, which further negatively affects living organisms.

Estuaries have become polluted with fertilisers being washed down from farmlands, from oil spills from ships and from chemicals that are released from factories upstream. As these estuaries act as breeding grounds and nurseries for many fish, these pollutants harm and kill the fish eggs and young fish, causing less fish to enter the oceans. Other animal life such as shellfish and molluscs which are found in estuarine habitats and form an important food source for animals and humans, are also affected.



A factory discharging its waste water into a nearby river

Eutrophication and algal blooms

Eutrophication is a process which starts with the addition of excess nutrients to a water body and ends with the collapse of the aquatic ecosystem. Sewerage plants, abattoirs, farm animal holding pens and runoff of fertilisers from crops, add excess nitrates and phosphates into river systems. The increase of nutrients in the water causes plants such as algae, to flourish to such an extent that the whole surface of the dam can become covered with them. Owing to the algal bloom, light can no longer penetrate below the surface of the water, which causes deeper dwelling aquatic plants to die. With their death, oxygen is no longer released during photosynthesis and so the oxygen supply for aquatic animals declines. The animals then die. As the dead plants and animals decompose, further oxygen is used up and methane gas is released, giving the dam a strong smell of putrefaction (rotting).



Algal bloom

The end result of eutrophication is that the dam is no longer a healthy ecosystem and its aquatic food webs and pyramids collapse.

Effect of mining on water quality

Many mines use vast quantities of water during their daily operations, including: washing the ore and for chemical processing. In the Witwatersrand gold mining area alone, an estimated 500 megalitres (500 million litres) per day is consumed by mining. The used water has to be continually pumped out of the mines to prevent flooding underground. Owing to the water having been used in various mining processes, it is acidic and can contain chemicals such as sulphides, toxic cyanides and heavy metals. Recently, water pumped from mines has also been found to be radioactive. This poor quality mine water creates serious pollution problems when it is released into local rivers.

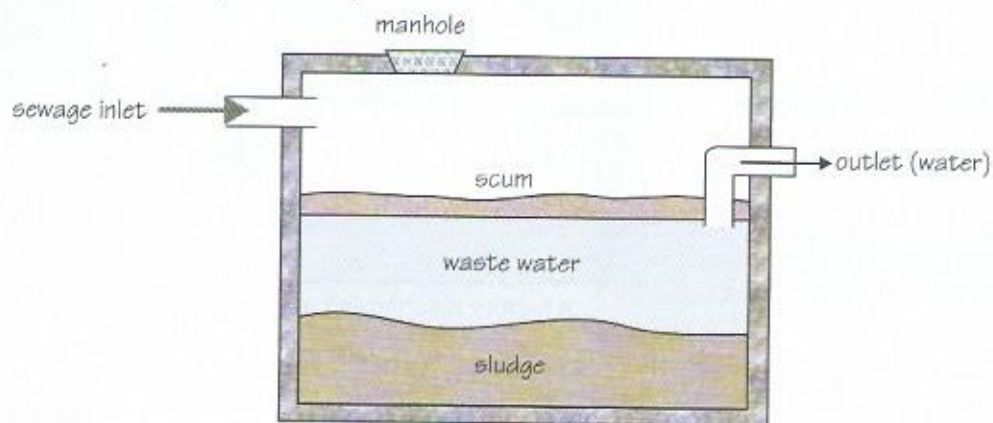
Thermal pollution

Many factories and power generators release hot water into rivers. The high temperatures can kill plants and animals. An increase in the temperature lowers the amount of oxygen that can dissolve in the water. This has a detrimental effect on all aquatic organisms.

The need for water purification and recycling

Owing to the number of waterborne diseases and deaths resulting from poor quality water, it is essential to ensure a clean supply of drinking water for everyone. One way of achieving this is by installing septic tanks that separate human wastes from water sources.

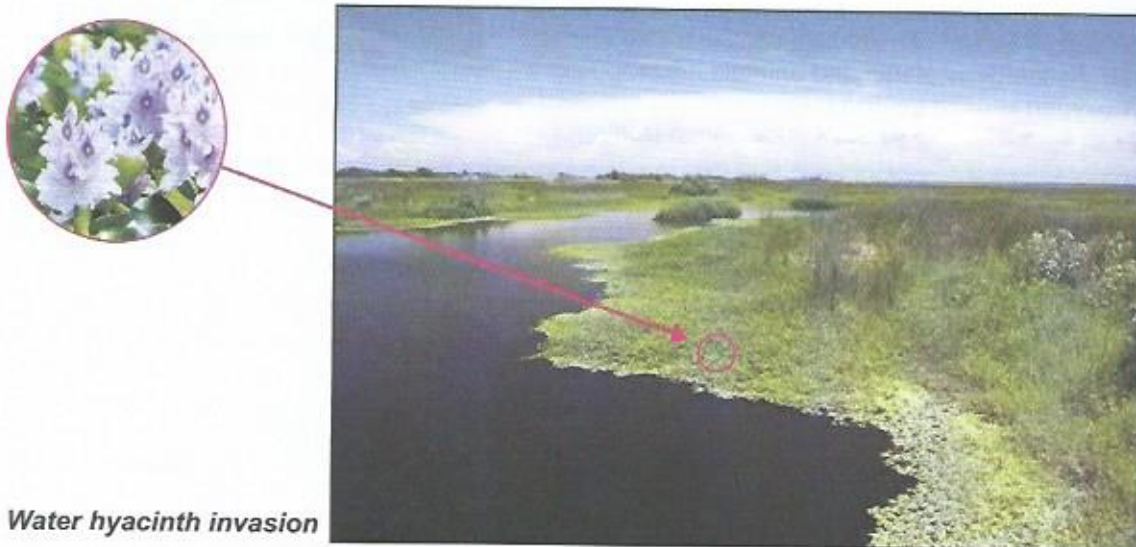
The diagram below shows a simple septic tank that could be used in rural areas and which is relatively easy to install. The system traps grease and large solids and discharges the remaining wastes over a large drainage field. As these wastes percolate downwards, the soil filters out potential pollutants. Soil bacteria decompose biodegradable material. To work effectively, these septic tanks must be installed in soils with adequate drainage, not be placed too close together or near borehole sites, rivers or dams. Septic tanks must be pumped out regularly when they become full.



Septic tank construction

Alien aquatic plants

Alien aquatic plants such as the water hyacinth, *Eichornia spp* shown below, are a threat to the quality of fresh water in storage bodies such as rivers, lakes and dams. In the absence of their natural predators, they rapidly increase in number. The dense mat they form and the organic material they provide, contributes to the eutrophication process as well as shutting out the sunlight required by indigenous aquatic plants that the indigenous food webs depend on. The dense mat of alien plants also clogs up waterways, blocks irrigation pipes and canals and block pumps that control the flow of water from dams.



Water hyacinth invasion

Bio-control measures have been introduced to decrease the numbers of these plants but the control methods are not particularly effective. Surveys have shown that physically clearing invasive alien plants from a watershed can increase the water yield significantly. The resulting extra water can then be sold and the money used to offset the clearing costs.

3. Food Security

The impact of human exponential population growth

Some of the reasons that have resulted in the exponential growth of the human population are:

- Improved diets
- Improved housing
- Improved medical health care for all age groups
- People are living longer.

The exponential growth of the human population underpins all the problems that are inflicted on the environment. The human population can no longer be sustained by the natural environment, so societies are increasingly dependent on intensive agricultural practices to provide food and resources. The problems of monoculture and the resulting soil erosion and water pollution have already been discussed. If people are not eating natural products, they are exploiting them for other means, such as for medicines, buildings, to burn or to trade. As natural products are consumed, the food webs and food pyramids that they previously supported are also destroyed, leading to a massive reduction in biodiversity and subsequent collapse of entire ecosystems.

The effects of climate change: droughts and floods

The extreme weather phenomena that are occurring as a consequence of human-induced climate change, have a direct impact on food security. In southern Africa, the provision of food is made even more complicated by the cyclical impacts of El Nino and La Nina.

For example, droughts in the central parts and western parts of the country in 2012 caused pastures to become so depleted, that farmers were compelled to sell their livestock because the grazing conditions were too poor to support them. Dry veld conditions also lead to extensive veld fires, which further reduce grazing land and accelerate soil erosion.

In the same year, extreme hail storms in Gauteng and Mpumalanga destroyed hectares of fruit crops, just as the fruit were starting to set. Unseasonal cold weather killed many new born lambs in the Eastern Cape and massive floods destroyed acres of crops in a number of provinces. Changing weather patterns have also been linked to the outbreak and spread of numerous animal diseases.

Owing to climate change, weather is becoming increasingly unpredictable, which makes it very difficult for farmers to plan their activities. The effect of this, is that food availability can no longer be guaranteed.

Poor farming practices

Large-scale modern farming often involves planting large areas with only one type of crop. This is termed monoculture. The land is used intensively to achieve the highest possible yield in order to maximize profits. Often farmers plant one kind of crop year after year, for example, maize or sugar cane. Farmers use fertilizers to enrich the soil, herbicides to kill weeds and pesticides to kill pests. All of these aspects have disadvantages. Fertilizers can enter water bodies following heavy rains, leading to eutrophication; herbicides blown by the wind can kill neighbouring indigenous plants and pesticides can kill non-target organisms and they have a tendency to encourage the development of resistance to them in the pests. Also, if fields are left fallow, wind can blow the top soil away and heavy rains can wash much of the top soil into rivers, leading to sedimentation.

There is no biodiversity where monoculture is practiced. This lack of biodiversity may encourage the breeding of pests, as they have vast amounts of food and no predators. This encourages the pests to breed extensively, destroying the crop. Farmers then have to use large amounts of pesticide, which in turn may wash into streams and pollute them.

Alien plants and the reduction of agricultural land

Alien plants are those which are not indigenous to a region and which have been introduced from another area. Because they are not indigenous, they often have no natural predators. As a result, they tend to spread rapidly, out-competing similar indigenous plants. When alien plants spread onto agricultural land, they compete with crops for natural resources. The costs of eradicating alien plants from farmland can be expensive and sometimes farmers choose to abandon fields invaded by aliens. If alien invasions cannot be stopped, less land will be available for agriculture.

Plantation species are blamed for 38% of all the alien plant invasions in South Africa. Pine and wattle plantations are valuable income-generating enterprises and supply timber and pulp for paper products. However, the central American pine, *Pinus patula*, and the Australian black wattle, *Acacia mearnsii*, are aggressive invaders and have overpowered many indigenous forests, woodlands and grasslands. Legislation exists to ensure that plantation owners do not allow their trees to invade the surrounding environment and they have to keep surrounding areas clear of seedlings.

Other sources of alien plants come from gardening centres which distribute species for hedges, ornamental use, shelter and shade. In the Western and Eastern Cape, alien Australian wattles are planted to fix or stabilize sand dunes. Large South American grass species that are adapted to the acid conditions of gold mine dumps are planted on Gauteng mining wasteland sites in an attempt to reduce the dispersion of the acid-laden sand by wind.

The pompom weed, is an example of an ornamental alien invader found in all South African provinces.



Courtesy Phetole Manyama (SANBI)

Pompom weed

The impact of the loss of wild crop varieties on the gene pool

Modern commercial farming uses hybrid varieties of crops which have been selectively bred to have the most desirable characteristics for that crop. For example: wheat that has large kernels, is drought tolerant and has a rapid growing cycle. The effect of selective breeding, combined with monoculture, is that many of the wild varieties of crops are no longer available. The problem arises when environmental conditions change, as is occurring through global warming. Hybrid crops often are not able to adapt to change and fail. Scientists have realised that the original wild varieties of the current crops may contain genes, which make them more adaptable to changing conditions and so finding and preserving wild crop varieties is vital to ensure food security.



Courtesy Yue Jin, USDA

Wheat stem rust
(Can cause losses of up to 70%)

Mung beans play a vital role in feeding some of the most vulnerable people in South Africa. Extensive crossbreeding has created mung bean plants with a 55-day maturation process, good yields and hardier pods that grow on the top of the plant for easy picking.



Mung beans

Genetically engineered foods

Genetically modified (GM) foods are foods that are derived from organisms which have had specific changes introduced into their DNA by genetic engineering techniques.

Maize and soybean are the only two GM food crops commercially grown in South Africa. Globally, these two food crops, plus cotton, account for 94% of all GM crops planted. In South Africa, 77% of all maize seeds that are sold to farmers and 78% of soybean seeds are genetically modified. Genes have been introduced into these crops that increase drought and herbicide tolerance and make plants more pest resistant.

People are often concerned about the consequences of eating GM foods and the impact that GM organisms may have on the natural environment. However, genetically engineering crops to enable them to grow in harsh environments and to make them resistant to diseases, will go a long way in alleviating hunger in many nations.

A good example of how GM can contribute to food security is the example of the development of "scuba" rice. Every year, 800 000 tons of rice - enough to feed 30 million people - are lost to flooding in Bangladesh and India. Scientists at the International Rice Research Institute in the Philippines developed "scuba" rice that can survive, completely submerged, for up to 2 weeks. When covered by water it becomes dormant. Researchers made the rice by isolating a gene that creates flood tolerance, from a variety that is particularly hardy but has yields too low for commercial use. After 3 years of testing across South Asia, the first scuba rice was released in 2009. After changing to the GM rice, one farmer recorded a 50% increase in his crop yield.

Golden rice, like scuba rice, is genetically modified rice. It is rich in vitamin A. The presence of β -carotene in golden rice helps prevent blindness and increases immunity to disease, especially in young children.



GM golden rice



"Normal" rice

Food wastage

According to the United Nations Food and Agriculture Organization (FAO), 925 million people were hungry in 2010. Of those people, 26% live in Sub-Saharan Africa. The FAO listed the causes of world hunger as:

1. The neglect of the agricultural sector in poor countries by governments and aid agencies.
2. The worldwide economic crisis.
3. The significant increase in food prices over the last few years.

Currently in South Africa, legislation forbids industries to sell food which has reached its expiry date at a cheaper price, or to give the food away to such things as soup kitchens. All leftover food has to be dumped. There is something seriously wrong, when the amount of food produced, or the pricing of food, leads to a surplus that is being discarded, while thousands of people are hungry. Wastage of food, from the individual level to the national level, needs to be addressed in order to ensure food security for everyone and not just the wealthy.

According to Food4Africa, an international aid organisation working in South Africa, 1 in 5 children suffer from chronic malnutrition and 1 in 10 children are severely malnourished. 20% of South African children have stunted growth because of a lack of adequate food.

4. Loss of Biodiversity (*The sixth extinction*)

In 2005, a detailed assessment of South African biodiversity was undertaken. The results were as follows:

- 34% of land ecosystems are threatened and 5% critically endangered.
- 82% of river ecosystems are threatened, 44% being critically endangered.
- 12% of marine bio-zones are under serious threat.
- 3 of the 13 estuarine ecosystems are in critical danger.

Habitat destruction

Poor farming methods, for example: overgrazing and monoculture, the development of golf estates, mining, urbanisation and commercial plantations are all contributing to deforestation, loss of wetlands and grasslands and general habitat destruction. The massive reduction of biodiversity associated with human activity is often termed "*The sixth extinction*". There have been five massive extinctions during the history of the Earth, but the current one is the only one caused by a single species: humans.

Overgrazing

Evidence of overgrazing is visible throughout South Africa. Goats are particularly detrimental because they rip up the roots of vegetation, which leads to soil erosion. Once the topsoil is removed, grasses and shrubs can no longer be supported and the entire food webs which depend on them are destroyed. Overgrazing, coupled with climate change, is causing the spread of arid land throughout the central part of the country.



Overgrazing leading to desertification

Fortunately there is a practical way of rolling back desertification using the remarkable succulent *Portulacaria afra* (spekboom). This plant grows in abundance in many areas. Spekboom can be grown from cuttings planted in either wet or dry soils. Farmers across the Eastern Cape have used spekboom cuttings to great effect for restoring large areas of the goat-degraded landscapes.

Thickets in their natural or restored state have significant environmental benefits:

- Black rhino, elephant and other game thrive in this vegetation and ecotourism opportunities abound with tens of thousands of hectares of spekboom-rich thicket in place.
- Bees are also highly productive insects in intact thicket. Beekeeping can be a viable business in the restored landscapes.
- Planting spekboom is labour intensive and consequently farmers will be major employers in the Eastern Cape, providing a much-needed stimulus to the depressed rural economy of the region.



Masked weaver perched on a spekboom

Monoculture and Increased Pest Population

Monoculture refers to the cultivation of a single species of a plant population. In order to obtain the maximum yield per hectare, large areas of land are cleared of their indigenous vegetation and a single kind of crop is grown. The removal of the natural flora also implies the indirect removal of the fauna in the area, and the subsequent decrease in the biodiversity in that area. In addition to disrupting predator-prey relationships, links in the food chain are also broken. The uniform flora (plant) attracts only a few species of animals. This lack of a variety of plants and animals may lead to the rapid increase in pest populations in the area.



An sugar cane plantation



An extensive wheat field

If a pest enters the monoculture, the pest population rapidly increases. This rapid increase is due to the presence of only one species and the lack or absence of predator populations.

The use of pesticides is not always successful because pesticides are not species-specific and not only kill pests but also their predators. Pesticides also wear off, and when this occurs, the pest population increases. Pests are also known to develop an immunity to pesticides which aids in the increase of the size of the pest population.

The solution to this problem is planting a variety of crops together i.e. a mixed species culture. A mixed species culture would attract a variety of animals and predators, increasing the biodiversity in the area. The natural predators of the pest will then act to regulate the pest population.

Biological control i.e. the artificial introduction of the predator is another effective method of controlling pest populations. An example of this would be the use of beetles to feed on the dung in which flies lay their eggs. Thus the maggots of the fly do not survive and the fly population is eventually greatly reduced.

Mining

The Minerals Act of 1991 requires a details about possible environmental risks of a proposed mine and what will be done about these risks, before mining begins and during and after mining has ended. This is termed "cradle to grave" environmental management.

In addition to the loss of biodiversity at the mining site, the processes associated with mining can also have a detrimental impact on organisms. Waste water from mining operations can contain chemicals such as: sulphides, toxic cyanides, heavy metals and radioactive material. If this water enters natural waterways, it is extremely detrimental to life and greatly reduces biodiversity. Experiments are currently being done with planting sunflowers around mines, as they seem to be able to absorb some of these poisonous chemicals and in so doing, reduce the amount of toxins entering the water.



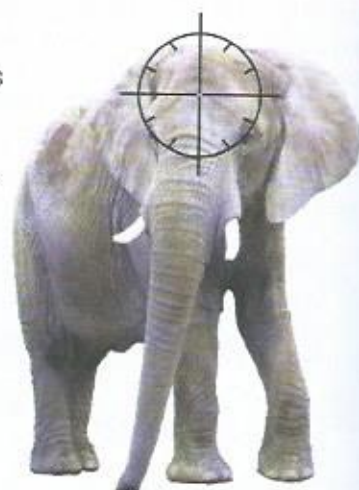
Toxic water from a gold mine

Poaching

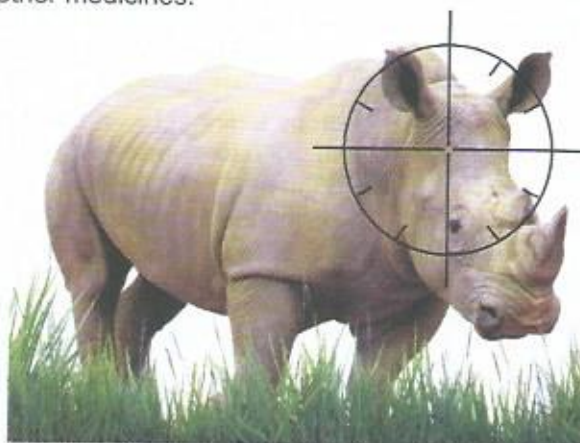
The illegal hunting and trade in bush-meat in Southern Africa, has been mistakenly perceived as a small scale phenomenon practised only for subsistence living, however it has the potential to cause a conservation crisis soon. This was according to a report recently released by conservation organisation, Panthera.

The report found that Africa's large carnivores such as cheetah, leopard, lion and wild dog were particularly vulnerable to bush-meat activities. This was because they were caught directly in unselected methods, such as snaring, or because their prey populations were being reduced by illegal hunting for the bush-meat trade.

Some of the key factors behind this increase included hunger and the increasing demand for the meat in rural and urban areas, human encroachment in wildlife areas, inadequate penal systems and lack of enforcement.



Pulled from the brink of extinction almost a century ago, South Africa's white rhino population was flourishing thanks to the extensive conservation measures that were put in place. However, their existence is being jeopardised once more due to the dramatic increase in rhino poaching over recent years. During 2008, 57 rhinos were illegally killed country-wide and this increase has been linked to a rising demand for rhino horn in the Far East. In 2011, the number of poached rhino was 488 and by the end of November in 2012, 612 rhino had already been killed. Rhino horn is used in traditional medicine as an anti-rheumatic and anti-inflammatory treatment and more recently rumours have surfaced about its anti-cancer properties. All these ailments can be treated with other medicines.



White rhino

Rhino horn has become a highly sought after commodity, which people are prepared to pay a lot of money for. Numerous poaching networks and syndicates thrive in this environment. Poachers are often recruited from communities neighbouring protected areas and private game farms. Their poverty makes them an easy target and their bush skills make them a prized asset. These are the people who are taking the largest risks and are making the least from it, as it is not the people at the beginning of the chain that make the money. It is the middle men, the poaching network leaders and exporters in South Africa and the importers of horn in the far Eastern countries who are capitalising on this illegal, yet lucrative trade.

"South Africa and Vietnam plan to sign a memorandum of understanding (MoU) that will address the illegal trade in rhino horn. Albi Modise, spokesperson for the Department of Environmental Affairs, said that the government was convinced that these international engagements and agreements were crucial in fighting the current scourge of poaching." *Taken from an article written by Lindi van Rooyen, Farmer's Weekly, 9 Nov 2012.*

Unless drastic measures are employed, rhinos will soon be extinct.

Alien plant invasions

Land owners needed to take responsibility for invasive plants on their properties. Invasive alien vegetation, including various species of wattle, pine, poplar, weeping willow, gum trees, hakea and prickly pear, among others, pose a serious threat to South Africa's water supply, as well as the country's agricultural potential and biodiversity. If the 20-million hectares of alien invasive vegetation across the country could be condensed into a single area, it would form a dense, impenetrable thicket about twice the size of the Kruger National Park.

The Eastern Cape has also lost over 200 000 hectares to prickly pear, and the same area again to invasive Australian gums. A further 250 000 hectares of KwaZulu-Natal have also been taken over by the North American invader, *Chromolaena odorata*, more commonly referred to as "paraffin" bush because of the fire hazard it poses.

Other significant alien invasives include lantana, syringa, queen of the night cactus, agave, guava, Spanish reed and sesbania.



The alien invasive lantana

The *Working for Water* programme was initiated in 1995 in an attempt to quantify alien invasion on a national scale. The program has since spent R3,2 billion on alien plant control. At a conservative estimate, it will cost R34 billion over the next 25 years to clear the 20-million hectares of alien vegetation. Left untouched, the alien vegetation will spread at an average rate of one percent a year, threatening water and food security.

Ways in which alien invasive species can be controlled

Mechanical removal is achieved by digging the whole plant out, roots included. In the larger tree species, such as syringa, ring barking can be used, however the trees have to be monitored closely and any new growth that starts emerging at the roots, has to be removed. If this is not monitored on a regular basis, very rapid regrowth can occur, resulting in an even thicker growth.

Chemical removal is carried out by using alien plant-specific herbicides that are biodegradable, to prevent the damage of indigenous food webs.

Biological methods are carried out using beetles, weevils, insects or fungi that will eat or destroy the organs, fruits and/or seeds of the alien plants. Biological control could reduce the clearing costs by between 10 and 20 percent, assuming that such control can reduce the plants' seed set and expansion.

Use in the commercial sector. Another possible way of dealing with alien vegetation is to utilise dense stands of alien vegetation for bulk fibre production, or as an energy source. This could also offset costs involved in clearing the area. An example of this is the use of syringa, which has medicinal values in certain cultures and is also an excellent wood with which to make furniture.

Indigenous knowledge systems and the sustainable use of resources

The use of indigenous plants for medicinal purposes, has been an important part of our indigenous knowledge system (IKS) for hundreds of years. The rapid growth of the population and the overuse of these traditional plants is damaging biodiversity. Almost 50% (± 2107 tonnes) of the approximately 4 400 tonnes of medicinal plant material traded annually in KwaZulu-Natal, is sourced from the forest biome. In addition to the already overexploited communal forest areas, forest areas on private land are the only other areas potentially available for medicinal plant harvest. To meet the current market demand for forest sourced medicinal plant material, 8.1 tonnes per square kilometre would be required. Existing forest resources cannot meet this demand. It is clear that forest-derived medicinal plant species will need to be cultivated on a large scale if wild populations of these plants, and the forests in which they occur, are to be conserved. Many of these species are slow growing and difficult to propagate.

In the Durban area of KwaZulu-Natal, Silverglen nursery, run by Durban Municipality, is successfully growing many of the traditional plants that are used medicinally. The nursery cultivates about 120 at-risk species, many of which are in large enough numbers to supply other nurseries. The municipality has developed a network of plant and seed suppliers, including private land owners, commercial nurseries and provincial conservation authorities. The Silverglen medicinal plant nursery is providing a viable, alternative source of medicinal plants for the local population and at the same time protecting the indigenous plant communities and local biodiversity.

Large corporations in Europe and the USA export expensive health supplements in the form of pills and capsules from indigenous African species such as the African potato (*Hypoxis sp.*), *Hoodia sp.*, devil's claw and rooibos. Currently, foreign companies do not have to enter into community-sharing agreements with communities if they develop medicines based on traditional knowledge. Although a plant may not be patented, any company can patent extracts of a plant, or a new use for plant extracts, if they can prove they are the first to discover this use. Rich foreign companies have snapped up hundreds of patents this way, despite ongoing protests from traditional healers who do not have the resources to compete.



African potato



Devil's Claw



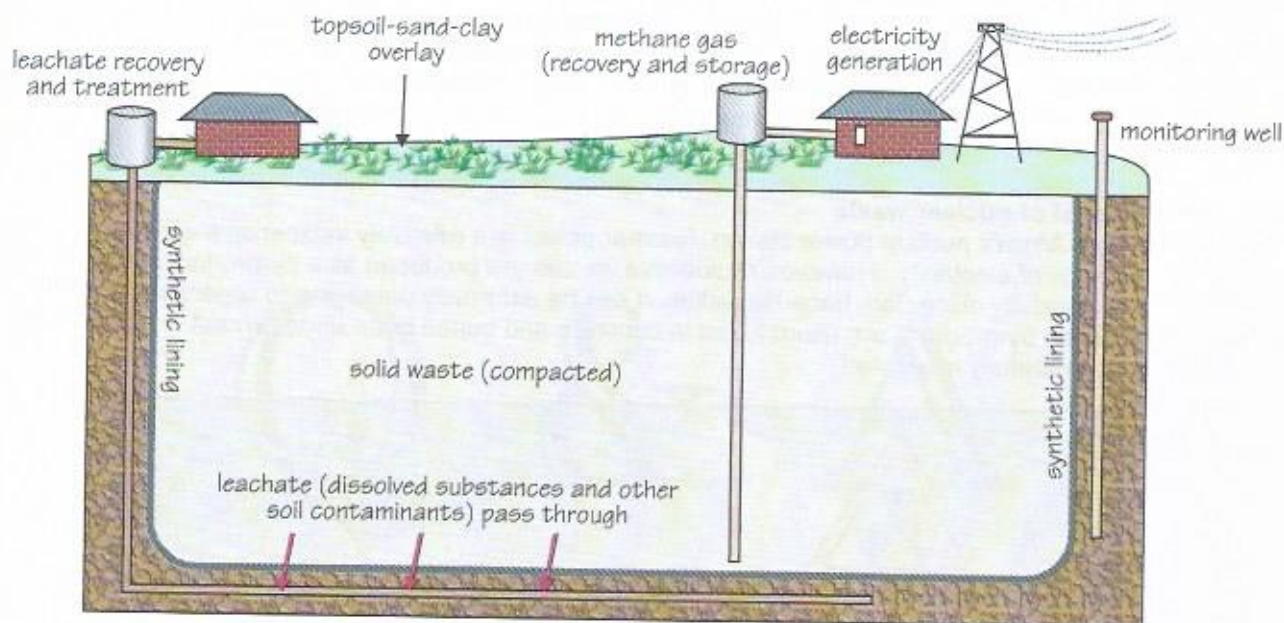
Hoodia



Rooibos tea

5. Solid Waste Disposal

The correct treatment of domestic and industrial waste is essential to prevent pollution of the environment. Major problems associated with landfills are leaching and air pollution caused by the burning of wastes. Leaching occurs when the soluble by-products from the decaying wastes leak into the soil and enter the groundwater. Many of these by-products are harmful to the environment. Modern landfills limit the amount of leaching into surrounding soil and also limit the need for the waste material to be burnt, thereby reducing the production of more greenhouse gases.



A modern landfill that should prevent excessive pollution of the surrounding area.

Using methane from dumpsites for domestic use

Durban is the first African city to use landfill gas to produce electricity. Millions of cubic metres of greenhouse gasses that would have ended up contributing to climate change have been captured and converted to electricity at the Marianhill and La Mercy landfill sites. The Durban methane harvesting project is able to generate 1500kW (1.5MW) of electricity and is expected to bring millions of rand in revenue to the city through the sale of electricity (locally) and carbon credits (internationally). It will also assist in improving air quality and providing social upliftment through job creation and providing study bursary schemes to engineering students.

Managing dumpsites

The responsibility of dealing with waste, whether it be domestic or industrial, remains with the community that produced it. Local municipalities must be responsible for dealing with sewerage and solid waste and industries must have an organised and legal method of recycling or dumping their waste.

Marianhill landfill site in KwaZulu-Natal is an example of a well run, productive landfill site. A conservancy buffer zone around the site reduces pollution to surrounding communities and helps maintain biodiversity.



A landfill site

The need for recycling

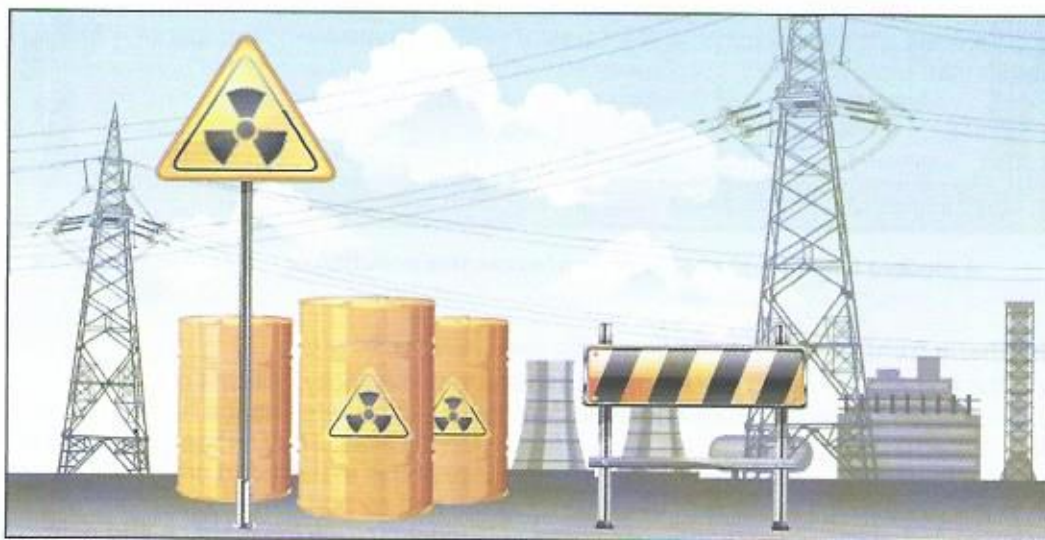
Human exploitation of the environment cannot continue indefinitely. As the human population continues to grow and as more communities have access to an increased standard of living, waste generation will keep increasing. Two major environmental consequences of increased consumption are:

1. natural resources that are used in the production of goods are being depleted; and
2. more space is required to dump the waste that is produced.

Successful public education policies have increased recycling by over 200% in the last 20 years and organizations and industries are increasingly becoming more environmentally conscious. In many nations, all domestic waste is separated and plastics, glass, paper and metal products are recycled. Currently, recycling is optional in South African households. People could be encouraged to recycle by having varying municipal waste disposal tariffs, based on the amount of non-recyclable waste they produce.

The safe disposal of nuclear waste

Koeberg is South Africa's nuclear power station. Nuclear power is a relatively inexpensive way to produce very large amounts of electricity. However, radioactive wastes are produced as a by-product of the process and have to be carefully discarded, because radiation can be extremely damaging to organisms, including people. Solid waste by-products are usually cast in concrete and buried deep underground in geologically stable areas and carefully monitored.



Hazardous nuclear waste in yellow barrels

Q & A

Page 129

1 Biodiversity, Change and Continuity

Biodiversity and Classification of Micro-organisms

A: Viruses

Question 1

Give the correct term for each of the following: (12)

1. An infectious particle capable of transmitting disease.
2. Parasites which live within the body of a host.
3. The type of nucleic acid found within bacteriophages.
4. An organism which transmits viruses to other species, but is not affected by the virus.
5. A medical condition that occurs when a person is HIV positive and has TB, or another disease.
6. The treatment given to rape victims who may have been exposed to the HI virus.

Question 2

1. List four characteristics of life that are not found in viruses. (4)
 2. State the characteristic of living organisms that is present in viruses. (1)
 3. List five different ways by which viruses can enter the human body. (5)
- [10]

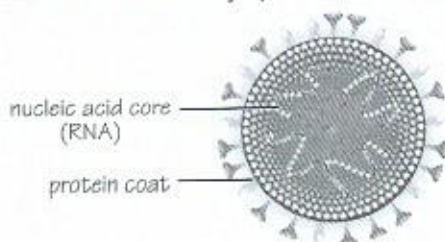
Question 3

1. Explain the difference between being HIV positive and having AIDS. (3)
 2. Describe two ways by which mothers can transmit the HI virus to their babies. (4)
 3. Is it necessary that an AIDS sufferer disclose their status in the work place? Explain your choice. (4)
- [11]

Question 4

Refer to this diagram of a virus.

1. This virus is able to infect people and cause influenza. Which evidence from the diagram supports this? (2)
 2. List three common symptoms of influenza. (3)
- [5]



B: Bacteria

Question 1

Write down the letter of the correct answer for the following multiple choice questions. (10)

1. Which of the following statements about bacteria is FALSE?
 - A. They are unicellular.
 - B. They reproduce by binary fission.
 - C. A clearly defined nucleus is present.
 - D. Some are autotrophic.

2. Bacteria...

- A. are microscopic, unicellular, prokaryotic organisms.
- B. have DNA and RNA in the cytoplasm.
- C. produce gametes during unfavourable environmental conditions.
- D. are always pathogenic.

3. All bacteria have

- A. a cell wall.
- B. a protective slime capsule.
- C. flagella or cilia.
- D. a nucleus.

4. Saprophytic bacteria...

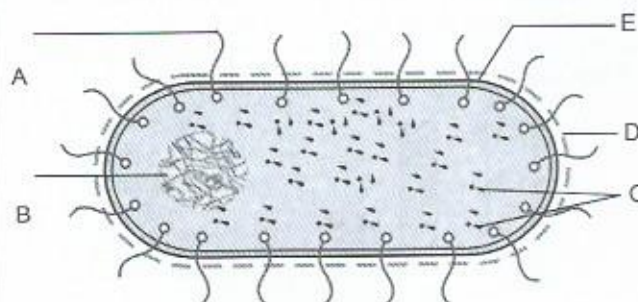
- A. always cause disease.
- B. require water and carbon dioxide to decompose organic matter.
- C. use energy from chemical processes to produce food.
- D. play a role in the nitrogen cycle.

5. Some bacteria are pathogenic because...

- A. they live symbiotically in the intestines of animals.
- B. they are prokaryotes.
- C. they feed on dead organisms.
- D. they cause disease.

Question 2

Study the diagram below then answer the questions that follow.



1. Provide labels for the parts marked A to E. (5)
 2. State one function of each of the parts labelled A, B and D. (6)
 3. State two ways in which this bacterial cell is similar to human body cells. (2)
 4. Name the type of bacterium illustrated in the diagram above. (1)
- [14]

Question 3

1. List three examples of mutualistic relationships between bacteria and other organisms. (6)
 2. Describe the role of autotrophic and saprophytic bacteria in a food chain. (4)
 3. Name four human diseases caused by bacteria. (4)
 4. What type of medicine is used to treat bacterial infections? (1)
- [15]

C: Protists

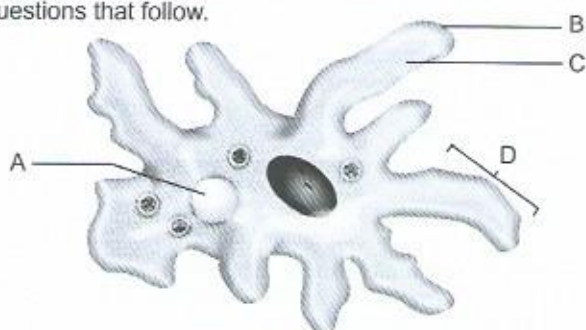
Question 1

Write down the letters A to I one below the other, then next to each letter, write down the word represented by that letter in the table below. (9)

	Plant-like protists	Fungi-like protists	Animal-like protists
Name of sub-group	A	B	C
Example	D	E	F
Mode of Nutrition	G	H	I

Question 2

Study the drawing of an *Amoeba* then answer the questions that follow.

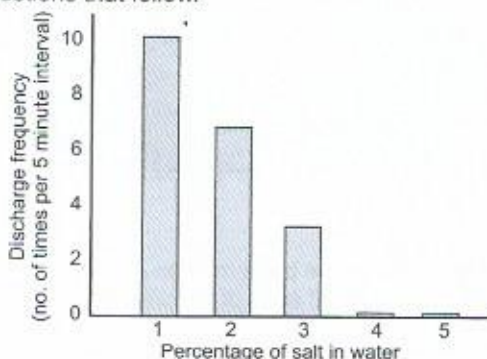


1. Provide labels for the parts marked A to D. (4)
2. Which structure, B or C, is more likely to give shape to *Amoeba*? Explain your answer. (4)
3. State two functions of the part labelled D. (2)

[10]

Question 3

The histogram below shows the frequency with which a protozoan expels water when placed in solutions of varying concentrations. Study the histogram then answer the questions that follow.



1. Name the water expulsion structure found in many protozoans. (1)
2. Using the information on the histogram, state the relationship that exists between the rate of discharge and the concentration of salt in the water. (2)
3. How often did the *Amoeba* discharge water when the salt concentration was 1%? (2)
4. How many times, in one hour, did the *Amoeba* discharge water when the salt concentration was 2%? (3)
5. Based on the information provided, is the *Amoeba* in this experiment a freshwater or a marine specimen? Explain your answer. (3)

[11]

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D: Fungi

Question 1

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 11 N. (10)

Column A

1. Thallus
2. Mycelium
3. Aseptate
4. Sporangium
5. Sporangophore
6. Rhizoid
7. Stolon
8. Columella
9. Spore
10. Fungal chitin

Column B

- A. a structure in which spores are produced.
- B. a root-like hypha that provides anchorage and assists with nutrition.
- C. a cross-wall which separates a sporangium from a hypha.
- D. a mass of tangled hyphae.
- E. produced in the sporangium and germinates into a new mycelium.
- F. the substance that provides structure to hyphae walls.
- G. being eukaryotic and having true nuclei.
- H. having no true roots, stems or leaves.
- I. fused hyphae found in mushrooms.
- J. an upward growing hypha which supports a sporangium.
- K. digestive enzymes used in saprophytic digestion.
- L. having no cross-walls present.
- M. a horizontally growing hypha.

Question 2

1. List five general characteristics of fungi. (5)
2. Name three fungal infections that commonly occur in people. (3)
3. Describe two environmental conditions that encourage fungal growth. (2)
4. Briefly describe three ways of reducing the chances of contracting a fungal infection. (3)

[13]

Question 3

1. Name the type of blue-green fungus which is used in the manufacturing of antibiotics. (1)
2. Who was the first person to discover the medicinal use of this blue-green fungus? (1)
3. Give two reasons why this blue-green fungus was not immediately used to treat infections. (2)
4. Which group of biological organisms is easily killed by this blue-green fungus? (1)
5. Apart from antibiotics, list five other beneficial uses of fungi to people. (5)

[10]

E: Immunity

Question 1

Explain the difference between the following terms:

1. Infection and immunity. (4)
2. Antibodies and antigens. (4)
3. Natural immunity and acquired immunity. (4)
4. Passively acquired immunity and actively acquired immunity. (4)
5. Attenuated vaccines and non-living vaccines. (4)
6. A hypersensitive response and systemic acquired resistance. (4)
7. MDR TB and XDR TB. (4)

[28]

Question 2

The media promotes the use of anti-bacterial soaps and detergents in the home.

List three advantages and three disadvantages of using anti-bacterial soaps and detergents in the home. (6)

Plant Biodiversity

Division: Bryophyta

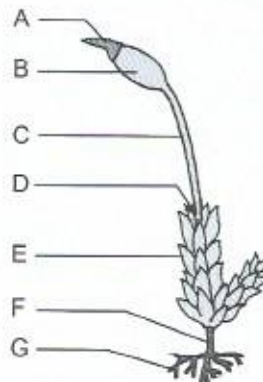
Question 1

Write down the letter of the correct answer for the following multiple choice questions. (10)

1. Bryophytes are adapted to living on land because they
 - A. contain vascular tissue.
 - B. have rhizoids.
 - C. can photosynthesize.
 - D. produce gametes.
2. The dominant phase of moss plants which produces "carpets" of green plants...
 - A. is semi-parasitic.
 - B. comprises the sporophyte generation.
 - C. is a thallus structure.
 - D. produces spores.
3. In bryophytes, the gametophyte generation is the...
 - A. adult plant.
 - B. foot, seta and capsule.
 - C. gametes.
 - D. protonema.
4. Which of the following statements about the moss plant is FALSE?
 - A. The gametophyte generation is autotrophic.
 - B. The sporophyte generation is semi-parasitic.
 - C. Gametes fuse to form the protonema.
 - D. Spores are produced during the sporophyte generation.
5. The zygote of a moss plant...
 - A. results from the fusion of two spores.
 - B. develops into the sporophyte.
 - C. develops into a protonema.
 - D. is part of the gametophyte generation.

Question 2

Study the diagram of below then answer the questions that follow.



1. Identify the parts labelled A to G. (7)
 2. List the letters that represent the sporophyte phase of the plant. (3)
 3. State two functions of the part labelled G. (2)
- [12]

Question 3

Moss plants are restricted to living in clumps in damp, shady habitats. Give five reasons why this is so. (10)

Division: Pterophyta

Question 1

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 11 N. (10)

Column A

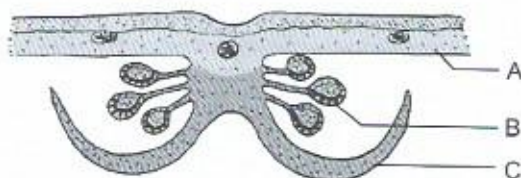
1. Frond
2. Pinna
3. Sorus
4. Sporangium
5. Rachis
6. Rhizome
7. Rhizoid
8. Prothallus
9. Adventitious
10. Archaeogonium

Column B

- A. consists of many sporangia.
- B. mid-vein of a frond.
- C. the gametophyte generation.
- D. a "leaflet"
- E. unicellular root-like structure.
- F. the organ in which ova are produced.
- G. the sporophyte generation.
- H. a compound leaf with many pinnae.
- I. the organ in which sperm are produced.
- J. an embryo which develops into a sporophyte.
- K. an underground stem.
- L. the root of the sporophyte plant.
- M. the structure in which spores are produced.

Question 2

Study the diagram of an *Amoeba* then answer the questions that follow.



1. Provide labels for the parts marked A and B. (3)
 2. State the function of the part marked C. (1)
 3. Does this portion of the fern plant represent the sporophyte or gametophyte? Give a reason for your answer. (3)
- [7]

Question 3

1. Describe three structural characteristics of ferns which enable them to live in more diverse habitats than mosses. (6)
 2. Explain why ferns are dependent on water to complete their life-cycle. (4)
- [10]

Division: Spermatophyta

Question 1

Give the correct biological term for each of the following:

1. A branch in *Pinus* sp. from which needle-like leaves arise.
 2. The woody scales of a pine cone.
 3. The type of symbiotic relationship that exists between the roots of pine trees and a mycorrhizal fungus.
 4. The tissue inside seeds which provides nutrients for the germinating embryo.
 5. A structure of seeds which prevents desiccation.
 6. The division of plants that is not dependent on water for fertilisation.
 7. The dominant form of plants on Earth.
 8. The brightly coloured whorl of a flower which attracts insects.
 9. The female whorl of a flower.
 10. The part of a flower which develops into a seed following fertilisation.
 11. The part of a flower which develops into a fruit following fertilisation.
 12. An organ within a flower which produces nectar.
- (12)

Question 2

1. Gymnosperms were the first plants to develop a tap root system.

Give two reasons why tap roots enabled the gymnosperms to exploit a greater range of environments than earlier plants.

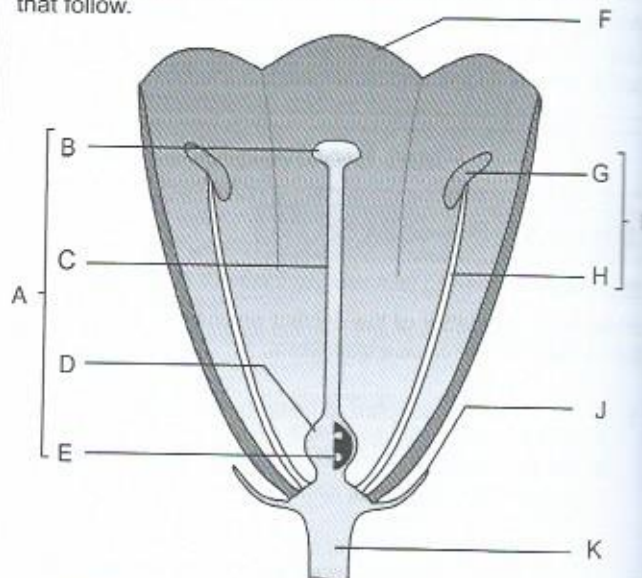
2. Many pine trees have to withstand heavy snowfalls each winter. Describe two structural features of the trees which enable them to do this. (4)
- [8]

Question 3

1. Explain why gymnosperms are not dependent on water for fertilization. (4)
 2. Name the dispersal agent of pine seeds. (1)
 3. Describe how pine seeds are structurally adapted in order to be dispersed. (2)
 4. List three pollinating agents of angiosperms. (3)
 5. State two advantages of producing seeds that are located within a fruit. (2)
 6. Name the process by which pollen grains are transferred to the stigma. (1)
 7. Describe five adaptations of Hibiscus flowers that encourage pollination. (5)
- [18]

Question 4

Study the diagram of a flower, then answer the questions that follow.



1. Provide labels for the parts marked A to K. (11)
 2. Give the letter of the part which produces pollen. (1)
 3. Which letter/s represent the female whorl? (3)
 4. State two functions of the part labelled J. (2)
 5. Give the letter of the part in which fertilisation occurs. (1)
 6. Give the letter of the part which will develop into a fruit following fertilisation. (1)
 7. Give the collective name for all the parts labelled I? (1)
 8. Give the letter of the part that represents the gynaecium. (1)
- [21]

Question 5

1. In a table, compare grains and pulses. Include two examples of each type of seed. (11)
 2. List three human activities that are contributing to a decline in biodiversity. (3)
 3. Explain what a seed bank is. (3)
 4. List three benefits of storing seeds in a seed bank. (3)
- [20]

Plant Reproduction

Question 1

Give the correct biological term for each of the following:

1. The type of reproduction involving the fusion of gametes.
2. The first diploid cell that forms following fertilization, that develops into an embryo.
3. The type of reproduction whereby offspring that are genetically identical to their parents are produced.
4. A form of cell division which only occurs during sexual reproduction.
5. A collective term for tubers, bulbs and corms.

(5)

Question 2

Explain the difference between:

1. Asexual and sexual reproduction. (4)
2. Spores and gametes. (4)
3. Self pollination and cross pollination. (4)

[12]

Question 3

1. State three advantages and three disadvantages of asexual reproduction in plants. (6)
2. State three advantages and three disadvantages of sexual reproduction in plants. (6)

[12]

Question 4

Study the image below then answer the questions which follow:



1. Define pollination. (2)
2. Name a possible agent of pollination of this flower? (1)
3. Give one visible reason for your answer to question 2 above. (2)
4. List three common features of bird pollinated flowers. (3)
5. Describe two ways in which insect pollinated flowers differ from bird pollinated flowers. (4)

[12]

Question 5

1. Name the process that occurs in the ovary of a flower immediately after pollination. (1)
2. What does the ovule develop into after the process named in question 1? (1)
3. a) Name the structure that the ovary develops into after the process named above has occurred? (1)
b) Describe two functions of this structure. (4)
4. Name three different types of animals that disperse the seeds of plants. (3)
5. Why is it important for plants to have their seeds dispersed? (2)

[12]

Animal Biodiversity

Question 1

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 16 S. (15)

Column A

1. Asymmetry
2. Radial symmetry
3. Bilateral symmetry
4. Cephalisation
5. Ectoderm
6. Mesoderm
7. Endoderm
8. Diploblastic
9. Triploblastic
10. Coelom
11. Hydrostatic skeleton
12. Blind gut
13. Through gut
14. Open blood system
15. Closed blood system

Column B

- A. most complex form of symmetry, allows for cephalisation.
- B. having two embryonic germ layers.
- C. a fluid filled cavity located in the mesoderm.
- D. a digestive system with a "mouth" at one end and an "anus" at the other.
- E. form of symmetry associated with unicellular and/or sedentary animals.
- F. fluid-filled cavity located in the endoderm
- G. structural support provided by a fluid filled cavity.
- H. form of symmetry associated with sessile animals, with a number of mirror images if sliced through the centre point.
- I. the outer germ layer in embryos, gives rise to skin.
- J. having three embryonic germ layers.
- K. blood remains within blood vessels and is pumped around the body by a heart.
- L. a circulatory system in which gaseous exchange cannot take place.
- M. middle embryonic germ layer, forms internal organs.
- N. a characteristic unique to unicellular animals.
- O. incorporates a blood-filled cavity called a haemocoel, in which tissues come into direct contact with the blood.
- P. inner embryonic germ layer which lines the gut.
- Q. a simple digestive system having only one opening.
- R. having a concentration of nerve cells in the anterior (head) region.

Phylum: Porifera

Question 1

1. Draw and label a typical sponge. Include the functions of each labelled part on your diagram. (12)
 2. Despite being multi-cellular, why are the Porifera considered to have no tissues? (2)
 3. Describe how sponges obtain their food. (4)
- [18]

Phylum: Cnidaria

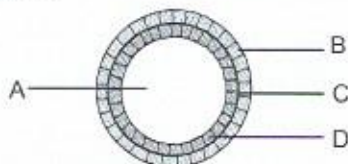
Question 1

Write down the letter of the correct answer for each of the following questions. (10)

1. The outermost layer of a cnidarian is the...
 - A. ectoderm and contains specialized protective stinging cells.
 - B. ectoderm and has modified cells for digestion.
 - C. mesoglea and comprises non-living substances.
 - D. endoderm and is concerned mainly with locomotion.
2. The symmetry of sea anemones is an adaptation for...
 - A. an aquatic life-style.
 - B. rapid movement.
 - C. a sedentary existence.
 - D. a parasitic life-style.
3. *Hydra* has a/an...
 - A. hydrostatic skeleton.
 - B. exoskeleton.
 - C. endoskeleton.
 - D. axial skeleton.
4. *Hydra*'s best defense mechanism from potential predators is to...
 - A. reduce its size by contracting its body and tentacles.
 - B. swim rapidly away.
 - C. wave its tentacles to frighten off the predator.
 - D. paralyse the predator.
5. Which one of the following is NOT a disadvantage of radial symmetry?
 - A. Cephalisation cannot develop.
 - B. The animal can react to stimuli in all directions.
 - C. Movement is random, or non-directional.
 - D. Specialised sensory organs cannot develop.

Question 2

Write down the letter of the correct answer for the following questions:



1. Aids in locomotion and capturing prey. (1)
 2. The location of extracellular digestion. (1)
 3. The location of intracellular digestion. (1)
 4. When filled with water, provides structural support to *Hydra*. (1)
- [4]

Phylum: Annelida

Question 1

Sketch a simple earthworm. On your diagram, indicate all the features earthworms have that are absent in the Platyhelminthes. Next to each feature give a brief explanation of why it is beneficial to the earthworm. (16)

Question 2

1. Give two reasons why earthworms are nocturnal. (4)
 2. Explain the significance of having a coelom. (3)
 3. Name the gaseous exchange organ. (1)
- [8]

Phylum: Arthropoda

Question 1

Name the class to which each of these animals belong and give two examples of animals in that class: (12)

1. Has three pairs of legs and the body is divided into a head, thorax and abdomen.
2. Has four pairs of legs and the body is divided into a cephalothorax and abdomen.
3. Has five pairs of legs.
4. Has numerous body segments and many pairs of legs.

Question 2

1. What is the function of an exoskeleton? (2)
 2. Describe three limitations of possessing an exoskeleton. (3)
 3. Name the two body systems which are located in the coelom. (2)
 4. Which two body systems are integrated into the haemocoel? (2)
- [9]

Question 3

Describe four beneficial roles that invertebrates play in agriculture. (12)

Phylum: Chordata

Question 1

In a table, compare the five main classes of chordates under the following headings:

1. Name of class. (5)
 2. Typical body covering. (5)
 3. For each class include one example of: (15)
- [20]

- an aquatic animal,
- a terrestrial (land-based) animal, and
- an aboreal (flying) animal.

Note: there may be a few classes which are not represented in all three environments. Write the word "none" in the appropriate place.

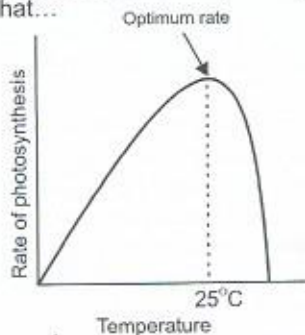
2 Life Processes in Plants and Animals

A: Photosynthesis

Question 1

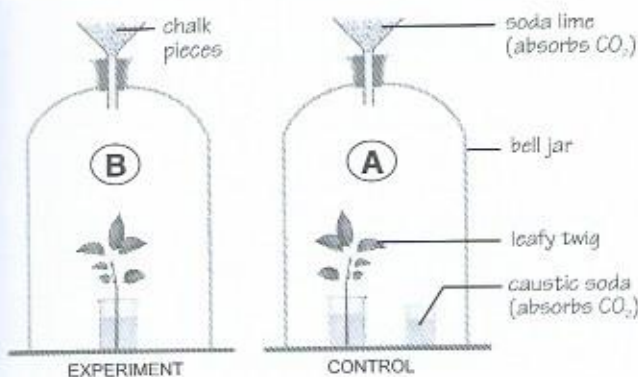
Write down the letter of the correct answer for the following multiple choice questions. (10)

- Photosynthesis is a process that...
 - converts radiant energy into chemical energy.
 - converts chemical energy into heat energy.
 - converts heat energy into chemical energy.
 - converts radiant energy into heat energy.
- If all the green plants in the world were destroyed, the atmospheric gas that would increase would be:
 - oxygen
 - nitrogen
 - hydrogen
 - carbon dioxide
- From the following graph representing the relationship between temperature and rate of photosynthesis, it can be deduced that...



- As the temperature increases, so does the rate of photosynthesis.
- Increasing the temperature above 25°C has no effect on the rate of photosynthesis.
- Photosynthesis increases until 25°C, then decreases rapidly thereafter.
- There is an inverse relationship between the rate of photosynthesis and temperature.

Questions 4 and 5 both refer to the following diagram.



- The aim of this experiment is to demonstrate that...
 - light is essential for photosynthesis.
 - oxygen is essential for photosynthesis.
 - the rate of photosynthesis is affected by changes in pH.
 - carbon dioxide is essential for photosynthesis.
- After 24 hours, the following results would be expected:
 - Leaves in B would test positive for starch.
 - Leaves in A would test positive for starch.
 - There would be no change in the starch content of the leaves in the experiment and the control.
 - Leaves in both A and B would test positive for starch.

Question 2

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 11 N. (12)

Column A

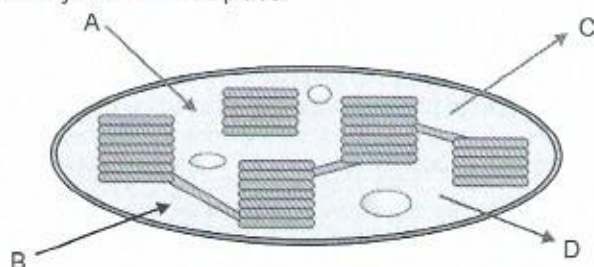
- autotrophic
- chlorophyll
- thylakoid
- granum
- stroma
- starch grain
- photolysis
- enzymes
- iodine
- destarching
- soda lime
- Elodea*

Column B

- a photosynthetic membrane containing chlorophyll.
- the matrix of the chloroplast, where the dark phase occurs.
- stores the insoluble converted product of photosynthesis.
- essential catalysts of photosynthesis.
- used to test for the presence of starch, indicating photosynthesis has occurred.
- removes carbon dioxide from the atmosphere.
- organisms that can manufacture their own food.
- the removal of all starch in leaves before an experiment to test for photosynthesis.
- an aquatic plant used to demonstrate that oxygen is a byproduct of photosynthesis.
- used to demonstrate the effect of temperature on photosynthesis.
- a green pigment that absorbs radiant energy.
- using light energy to split water molecules to release high-energy hydrogen ions.
- a stack of thylakoids.

Question 3

The following diagram represents a chloroplast in which photosynthesis takes place.



1. Name the raw materials labelled A and B. (2)
 2. Name the parts of the plant where raw materials A and B are obtained. (2)
 3. What is the name of gas C? (1)
 4. Name product D and also give the name of the insoluble substance that it is converted into. (2)
- [7]

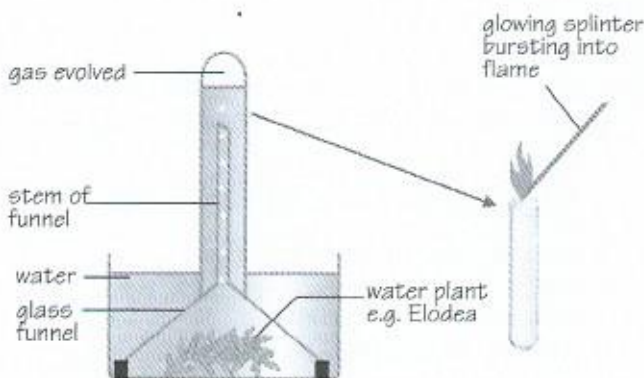
Question 4

Complete the table comparing the light and dark phases of photosynthesis. Write only the word that is represented by each letter. (8)

	Light Phase	Dark Phase
Location in chloroplast:	A	B
Raw materials:	Radiant energy + C	H ⁺ ions + D
Products:	E + F	G
Name of process:	H	-

Question 5

The following apparatus was set up in the laboratory.



1. State the aim of this experiment. (2)
 2. Why was the glass funnel placed on blocks? (2)
 3. Name the gas which evolved and was collected at the top of the test tube. (2)
 4. What procedure was used to determine the composition of the gas? (3)
 5. Write the conclusion for this experiment. (2)
 6. Describe how you would set up a control for the experiment. (2)
- [13]

B: Animal Nutrition

Question 1

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 14 P. (13)

Column A

1. herbivore
2. omnivore
3. carnivore
4. ingestion
5. egestion
6. mechanical digestion
7. chemical digestion
8. absorption
9. assimilation
10. secretion
11. excretion
12. peristalsis
13. deamination

Column B

- A. elimination of undigested food, usually via defecation.
- B. an animal that eats primarily meat.
- C. the breakdown of food using enzymes and acids.
- D. the release of energy from nutrients at the cellular level.
- E. the breaking down of excess amino acids.
- F. the release of useful substances into the body.
- G. rhythmic muscular contractions of the alimentary canal that move food boluses along.
- H. an animal that eats only plant material.
- I. enzymes used in the process of digestion.
- J. eating food
- K. a process associated with excess intake of food.
- L. the release of waste products from the body.
- M. pigs and humans.
- N. the movement of digested food from the digestive system into the circulatory system.
- O. the physical breakdown of food by chewing and churning of the stomach.

Question 2

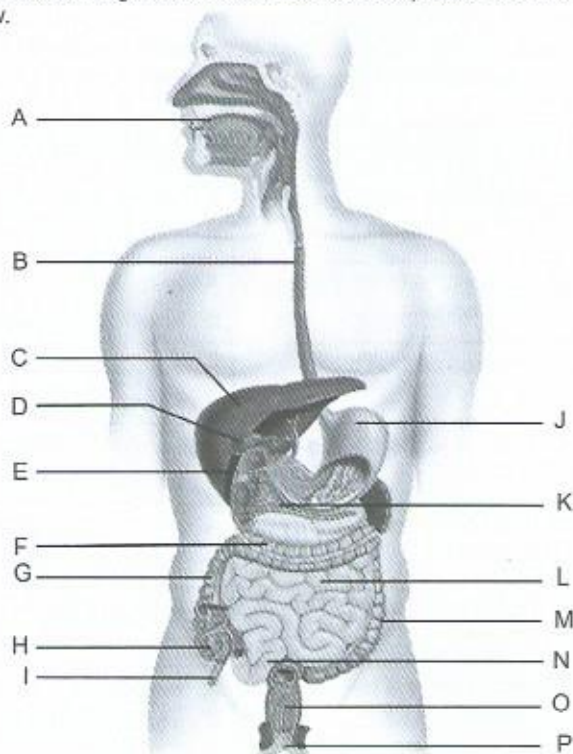
The following table compares the dental formulae of three animals: a warthog, a buffalo and a lion. Study it, then answer the questions that follow.

Animal	I	C	P	M
A	$\frac{0}{4}$	$\frac{0}{1}$	$\frac{3}{3}$	$\frac{3}{3}$
B	$\frac{3}{3}$	$\frac{1}{1}$	$\frac{3}{2}$	$\frac{1}{2}$
C	$\frac{1}{3}$	$\frac{1}{3}$	$\frac{3}{2}$	$\frac{3}{3}$

1. State which animal, warthog, buffalo or lion is represented by A, B and C. (3)
 2. Explain each of your three choices to Q 1 above. (6)
 3. Calculate the total number of teeth that each adult animal has. (6)
- [15]

Question 3

Refer to the image below then answer the questions which follow.



- Name parts labelled A to P. (15)
- Give the letter/s of the parts in which each of the following processes takes place:
 - 2.1 ingestion (1)
 - 2.2 mechanical digestion (4)
 - 2.3 chemical digestion (3)
 - 2.4 absorption (2)
 - 2.5 peristalsis (7)
 - 2.6 complex carbohydrates begin being digested (1)
 - 2.7 most proteins are digested (1)
 - 2.8 the final digestion of food (1)
 - 2.9 bile is stored (1)
 - 2.10 defaecation (1)

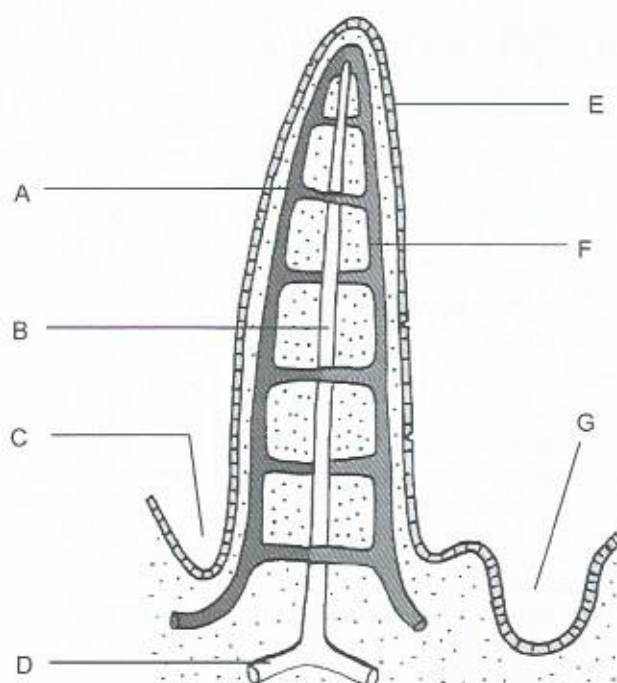
[37]

Question 4

Refer to the diagram in the next column then answer the questions which follow.

- Provide a heading for this diagram. (2)
- Provide labels for the parts A to G. (7)
- What is the function of this structure? (2)
- Give the letter / s in which amino acids and monosaccharides are transported. (2)
- Provide the letter / s which transport fatty acids. (2)
- In which part of the small intestine does this particular structure occur? Give a reason for your answer. (3)
- State the function of the part labelled G. (4)

[22]



Question 5

- List five sources of roughage. (5)
- What is roughage? (2)
- Describe the role of roughage in the process of digestion in humans. (6)
- List three reasons why water is essential for digestion. (6)

[19]

Question 6

Homeostasis refers to the ability of the body to maintain a fairly constant internal environment to ensure the normal functioning of all the cells.

- Complete the following table that compares the role of the hormones insulin and glucagon in maintaining a fairly constant glucose level in the blood. (7)

Blood glucose level	High	Low
Hormone secreted	A	E
Name of cells in pancreas that secrete the hormone	B	F
Effect of the hormone	1. C 2. D	1. G ---
End result	Blood glucose level returns to normal.	Blood glucose level returns to normal.

- List the typical symptoms of someone suffering from diabetes. (5)
- Type 2 diabetes is one of the most rapidly growing diseases in South Africa. It is also increasingly found in children and young adults. Give three reasons why you think this is happening. (6)

[11]

C: Cellular Respiration

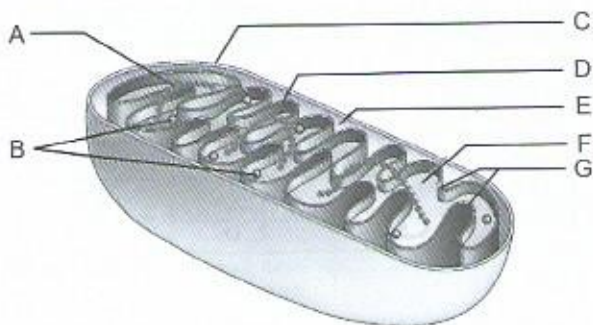
Question 1

Write down the letter of the correct answer for the following multiple choice questions. (10)

- The substance released during cellular respiration is...
A. glucose
B. oxygen
C. carbohydrates
D. energy
- In green plants, cellular respiration occurs...
A. only during the day.
B. only during the night.
C. only in chlorophyll containing tissues.
D. continuously.
- A common characteristic of both aerobic and anaerobic respiration is that...
A. oxygen is used and carbon dioxide is released.
B. carbon dioxide is used and oxygen is released.
C. glucose is the source of energy.
D. they both occur in the mitochondria.
- Two products of cellular respiration are:
A. Water in urine and exhaled carbon dioxide.
B. Inhaled oxygen and exhaled carbon dioxide.
C. Inhaled oxygen and water in urine.
D. Exhaled carbon dioxide and glucose.
- The source of atmospheric oxygen that is needed for cellular respiration by all organisms is...
A. decomposing organic matter.
B. photosynthesis.
C. combustion reactions.
D. from the destruction of the ozone layer.

Question 2

Refer to the diagram below then answer the questions which follow.



- Name parts labelled A to G. (7)
 - Name the cellular respiration processes that occur inside this organelle. (2)
 - State the purpose of cellular respiration. (2)
 - Which would have more of these organelles, a muscle cell or a bone cell? Give a reason for your answer. (3)
- [14]

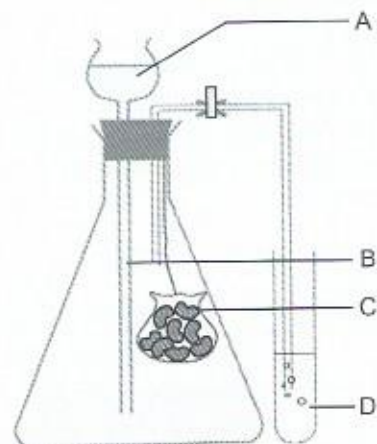
Question 3

For each of the terms in Column I, state whether it applies to A only, B only, Both or None of the statements in Column II. Write the number of the answer, followed by A only, B only, Both or None. For example: 9. A only. (16)

Column I	Column II
1. occurs when oxygen is present in a cell	A. aerobic respiration B. anaerobic respiration
2. takes place in the cytosol of mitochondria	A. aerobic respiration B. anaerobic respiration
3. requires carbon dioxide	A. aerobic respiration B. anaerobic respiration
4. glucose is the source of energy	A. aerobic respiration B. anaerobic respiration
5. reaction is controlled by enzymes	A. aerobic respiration B. anaerobic respiration
6. end product is 38 ATP molecules	A. aerobic respiration B. anaerobic respiration
7. lactic acid is a by-product in animals	A. aerobic respiration B. anaerobic respiration
8. used in the manufacturing of beer	A. aerobic respiration B. anaerobic respiration

Question 4

Refer to the diagram below then answer the questions which follow.



- Provide labels for the parts: A to D. (4)
 - Write a hypothesis for this experiment. (2)
 - Explain the function of the items labelled C. (3)
 - What is the purpose of the substance labelled D? (2)
 - Describe the results of this experiment. (2)
 - Briefly describe how you would you prepare a control for this experiment? (3)
- [16]

D: Gaseous Exchange

Question 1

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 12 N. (11)

Column A

1. respiratory system
2. cardio-vascular system
3. breathing
4. gaseous exchange
5. cellular respiration
6. diffusion
7. spiracle
8. stomata
9. skin
10. alveoli
11. diaphragm

Column B

- A. the diffusion of gases across alveoli membranes and between blood capillaries and body cells.
- B. a form of gaseous exchange used by unicellular organisms, earthworms and plants.
- C. the organ through which earthworms and some amphibians breath.
- D. protects the gills of fish.
- E. transports dissolved gases between the lungs and the body's cells.
- F. the gaseous exchange surface of mammals.
- G. protects the lungs of mammals.
- H. a chemical process requiring oxygen, in order to break down glucose to release energy.
- I. an opening on the thorax and abdomen of insects which facilitates gaseous exchange.
- J. the gaseous exchange opening on leaves and young stems.
- K. transports gases between the lungs and the nose.
- L. the muscle that controls air pressure inside the thoracic cavity.
- M. a mechanical process involving inhalation and exhalation.

Question 2

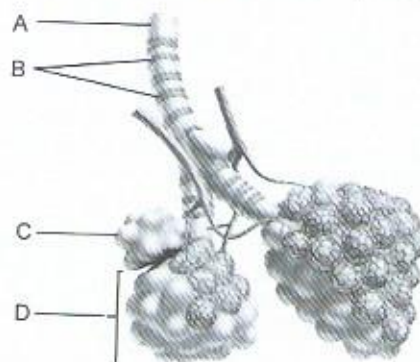


1. For each animal, name the organ of gas exchange. (2)
2. Name the process by which gases enter and leave the body of insects. (1)
3. The concentration of oxygen in water is less than in air. Describe the structural adaptations of the gaseous exchange organs of fish which enable them to extract maximum oxygen. (3)

[6]

Question 3

Refer to the image below then answer the questions which follow.

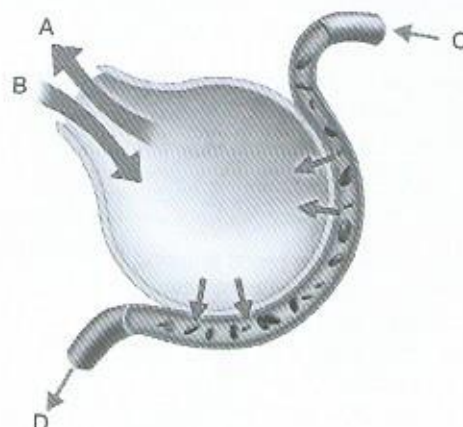


1. Exactly where in the body would one expect to find this structure? (1)
2. Provide labels for the parts marked A to D. (4)
3. Describe three structural adaptations of C that enable it to function efficiently. (6)
4. State the function of the parts labelled B. (2)

[13]

Question 4

Refer to the image below then answer the questions which follow.



1. Give the letter of the arrow which represents the inhalation of air. (1)
2. Give the letter which represents deoxygenated blood. (1)
3. State the letter that represents the pulmonary vein and state whether the blood it transports is oxygenated or deoxygenated. (2)
4. Name the molecule in blood that is responsible for transporting dissolved gases. (1)

[5]

Question 5

1. Name the organism responsible for tuberculosis (TB). (1)
2. List five symptoms of TB. (5)
3. Explain how TB is transmitted. (4)
4. Can TB be cured? (1)
5. What is DOTS is an abbreviation for? (2)
6. Describe what DOTS monitoring is. (3)
7. Why did the World Health Organization (WHO) introduce DOTS? (4)

[20]

Question 6

1. List three respiratory illnesses that can be caused by smoking. (3)
2. What is the effect of cigarette smoke on gaseous exchange? (1)
3. Complete the table below which summarizes the impact of cigarette smoke on various parts of the respiratory system. Write the letter and the term or explanation it represents. (10)

Component of cigarette smoke	Part affected	Negative effect of smoke
Smoke	1. A 2. B	1. C 2. D
Tar	E	F
Nicotine	G	H
Carbon monoxide	I	J

E: Excretion

Question 1

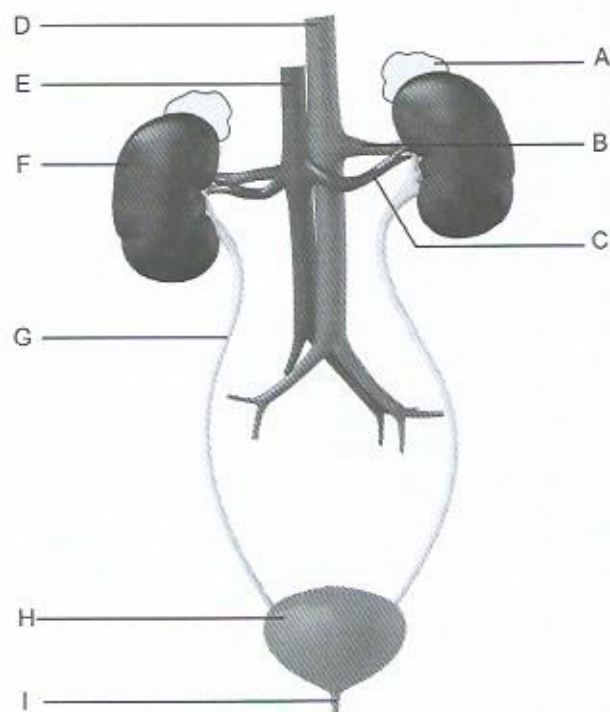
Write down the letter of the correct answer for the following multiple choice questions. (14)

1. The skin, lungs and kidneys all excrete...
A. carbon dioxide
B. mineral salts
C. water
D. urea
2. Compared with blood entering the kidney, blood that leaves the kidney contains...
A. more glucose.
B. more water.
C. less carbon dioxide.
D. less urea.
3. Glomerular filtrate contains...
A. water, glucose, amino acids, urea and uric acid.
B. water, blood, glucose, urea and uric acid.
C. blood, glucose, plasma proteins, urea and uric acid.
D. water, plasma proteins, amino acids and uric acid.
4. Sodium ions are actively pumped out of the...
A. glomerulus.
B. descending loop of Henle.
C. ascending loop of Henle.
D. distal convoluted tubule.
5. Water cannot leave the ascending loop of Henle because...
A. a diffusion gradient does not exist.
B. reverse osmosis cannot occur.
C. the sodium pump is activated.
D. the tubule walls are impermeable.

6. When sodium levels in the blood drop...
A. more ADH is secreted into the blood.
B. more aldosterone is secreted into the blood.
C. less ADH is released into the blood.
D. less aldosterone is released into the blood.
7. Kidneys maintain a homeostatic state in the blood by controlling...
A. water content, pH and haemoglobin level.
B. water content, haemoglobin level and urea content.
C. haemoglobin level, urea content and pH.
D. water content, pH and urea content.

Question 2

Refer to the image below then answer the questions which follow.

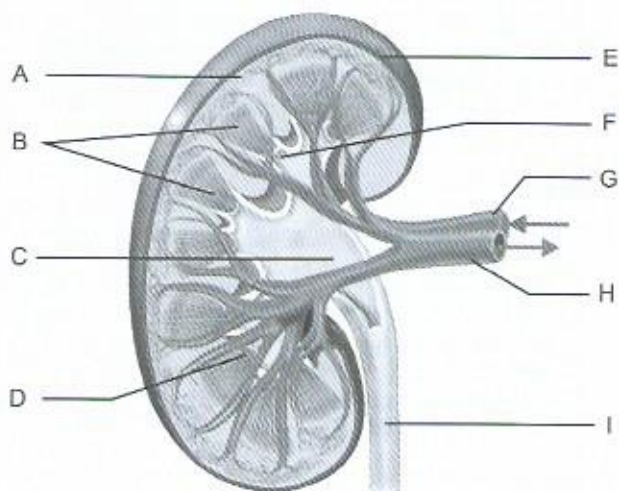


1. Provide labels for the parts marked A to I. (9)
2. Name the hormone secreted by structure A that is involved with excretion. (1)
3. What substance is regulated by the hormone identified above? (1)
4. Name the structure that can possibly cause a blockage in part G (2)
5. State the function of the structure labelled H. (2)
6. Describe two ways by which structure H is suited to its function. (4)
7. List two functions of structure I in males. (2)

[21]

Question 3

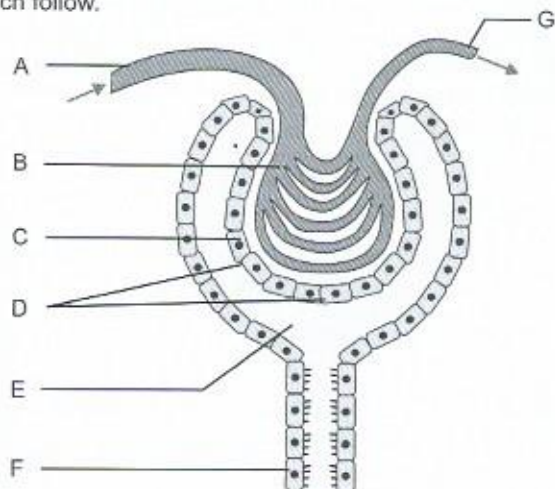
Refer to the image below then answer the questions which follow.



1. Provide labels for the parts marked A to I. (9)
 2. State the function of the part marked E. (4)
 3. List three substances that are dissolved in the blood in tube G but will not be found in tube H. (3)
 4. Name the part of the nephron that is located at A. (1)
 5. Which parts of the nephron are located in B? (3)
 6. Name the excretory substance found at C. (1)
- [21]

Question 4

Refer to the diagram below then answer the questions which follow.



1. Provide labels for the parts marked A to G. (7)
 2. Name the structure represented by this diagram. (1)
 3. Explain why the diameter of tubule A is greater than tubule G. (3)
 4. Name the process that takes place between B and C. (1)
 5. Describe three ways by which this structure is well adapted for its function. (6)
 6. List five substances that move from B to C. (5)
 7. List two substances that do not leave tubules A or G. (2)
 8. State the function of the micro-villi on cells F. (2)
- [27]

Question 5

1. State the function of ADH. (2)
 2. Where in the body is ADH produced? (1)
 3. Where along the nephron does ADH target? (2)
 4. How does ADH affect the permeability of cells in the nephron? (2)
 5. What is the consequence of ADH secretion on the movement of water in the nephron? (3)
 6. If a person had done strenuous exercise on a hot day, would you expect blood ADH levels to increase or decrease? Explain your answer. (4)
- [14]

Question 6

1. How are kidney stones formed? (2)
 2. Why are kidney stones dangerous? (2)
 3. Name two medical procedures that can be used to remove kidney stones. (2)
 4. How can a person reduce their chances of developing kidney stones? (1)
 5. Explain why there is a difference in the composition of dialysis fluid and blood. (3)
- [10]

3 Environmental Studies

Population Ecology

1. Population Size

Question 1

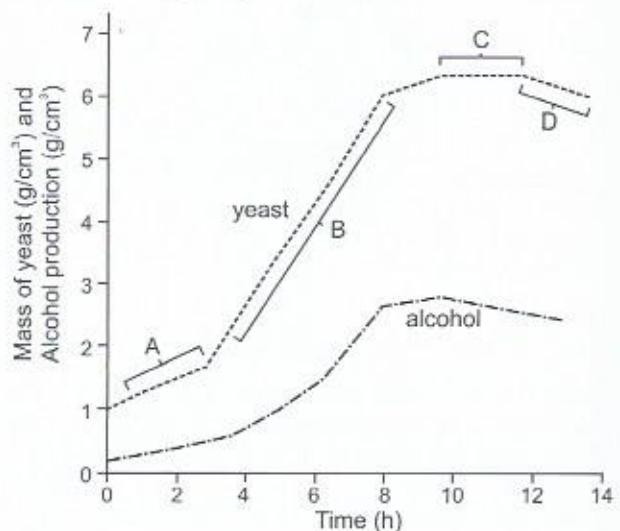
Write down the letter of the correct answer for the following multiple choice questions. (16)

- Factors that will cause a decrease in population size include...
 - Emigration
 - High natality rate
 - Predation
 - High mortality rate
 - (i), (ii) and (iii)
 - (i), (ii) and (iv)
 - (ii), (iii) and (iv)
 - (i), (iii) and (iv)
- Environmental resistance occurs when...
 - population sizes are low.
 - natural resources are limited.
 - population growth is exponential.
 - diseases cause high mortality rates.
- Density independent factors are:
 - Food, space and shelter.
 - Predation, competition and floods.
 - Seasonal fluctuations, earthquakes and accumulation of wastes.
 - Droughts, hail storms and very cold temperatures.
- A game farmer introduced 6 adult impala (5 females and 1 male) onto his medium-size farm. Food, shelter and water are all available and there are no predators or other herbivores competing for the resources. Which description best describes the expected change in the impala population?
 - The population will grow exponentially.
 - Initially there will be a lag phase as the impala establish themselves, but then the population will grow exponentially.
 - The population will grow slowly until environmental resistance occurs.
 - Initially there will be a lag phase as the impala establish themselves, but then the population will grow exponentially until the farm's carrying capacity is reached, then the population will remain fairly stable.
- A census would NOT be appropriate to use when determining the population size of...
 - Baobab trees on a golf course.
 - Forest-dwelling samango monkeys.
 - Hippopotamuses in a small dam.
 - Lichen on the side of a building.

- During a mark-recapture event, 12 meerkats were initially captured and marked. During the second capture, 15 meerkats were caught and three of them had previously been marked. Using the Petersen Index, the estimated size of the meerkat population is:
 - 40
 - 60
 - 24
 - 540
- The accuracy of mark-recapture methods can be improved by...
 - Feeding the captured animals before releasing them.
 - Using bright lights and loud noises to ensue the animals do not get accustomed to being caught.
 - Sampling during the breeding season.
 - Undertaking a number of samples and determining an average value.
- The quadrat method was used to determine the total number of beehives in a forest. Six quadrats were sampled and a total of 42 hives were counted. The area of each quadrat was 1ha. If the total forest size is 565ha, approximately how many beehives will there be in the forest?
 - 3,390
 - 3,955
 - 78
 - 23,730

Question 2

The graph below illustrates the growth of yeast, *Saccharomyces sp.*, and the amount of alcohol it produces. The quantity of yeast cells was not measured by the number of yeast cells present, but by the mass of the yeast cells ($\text{g}\cdot\text{cm}^{-3}$).



- Identify the phase of growth at C. (1)
- Explain the shape of the graph at: (i) A and (ii) B (6)
- Using the graph, state the carrying capacity for yeast in this environment. (2)
- State the general relationship between the growth of yeast and the production of alcohol. (2)
- Give two reasons to explain the decrease in the yeast population over the last two hours. (2)

[13]

Question 3

The quadrat method was used to determine elephant damage to mopane trees in the Kruger National Park. 60 quadrats were sampled and the number of mopane trees that had been damaged by elephants was counted. The area surveyed was 1 340 hectares in extent and each quadrat was $\frac{1}{4}$ of a hectare large. The average number of mopane trees that had been damaged in each quadrat was determined to be 22.

1. Calculate the total number of mopane trees that probably had been damaged by elephants in the section of the KNP that was surveyed. (5)
2. Explain how the reliability of this sampling method could be improved. (2)
3. List two factors that may have influenced the results of the survey. (2)

2. Interactions in the Environment

Question 1

For each of the terms in Column I, state whether it applies to A only, B only, Both or None of the statements in Column II. Write the number of the answer, followed by A only, B only, Both or None. For example: 9. A only. (16)

Column I	Column II
1. Predator-prey relationship	A. lion - impala B. zebra - buffalo
2. Intraspecific competition	A. baboon - vervet monkey B. white rhino - black rhino
3. Interspecific competition	A. impala - kudu B. fig tree - maroela tree
4. Resource partitioning	A. forest stratification B. lions and leopards
5. Mutualism	A. one species benefits while the other is not affected B. both species benefit
6. Commensalism	A. remora fish and sharks B. bilharzias and humans
7. Social organization	A. provides protection from predation B. improves chances of survival of the group
8. Division of labour	A. ensures only dominant breeding pair mate B. all members of the group have identical roles

3. Community Change Over Time

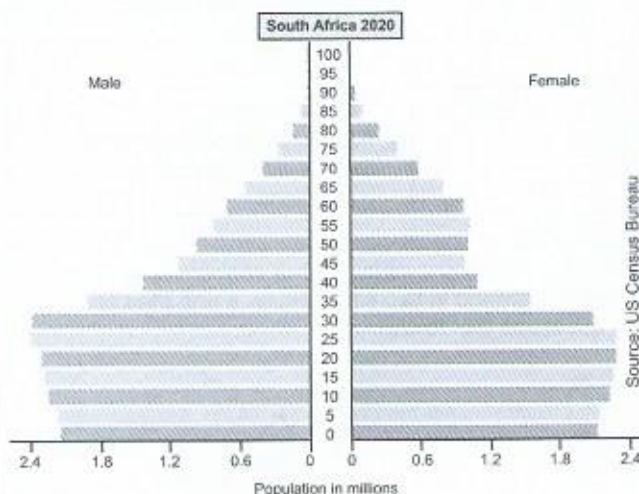
Question 1

Complete the table comparing primary and secondary succession. Write only the letter, followed by the correct answer. (14)

	Primary succession	Secondary succession
Examples of where it occurs:	A + B	C + D
Speed of the process:	E	G
Explanation of why the process occurs at that speed:	F	H
First species to colonise the area:	I	L
Characteristics of 1st species that colonise the area:	J + K	M + N

Question 2

The population pyramid below predicts South Africa's population structure in 2020. Study the pyramid and answer the following questions.



1. Does the pyramid reflect a developing or developed nation? Give a reason for your answer. (3)
2. Which age group has the most males? (2)
3. List two reasons why the predicted pyramid for SA shows a negative growth rate. (2)
4. Approximately how many women are between 40-45 years old? (2)
5. Which age group of men has only approximately 600,000 people? (2)

[11]

Human Impact on the Environment

1. The Atmosphere and Climate Change

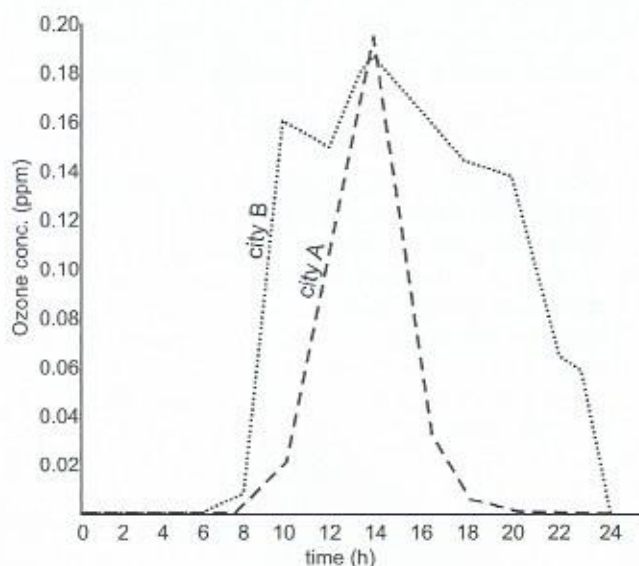
Question 1

For each of the terms in Column I, state whether it applies to A only, B only, Both or None of the statements in Column II. Write the number of the answer, followed by A only, B only, Both or None. For example: 7. A only. (12)

Column I	Column II
1. greenhouse gas	A. carbon dioxide B. oxygen
2. carbon footprint	A. amount of carbon dioxide generated by a person B. amount of carbon dioxide generated by a country
3. methane	A. results from burning fossil fuels B. released by domestic herbivores
4. carbon sink	A. an area that absorbs CO ₂ B. being lost because of deforestation
5. desertification	A. primarily caused by droughts B. a consequence of poor land management
6. afforestation	A. the cutting down of forests B. the replacing of indigenous forests with commercial tree plantations

Question 2

The graph below shows the ozone concentration 10m above the ground in two cities. Study it and then answer the questions that follow.



- What is the role of ozone in the stratosphere? (2)
- In the lower atmosphere, ozone is poisonous and contributes to the formation of two atmospheric pollutants. Name them. (2)

- Overall, which city, A or B, has the greater ozone concentration? (1)
- For how many hours a night does City B have no ozone in the atmosphere? (2)
- State the dependent variable on the graph. (1)
- Name a substance that contributes to the destruction of the ozone layer in the stratosphere. (1)
- Name the document that was drawn up by many countries in the world to reduce the destruction of the ozone layer. (1)
- Has the document mentioned above been successful? (1)
- State one human health benefit that has happened because of the effects of the international document. (2)

2. Water Availability and Quality

Question 1

Match the description in Column B with the correct term in Column A. Write only the letter of the correct answer, for example: 19 T. (18)

Column A

- perennial river
- Lesotho Highlands Water Project
- mines in Gauteng
- hydro electric power
- Drakensberg Water Scheme
- common problems of most SA dams
- wetlands
- large-scale sprinkler irrigation systems

Column A (continued)

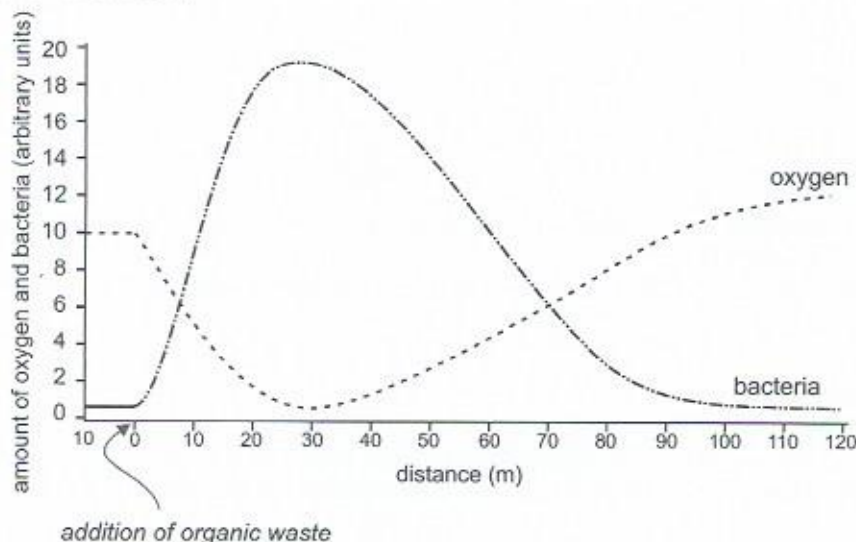
- El Nino
- La Nina
- commercial plantations
- aquifers
- grey water
- waterborne diseases
- estuaries
- eutrophication
- thermal pollution
- Biological Oxygen Demand

Column B

- a clean and cost-effective means of producing energy
- prevent flood damage and act as natural filters
- causes hot, dry conditions
- reduce biodiversity and consume large amounts of water
- the source of much of South Africa's water
- water that has been used for domestic washing and can be recycled in gardens
- third highest cause of death amongst young children in SA
- the amount of oxygen needed for decomposition of organic matter
- caused by excessive nitrates and phosphates
- one that flows all year round
- kills aquatic organisms and lowers the amount of dissolved oxygen
- stores water and provides HEP
- contaminate water and use vast amounts of SAs water
- alien aquatic plant
- high evaporation and sedimentation rates
- causes heavy rainfall and flooding
- waste water and contribute to salination of the soil
- a fairly large source of clean water
- experience pollution from fertilizers and marine oil spills

Question 2

The following graph depicts the effect on an aquatic bacteria population of releasing organic waste into a river. Study it then answer the questions that follow.

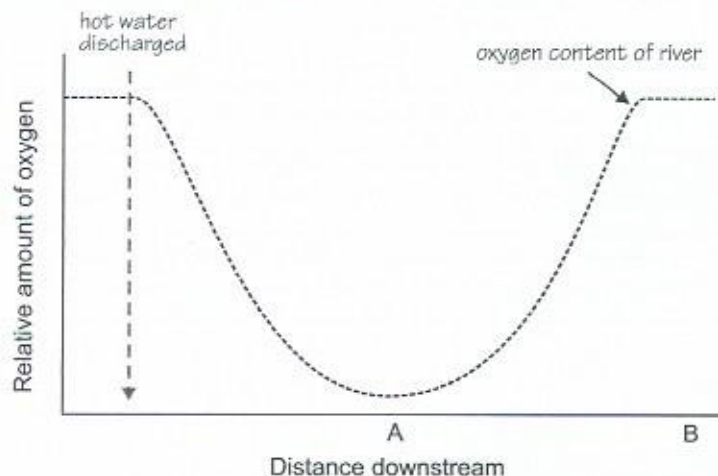


1. Give two examples of organic waste that may have been added to the water. (2)
2. Describe the relationship between organic waste concentration and the amount of aquatic bacteria. (2)
3. What do bacteria do to organic waste? (1)
4. Briefly explain why the amount of bacteria decreases as the distance from the source of the organic waste increases. (2)
5. At what distance from the point of introduction of organic waste is:
 - i) the concentration of bacteria the highest? (2)
 - ii) the concentration of oxygen the highest? (2)

[11]

Question 3

Thermal pollution results from large inputs of heated water into water bodies. Study the effect of hot water being pumped from a power station into a river, then answer the questions.



1. Explain the effect that hot water has on the oxygen concentration of the river. (2)
2. Why does the oxygen concentration increase downstream? (2)
3. What will happen to fish living in the river at point A? (2)
4. Discuss two strategies that the owner of the power plant could adopt to prevent harmful hot water entering the river. (4)

[10]

3. Food Security

Question 1

In point form, explain the impact of each of the following on food security in South Africa:

1. Droughts (4)
 2. Floods (2)
 3. Monoculture (10)
 4. Alien plants (3)
- [19]

Question 2

1. List two crops which are genetically modified in SA and state the percentage of the total national crop that is genetically modified for each one. (4)
 2. In point form, explain how the use of genetically modified crops may help alleviate food security in South Africa. (5)
- [9]

4. Loss of Biodiversity

Question 1

For each of the terms in Column I, state whether it applies to A only, B only, Both or None of the statements in Column II. Write the number of the answer, followed by A only, B only, Both or None. For example: 10. A only. (16)

Column I	Column II
1. habitat destruction	A. caused by poor farming practices, residential, urban, industrial and sporting developments B. 34% of SAs land and 82% of SAs rivers effected
2. overgrazing	A. major culprit in SA is goats B. easily corrected by rehabilitating with grass
3. spekboom	A. cheap to use for rehabilitation because grows from seed B. used to rehabilitate barren land in the Eastern Cape
4. monoculture	A. not practiced extensively in SA B. attracts a variety of herbivores and their predators
5. biological control	A. a more environmentally friendly means of controlling agricultural pests B. means that less herbicides are required
6. mining	A. introduces numerous toxic chemicals into water bodies B. dumps on surface smother indigenous plants
7. poaching	A. the hunting of animals to provide "bush meat" for local rural communities B. large-scale international operations driven by greed and ignorance
8. alien invasives	A. plants that have been removed from their natural environment B. non-indigenous plants that out-compete indigenous species

5. Solid Waste Disposal

Question 1

1. Briefly explain what the Durban Methane Harvesting Project is. (3)
 2. List five benefits that the Durban Methane Harvesting Project has created for the local environment and community. (5)
 3. Describe two positive environmental management strategies that the Mariannhill landfill site has adopted and explain why they are so good. (4)
- [12]

Answers

Chapter 1: Biodiversity, Change...

A. Viruses

Question 1

1. Virus
2. Endoparasites
3. DNA
4. Vector
5. AIDS
6. PEP / post exposure prophylaxis (12)

Question 2

1. Breathing / gaseous exchange; eating; respiration; respond to stimuli. (4)
2. Reproduction (1)
3. Breathing / in the air; ingestion – in water or food; through an open wound; through sexual intercourse / exchange of body fluids; via a vector. (5)

Question 3

1. HIV positive means a person is infected with the HI virus, having AIDS means that the HIV has weakened the immune system to such an extent that an AIDS defining, eg: TB, pneumonia, is also present. (3)
2. Via the placenta during pregnancy and also via breast milk. (4)
3. Personal opinion – explanation must match the choice:
No – people have a right to privacy; they may be discriminated against etc.
Yes – sickness may reduce productivity; employers may have more medical expenses etc. (4)

Question 4

1. It contains RNA – viruses that infect people may contain RNA; it is not a bacteriophage; it is spherical like the 'flu virus. [any 1] (2)
2. Fever, headache, runny nose, itchy/burning eyes, sore joints. [any 3] (3)

B. Bacteria

Question 1

- | | |
|------|------|
| 1. C | 4. D |
| 2. A | 5. D |
| 3. A | |
- (10)

Question 2

1. A. Cilium
B. chromatin material
C. ribosomes / starch granules
D. slime capsule
E. cell wall (5)
2. A - movement / locomotion
B - contains all hereditary information / genes
D - protection from harmful chemicals of host. (6)
3. has ribosomes; has a cell membrane; has DNA [any 2] (2)
4. bacillus / rod-shaped (1)

Question 3

1. Nitrogen fixing bacteria in root nodules of legume plants.
Bacteria in digestive tract of animals.
E. coli bacteria in digestive tract of humans. (6)
2. Autotrophic bacteria – photosynthesize, so are primary producers in the food chain.
Saprophytic bacteria – are decomposers, so break down dead organic matter - recycling of nutrients in food chains. (4)
3. TB/ tuberculosis; cholera; bronchitis; anthrax; pneumonia [any 4] (4)
4. antibiotics (1)

C. Protists

Question 1

- | | |
|---|-----|
| A – algae | |
| B – slime moulds | |
| C – protozoa | |
| D – green algae | |
| E – slime mould | |
| F – Amoeba | |
| G – autotrophic | |
| H – saprophytic/heterotrophic decomposers | |
| I – heterotrophic | (9) |

Question 2

1. A – contractile vacuole
B – ectoplasm
C – endoplasm
D – pseudopodium (4)
2. B – it is firmer / more gel like than C, thus provides more structural support. (4)
3. Locomotion and capturing of prey / engulfing food particles. (2)

Question 3

1. Contractile vacuole (1)
2. As the salt concentration in the water increases, the frequency of discharges decreases, or
The higher the salt concentration, the less the number of discharges. (2)
3. 10 times / every 30 seconds (2)
4. 7 x every 5 minutes, so: $7 \times 12 = 84$ times per hour (2)
5. Marine – at low salt concentrations, the contractile vacuole is very active, trying to expel excess water that enters via osmosis or: if it was a freshwater specimen, the salt concentration of the cytoplasm would be very similar to freshwater, so not much water would enter the body via osmosis and the contractile vacuole would not be very active. (3)

D. Fungi

Question 1

- | | |
|------|-------|
| 1. H | 6. B |
| 2. D | 7. M |
| 3. L | 8. C |
| 4. A | 9. E |
| 5. J | 10. F |
- (10)

Question 2

1. Eukaryotic; body consists of hyphae; collectively the hyphae form a mycelium; cell walls contain fungus-chitin; they lack chlorophyll and are heterotrophic; most are saprophytic. [any 5] (5)
2. Ringworm; candidiasis / thrush; athlete's foot (3)
3. Dark + damp/ moist conditions (2)
4. Keep skin clean + dry; stay healthy / have a strong immune system; use antibiotics correctly; if diabetic, try and keep blood sugar levels under control. [any 3] (3)

Question 3

1. *Penicillium notatum* (1)
2. Alexander Fleming (1)
3. Hard to produce on a large scale + the medical fraternity were skeptical / didn't believe him (2)
4. Bacteria (1)
5. Food – eg: mushrooms; cheese making; yeast used in baking; used to create alcoholic beverages; used in the manufacturing of certain consumer products, which also creates jobs. [any 5] (5)

E. Immunity

Question 1

1. Infection – the introduction of a pathogen into the body.
Immunity – the body's ability to resist / fight off an infection. (4)
2. Antibodies – produced in the blood and form part of the body's natural defense mechanism.
Antigens – proteins on the surface of pathogens which are recognized by antibodies. (4)
3. Natural immunity – the body's ability to resist infection.
Actively acquired immunity – immunity that results from a vaccination or infection. (4)
4. Passively acquired immunity – immunity that is not natural, but is obtained either via breast milk, or in a serum that is ingested.
Actively acquired immunity – immunity that results from a vaccination or infection. (4)
5. Attenuated vaccines – solutions of "live" pathogens which have been altered to prevent them from causing a disease.
Non-living vaccines – solution of parts of dead micro-organisms. (4)
6. Hypersensitive response – a very rapid response to infection in plants, causing rapid death of cells.
Systemic acquired resistance – a slower process results in the plant becoming resistant to the infection. (4)
7. MDR TB – multiple drug resistant TB – bacteria are resistant to at least 2 of the main TB drugs.
XDR TB – extreme drug resistant TB – bacteria are resistant to 3 or more of the main TB drugs. (4)

Plant Biodiversity

Division: Bryophyta

Question 1

1. B
2. C
3. A
4. C
5. B (10)

Question 2

1. A – calyptras
B – capsule
C – seta
D – foot of sporophyte
E – "leaf" of thallus
F – "stem" / axis
G – rhizoid (7)
2. B, C + D (3)
3. Anchorage of plant + absorption of water + dissolved mineral salts. (2)

Question 3

- no vascular tissue – need to be in clumps because no supporting tissue.
- no cuticle – shady areas to reduce desiccation.
- thallus structure – so clumps of plants support each other.
- small sized plant – can rely on diffusion and osmosis for movement of water.
- no true roots – can't access soil water.
- need water for fertilisation. [any 5] (10)

Division: Pterophyta

Question 1

- | | |
|------|-------|
| 1. H | 6. K |
| 2. D | 7. E |
| 3. A | 8. C |
| 4. M | 9. L |
| 5. B | 10. F |

Question 2

1. A – ventral surface of pinna
B – capsule (2)
2. Protection of the sporangia / capsules. (1)
3. Sporophyte – spores are produced in the capsules/sporangia. (3)

Question 3

1. Have true roots, stems + leaves – can grow bigger.
Presence of vascular tissue – structural support + grow bigger.
Presence of cuticle – not restricted to damp environments. (6)
2. Male gametes / sperm have to "swim" in a film of water on the ventral surface of the prothallus from the antheridia (male) to the archegonia (female) in order to fertilise the ova. (4)

Division: Spermatophyta

Question 1

- | | |
|------------------|------------------|
| 1. Dwarf shoot | 7. Angiosperms |
| 2. Bract | 8. Corolla |
| 3. Mutualistic | 9. Gynaecium |
| 4. Endosperm | 10. ovule |
| 5. Testa | 11. Ovary |
| 6. Spermatophyta | 12. Nectary (12) |

Question 2

1. Longer and therefore provides better anchorage than adventitious roots.
Penetrates deeper into the soil to access deeper sources of ground water. (4)
2. Pyramid shaped – so snow can easily fall off branches.
Have thin needle-like leaves – don't allow snow to accumulate on them. (4)

Question 3

1. Male gamete/pollen grains dispersed by wind to female bracts of cones, where they fertilise the exposed ova. (4)
2. Wind.
3. Light weight with a papery wing-like structure. (2)
4. Birds; bats; insects; animals; wind; water [any 3] (3)
5. Protection; source of nutrients when plant germinates; encourages greater dispersion by animals that eat their fruit. [any 2] (2)
6. Pollination (1)
7. Brightly coloured + sweetly scented – attract birds insects.
Produces many light-weight pollen grains.
Sticky stigma for pollen grains to attach to. (5)

Question 4

- | | |
|---------------|--------------|
| 1. A – pistil | G – anther |
| B – stigma | H – filament |
| C – style | I – stamen |
| D – ovary | J – sepal |
| E – ovule | K – pedicel |
| F – petal | (11) |

2. G (1)
3. A, B, C, D + E (3)
4. Protect the flower in the bud stage + photosynthesize. (2)
5. E (1)
6. D (1)
7. Androecium (1)
8. A (1)

Question 5 (11)

Grains	Pulses
Seeds of cereal grasses.	Seeds of leguminous plants.
Major source of carbohydrates.	Good source of protein.
E.g: oats, rice, wheat, maize.	E.g: peas, beans, soya, lentils.

2. Urbanization, deforestation, extensive farming, human population growth. (3)
3. A secure place where seeds from around the world can be safely stored without risk of damage, in order to conserve biodiversity.
4. Endangered plants can be prevented extinction. Endangered plants can be cultivated + reintroduced into the environment. Provides a source of genetic material – may be useful for GM crops / research in future. Valuable research resource. [any 3] (3)

Plant Reproduction

Question 1

1. Sexual reproduction (1) 4. Meiosis (1)
2. Zygote (1) 5. Vegetative organs (1)
3. Cloning / asexual reproduction (1)

Question 2

1. Asexual reproduction – no gametes are produced. Offspring are identical to their parents. Sexual reproduction – gametes are produced. Fusion of male and female gametes produces a zygote which develops into an offspring that is a genetic mixture of both parents. (4)
2. Spores are produced by mitosis and are genetically identical to each other. Gametes are produced by meiosis, so have half the amount of genetic material of normal cells and are all genetically unique. (4)
3. Self pollination – pollen / male gametes fertilize ova on the same flower or plant. Cross-pollination - pollen / male gametes fertilize ova of different plants of the same species. (4)

Question 3

1. Advantages – only one individual plant is required; offspring will share the same beneficial genes as their parents; relatively quick form of reproduction; agents of pollination + seed dispersal not required. [any 3] (3)
Disadvantages – a weak parent will produce weak offspring; plants often can't adapt to changing environments; plants can be very vulnerable to disease, frost, drought etc. (3)
2. Advantages – offspring are all genetically unique; genetic variation means there is more chance of individuals in a population surviving if environmental conditions change; may result in formation of new species. (3)
3. Disadvantages - relatively slow process; adult male + female organisms are required; mutations can occur; pollination and agents of seed dispersal are required. [any 3] (3)

Question 4

1. The transfer of pollen grains to the stigma / gynaecium of a flower. (2)
2. Bird / bat / insect (1)
3. Brightly coloured; base of flower acts as a "landing pad" for the animal. [any 1] (2)

Life Sciences 11

4. Flowers are long + trumpet-shaped; brightly coloured eg: red, orange, yellow; nectar is produced; flowers are not scented. [any 3] (3)
5. Large petals act as "landing pads" for insects; flowers are scented to attract insects. (4)

Question 5

1. Fertilisation (1)
2. Seed (1)
3. a) fruit (1)
b) source of nourishment for germinating plant; encourages seed to be dispersed further by animals that eat the fruit. (4)
4. insects; birds; bats; mammals (3)
5. reduces competition for resources with parent plant + encourages survival of the species. (2)

Animal Biodiversity

Question 1

- | | | |
|------|-------|------------|
| 1. N | 6. M | 11. G |
| 2. H | 7. P | 12. Q |
| 3. A | 8. B | 13. D |
| 4. R | 9. J | 14. O |
| 5. I | 10. C | 15. K (15) |

Phylum : Porifera

Question 1

1. See diagram page 31. (12)
2. Cells are not grouped together into specific types/functions; differentiated cells are dispersed randomly throughout the animal. (2)
3. They are filter feeders – pores draw water + fragments of food/ bacteria into the spongocoel where they circulate + food is engulfed by the cells. (4)

Phylum: Cnidaria

Question 1

1. A
2. C
3. A
4. D
5. B (10)

Question 2

1. B
2. A
3. D
4. A (4)

Phylum: Annelida

1. Sketch of earthworm with labels pointing or referring to:
 - moist skin for gaseous exchange
 - simple blood system for more efficient gaseous exchange and cellular respiration
 - head end: greater cephalisation
 - anus: through-gut is present enabling more efficient digestion (16)
1. - Earthworms are nocturnal so that when they come to the ground surface, the skin does not dry due to the sun and gaseous exchange can take place.
- Sperm exchange can take place without the possibility of the sperm drying up.
2. By dividing the mesoderm, the coelom enables muscles of the ectoderm to move independently of the endoderm, resulting in greater efficiency. Coelom also provides a hydrostatic skeleton to the worm. (4)
3. Skin (1)

Phylum : Arthropoda

Question 1

1. Insecta - grasshopper, ladybug, butterfly, ant, locust, fly, bee [any 2] (3)
2. Arachnida – spider, scorpion, tick [any 2] (3)
3. Crustacea – crab, shrimp, crayfish, prawn [any 2] (3)
4. Myriapoda – centipede, millipede (3)

Question 2

1. Protect the internal organs and provide support framework for locomotion. (2)
2. Size is restricted; animals have to moult in order to grow; during moulting animals are vulnerable to predation and desiccation. (3)
3. Excretory + reproductive systems. (2)
4. Respiratory + digestive systems. (2)

Question 3

- Pollinating agents – greatly increases yield in many fruit + vegetable crops. (3)
- Decomposers – recycle nutrients back into soil, maintaining fertility. (3)
- Soil aerators – burrowing animals increase availability of air to roots + soil-dwelling organisms. (3)
- Biological pest control – ladybird beetles control aphids, wasps eat caterpillars of moths + butterflies. (3)

Phylum : Chordata**Question 1**

Class:	Osteichthyes	Amphibia	Reptilia	Aves	Mammalia
Body covering:	Scales (slimy)	Moist skin	Dry scales	Feathers	Fur or hair
Example:					
Aquatic	tuna, hake, sardine	frog, salamander, newt	crocodile, alligator, turtle	penguin, darter, pelican	whale, dolphin
Terrestrial	none	toad, tree frog	snake, tortoise, chameleon	ground hornbill, ostrich	elephant, rhino, human, lion
Aboreal	none	none	none	eagle, swallow	bat

Note: there are many more examples for each category of Chordata. (25)

Chapter 2: Life Processes in Plants and Animals**A: Photosynthesis****Question 1**

1. A
2. D
3. C
4. D
5. A (10)

Question 2

1. G
2. K
3. A
4. M
5. B
6. C
7. L
8. D
9. E
10. H
11. F
12. I (12)

Question 3

1. A – CO_2 / H_2O
B – H_2O / CO_2 (2)
2. CO_2 – from air that enters stomata.
 H_2O – from water that enters via the root hairs. (2)
3. Oxygen (1)
4. D – glucose, converted into insoluble starch. (2)

Question 4

- A – grana
- B – stroma
- C – water
- D – carbon dioxide
- E – oxygen / hydrogen ions
- F – hydrogen ions / oxygen
- G – glucose
- H – photolysis (8)

Question 5

1. To demonstrate that oxygen is released during photosynthesis
or To determine if oxygen is released during photosynthesis. (2)
2. To enable water to flow out of the funnel as it is displaced by gas in the test tube. (2)
3. Oxygen (2)
4. A glowing splinter was inserted into the test tube after the gas was collected. Because the glowing splinter burst into flame, the gas which is present must be oxygen. (3)
5. Oxygen is released from aquatic plants/*Elodea* during photosynthesis. (2)
6. Set up the experiment in exactly the same way, but exclude the aquatic plant. (2)

B: Animal Nutrition**Question 1**

1. H
2. M
3. B
4. J
5. A
6. D
7. C
8. N
9. D
10. F
11. L
12. G
13. E (13)

Question 2

1. A – buffalo
B – lion
C – warthog (3)
2. A – buffalo is a herbivore, herbivores have no canines. (2)
B – lion – is a carnivore, so has many incisors for biting and canines for tearing flesh. (2)
C – warthog is an omnivore, so has all types of teeth present. The molars are used for the grinding of roots and bark. (2)

3.

$$A = \frac{0 + 0 + 3 + 3}{4 + 1 + 3 + 3} \times 2 \rightarrow \frac{12}{22} = 34 \text{ teeth}$$

$$B = \frac{3 + 1 + 3 + 1}{3 + 1 + 2 + 2} \times 2 \rightarrow \frac{16}{16} = 32 \text{ teeth}$$

$$C = \frac{1 + 1 + 3 + 3}{3 + 3 + 2 + 3} \times 2 \rightarrow \frac{16}{22} = 38 \text{ teeth}$$

Question 3

1. A – mouth / oral cavity
B – oesophagus
C – liver
D – gall bladder
E – duodenum
F – transverse colon
G – ascending colon

- H – caecum
I – appendix
J – stomach
K – pancreas
L – jejunum / small intestine
M – descending colon
N – ileum / small intestine
O – rectum
P – anus

2. 1. A
2. A, B, J, L + N
3. A, J, E
4. L + N and H, F + M
5. B, J, E, L, N, G, F, M
6. A
7. J
8. L + N
9. D
10. P

Question 4

1. Diagram of a longitudinal section of a villus.
2. A – arteriole
B – lacteal
C – crypt of Lieberkuhn
D – lymph vessel
E – columnar epithelial cell
F – venule
G – Brunner's gland
3. To increase the surface area of the small intestine for absorption of nutrients.
4. A + F
5. B + D
6. Duodenum – a Brunner's gland is present and Brunner's glands are only found in the duodenum.
7. Secrete alkaline mucus to neutralise the acidic chyme so as to protect the lining of the small intestine and to act as a lubricant for peristalsis.

Question 5

1. Raw, cooked and dried fruit and vegetables, peanuts, tree nuts, whole-wheat + brown bread.
2. Indigestible plant cell material, eg: cellulose, pectin + lignin.
3. Gives volume / bulk to waste material in the colon. The bulk causes the colon to stretch, which stimulates peristalsis. Peristalsis is responsible for the movement of waste along the colon in order for it to be defecated. Roughage also enables faeces to retain water, which prevents constipation and haemorrhoids.
4. Acts as a lubricant, enabling food to move freely along the alimentary canal.
Enables tissues of alimentary canal to remain soft and pliable, which assists with movement + digestion.
It is necessary for all chemical digestion reactions.

Question 6

1. A – insulin
B – β cells of islets of Langerhans
C – absorbs glucose into body cells
D – converts glucose into glycogen
[C+D are interchangeable]
E – glucagon
F – α cells of islets of Langerhans
G – stored glycogen is converted back into glucose

2. Frequent urination; blurred vision; glucose present in the urine; thirsty; wounds heal slowly.
3. Their pancreases are not secreting adequate insulin. Caused by obesity – people are not exercising enough and are eating unhealthily, particularly lots of fast foods which contain refined sugar and starch, which cause the blood glucose level to be continually too high.

C: Cellular Respiration

Question 1

1. D
2. D
3. C
4. A
5. B

Question 2

1. A – mitochondrial DNA
B – ribosomes
C – outer membrane
D – inner membrane
E – inter-membrane space
F – matrix
G – cristae
2. Krebs cycle + oxidative phosphorylation.
3. To release the energy stored in glucose to enable all metabolic processes / life to occur.
4. Muscle cell – far more energy is used by muscle cells as they are continually moving / bone cells do not require a lot of energy as their major role is structural support.

Question 3

1. A only
2. Both
3. None
4. Both
5. Both
6. A only
7. B only
8. B only

Question 4

1. A – water
B – thistle funnel
C – germinating seeds
D – clear lime water
2. Seeds undergoing cellular respiration release carbon dioxide.
3. The bag holds the germinating seeds that undergo cellular respiration rapidly.
4. Clear lime water turns milky in the presence of carbon dioxide. This will confirm whether respiring seeds give off carbon dioxide.
5. Clear lime water turns milky, implying that carbon dioxide is released by the respiring seeds.
6. Control will have the same set up except the bag will have dead seeds that have been sterilized.

D: Gaseous Exchange

Question 1

1. K
2. E
3. M
4. A
5. H
7. I
8. J
9. C
10. F
11. L

Question 2

1. Grasshopper – spiracle
Fish – gill (2)
2. Diffusion (1)
3. Gills are very thin and have a very large surface area and in close proximity to the blood supply, all of which ensure efficient gaseous exchange. (3)

Question 3

1. Inside the lungs. (1)
2. A – bronchiole
B – cartilage rings
C – alveolus
D – infundibulum (4)
3. Alveoli walls are one cell thick + fluid is secreted which both enable rapid diffusion of gases. Alveoli are in close proximity to blood capillaries, which also ensures rapid transportation of gases. (6)
4. Prevent the bronchioles from collapsing, thus they enable continuous gaseous exchange. (2)

Question 4

1. B (1)
2. C (1)
3. D – oxygenated blood (2)
4. Haemoglobin (1)

Question 5

1. Bacterium; Mycobacterium tuberculosis. (1)
2. Loss of appetite; weight loss; fever; chills; chest pains; night sweats; a bad cough that lasts longer than 2 weeks; blood in the sputum. (5)
3. TB is transmitted in the air when infected people cough or sneeze. If an uninfected person breathes in the infected air, the TB bacteria are transported to the lungs, where they can settle and start multiplying, causing infection. (4)
4. Yes. (1)
5. Directly Observed Therapy Short course. (1)
6. A trained health care worker visits each TB patient daily and observes them taking their TB medication. It is used to ensure that the patients take all their medication correctly. (3)
7. After a few weeks of being on TB medication, patients start feeling better and often stop taking their medicine. At this stage, the TB has not been cured and the bacteria that are still present may become resistant to the medication and mutate into MDR TB. DOTS ensures that TB patients are properly cured and that the TB bacteria do not mutate into more dangerous forms. (4)

Question 6

1. Lung cancer, emphysema, bronchitis. (3)
2. It reduces it. (1)
3. A. blood vessels
B. alveoli
C. narrows vessels, reducing amount of O₂ that can reach cells
D. rupture, reducing efficiency of gaseous exchange
[A and B, and thus C and D are interchangeable].
E. lung tissue
F. causes lung cancer
G. cilia
H. paralyzes cilia, allowing smoke particles to block alveoli
I. haemoglobin molecules
J. carbon monoxide, rather than oxygen is transported in blood (10)

E. Excretion

Question 1

1. C 5. D
2. D 6. B
3. A 7. D (14)
4. C

Question 2

1. A – adrenal gland
B – renal artery
C – renal vein
D – aorta
E – inferior vena cava
F – (right) kidney
G – ureter
H – bladder
I – urethra (9)
2. Aldosterone (1)
3. Blood sodium levels (1)
4. Kidney stones (1)
5. Temporary storage of urine. (2)
6. Thin and elastic, so can stretch as it fills. (2)
7. Urination + release of semen during copulation (2)

Question 3

1. A – cortex
B – pyramids (of the medulla)
C – pelvis
D – papilla (of pyramid)
E – renal capsule
F – calyx
G – renal artery
H – renal vein
I – ureter (9)
2. Enclose kidney + protection of kidney (2)
3. Urea, uric acid, synthetic substances like artificial food colourant, creatinine (3)
4. Bowman's capsule (1)
5. Convoluted tubules (proximal + distal) + loop of Henle (3)
6. Urine (1)

Question 4

1. A – afferent vessel
B – glomerulus
C – wall of Bowman's capsule
D – podocytes
E – capsular space
F – proximal convoluted tubule / cuboidal cells with modified brush border of micro-villi. (7)
2. Malpighian body / renal corpuscle (1)
3. In order to create hydrostatic pressure in the glomerulus. More blood enters the glomerulus (at A) than can leave it (at G), the buildup of pressure forces blood to leave the glomerulus and enter the nephron. (3)
4. Glomerular filtration / ultra filtration (1)
5. Cup-shaped – increase surface area for filtration.
Glomerulus + Bowman's capsule in close proximity to each other – rapid diffusion.
Walls of Bowman's capsule + glomerulus are each a single layer of cells thick – easy diffusion.
Modified epithelial cells of Bowman's capsule (podocytes) form effective filtration slits.
Capsular space ensures efficient drainage of filtrate from the Malpighian body.
[any 3] (6)
6. Water, glucose, amino acids, urea, uric acid. (5)
7. Plasma proteins + blood cells / corpuscles. (2)
8. Increase the surface area of the proximal convoluted tubule for tubular reabsorption. (2)

Question 5

1. Controls the amount of water reabsorbed back into the blood. (2)
2. Hypothalamus of the brain. (1)
3. Distal convoluted tubule and collecting tube. (2)
4. The greater the amount of ADH, the more permeable the tubules. / It increases the permeability of the tubules. (2)
5. ADH increases distal tubule permeability, causing water to leave the nephron via osmosis and move into the hypertonic (very salty) medulla, from where it moves by osmosis back into the blood capillaries. (3)
6. ADH will increase because the body needs to conserve water and not excrete it in the urine. By ADH levels rising, distal tubule permeability will increase, causing more water to leave the nephrons and return to the blood stream. (4)

Question 6

1. From the crystallisation of calcium or urea salts in the urine. (2)
2. They can block the ureter, causing a buildup of urine in the kidney. (2)
3. Surgery + laser treatment. (2)
4. Drink at least 8 glasses of water per day / consume approximately 2l of fluids daily. (1)
5. Dialysis machines work only on filtration – they do not have a tubular reabsorption function. Because of this, only the substances that need to be excreted from the blood are removed by dialysis. To achieve this, the substances that should remain in the blood, eg: glucose, sufficient water and other useful substances, are present in the dialysis fluid. As a result, no diffusion of the useful substances from the blood into the dialysis fluid occurs.
By contrast, none of the harmful substances are present in fresh dialysis fluid. This causes a steep diffusion gradient to form, resulting in the harmful substances leaving the blood. (3)

Chapter 3: Environmental Studies

A: Population Ecology

1. Population Size

Question 1

1. D 5. B
2. B 6. B
3. D 7. D
4. D 8. B (16)

Question 2

1. Stationery / equilibrium phase (1)
2. i) A – lag / establishment phase – gradual increase in population size because animals are adapting to the environment + reaching sexual maturity. (3)
ii) B – geometric / logarithmic phase – very rapid expansion of population because population has reached full sexual maturity and there is no environmental resistance. (3)
3. $6 - 6,2 \text{ g/cm}^3$ (2)
4. As the yeast population increases, so does the amount of alcohol produced / there is a direct relationship between yeast population size and the amount of alcohol produced. (2)
5. competition for space / food / resources / or disease, is causing environmental resistance. [any 2] (2)

Question 3

1. 1 quadrat = $\frac{1}{4}$ ha and has 22 damaged trees
Therefore: 1ha has $4 \times 22 = 88$ damaged trees
Area in KNP surveyed = 1 340ha
So total elephant damage: $1\,340\text{ha} \times 88 \text{ trees / ha} = 117\,920$ mopane trees damaged (5)
2. Repeat the experiment using different quadrats in the area and/or increase the number of quadrats sampled.
3. The season / time of the year that quadrats were sampled.
The age of the mopane trees.
The ability of the researchers to identify trees correctly.
The presence of other types of vegetation in the area that the elephants could damage.
[any 2, there will be other correct answers] (2)

2. Interactions in the Environment

Question 1

1. A only 5. B only
2. None 6. A only
3. Both 7. Both
4. Both 8. None (16)

3. Community Change over Time

Question 1

- A + B – bare rock; newly formed sand dune; surface mine; newly formed island [any 2] (2)
- C + D – landslide; abandoned farm land; building site; deforested area; polluted stream; dammed / flooded land [any 2] (2)
- E – very slow (1)
- G – quicker (1)
- F – new topsoil has to be created (1)
- H – usually some form of topsoil already exists (1)
- I – lichens, moss (1)
- L – alien species /weeds eg: lantana, bugweed (1)
- J + K – usually dispersed by wind; small plants with very shallow root systems; grow + reproduce rapidly; some secrete acids that weather rocks. [any 2] (2)
- M + N – often alien plants; establish easily and out-compete indigenous species; fast growers; often bigger than primary pioneer species. [any 2] (2)

Question 2

1. Developing – a large proportion of the population is young / under 35 years old + there population decreases rapidly in the older age groups. (3)
2. 25-30 years old (2)
3. deaths from AIDS; high infant mortality; decline in fertility [any 2] (2)
4. approximately 1 million [bet. 800 000 – 1 100 000] (2)
5. 65-70 year olds (2)

Human Impact on the Environment

1. The Atmosphere and Climate Change

Question 1

1. A only 4. Both
2. Both 5. B only
3. B only 6. B only (12)

Question 2

1. Filters ultraviolet (UV) rays from sunlight and this protects the Earth. (2)
2. photochemical smog + acid rain (2)
3. City A (1)
4. between midnight (24:00 hrs) and 6am, therefore: 6 hours (2)
5. ozone concentration (1)
6. CFCs - chloro fluoro carbons (1)
7. Montreal Protocol (1)
8. Yes (1)
9. there is less: sunburn, eye damage, skin cancer, premature wrinkling [any 1] (2)

2. Water Availability and Quality

Question 1

1. J 7. B 13. F
2. E 8. Q 14. G
3. M 9. C 15. S
4. A 10. P 16. I
5. L 11. D 17. K
6. O 12. R 18. H (18)

Question 2

1. sewerage; organic fertilizer; runoff from feedlots +/- abattoirs
[any 2] (2)
2. As the amount of organic waste increases, so does the size of the aquatic bacteria population. (2)
3. decompose it / use the nutrients within the organic waste for growth (1)
4. The concentration of organic waste decreases downstream of the source, so less bacteria can be supported by it. (2)
5. i) 24 – 26m downstream (2)
ii) approximately 115m downstream (2)

Question 3

1. Hot water rapidly decreases the concentration of dissolved oxygen in the water. (2)
2. The hot water cools down and is mixed with the normal river water, allowing the cooler water to hold more dissolved oxygen. (2)
3. They will suffocate / die. (2)
4. Allow the water to cool in tanks before releasing it into the river.
Add ice to the water.
Change to an alternative form of power generation.
Upgrade the technology to reduce the heat of water being released.
[any 2] (4)

3. Community Change over Time

Question 1

1. Droughts
 - Deplete pastures, causes less feed for livestock, reduces number of livestock that can be supported.
 - Deplete crops, resulting in less staple food available, eg: less maize, wheat, rice.
 - Less vegetation cover encourages topsoil erosion, which reduces soil fertility.
 - Dry veld can lead to extensive veld fires, which further reduce food availability. (4)
2. Floods
 - Destroy acres of crops, therefore less food available.
 - Lead to soil erosion by washing away top soil.
 - Soil erosion causes sedimentation of rivers and dams, reducing available water for the production of food. (2)
3. Monoculture
 - Runoff of fertilizers leads to eutrophication, which reduces fish populations as a food source.
 - Herbicides can be blown onto neighbouring farmlands and destroy crops + orchards.
 - Pesticides can kill pollinator species, resulting in less fruit set.
 - Wind erosion removes topsoil of fallow fields.
 - Heavy rains also cause soil erosion of fallow fields.
 - Lack of biodiversity can encourage massive increases in pest populations, because of unlimited food supply for them, resulting in destruction of crops by pests.
 - All of these factors result in an environment that is depleted and not capable of supporting large crops indefinitely, which contributes to a reduction in food security. (10)
4. Alien plants
 - Spread rapidly and outcompete indigenous vegetation for resources: sunlight, soil nutrients and water. Where they outcompete food plants, they reduce food security.
 - Rapid colonization of aliens reduces the total amount of available arable land.
 - The expense of clearing aliens from farms is often prohibitive and farmers choose to abandon their land, further contributing to a decline in food availability. (3)

Question 2

1. Maize - 77% + Soybean - 78 % (4)
2. Genetically modified crops can alleviate hunger because GM plants are:
 - More drought resistant.
 - More pest resistant.
 - Require less water than regular crops.
 - More herbicide tolerant, so less herbicides need to be used, resulting in less accidental herbicide damage to other food crops.
 - GM crop yields are therefore less affected by droughts + pests, so more staple food can be produced annually, which should alleviate food scarcity (provided it is supplied to the communities that need it). (5)

4. Loss of Biodiversity

Question 1

1. Both
2. A only
3. B only
4. None
5. Both
6. Both
7. Both
8. B only (16)

5. Solid Waste Disposal

Question 1

1. Uses the methane gas that is produced by decomposition in landfill sites to generate electricity. (3)
2. 1. Captures greenhouse gases, reducing potential climate change.
2. Generates electricity for local community.
3. Generating electricity from methane results in a reduction of other, more environmentally damaging forms of electricity generation (eg: coal or HEP).
4. Income is generated from sale of electricity + carbon credits.
5. Local communities are more environmentally aware / environmental education programmes may cause an increase in other environmentally beneficial practices, like recycling. (5)
3. 1. Harvest methane gas – reduces emission of greenhouse gases into the environment. (2)
2. Have constructed a conservancy buffer zone around the landfill site – reduces pollution affecting neighbouring communities and also maintains biodiversity. (2)