LIVING SCIENCE: BIOLOGY

FOR SACE STAGE 1

SASTA
South Australian Science Teachers Association

Supporting Teachers of Science
Advancing Science Education

AUSTRALIAN CURRICULUM EDITION

DR KATHY ADAMS

CONTENTS

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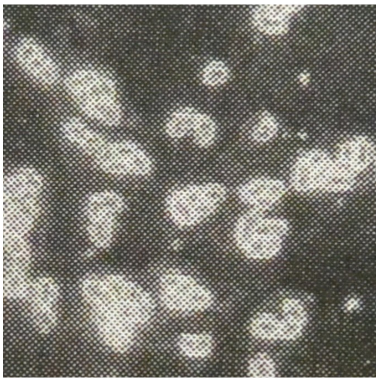
1.0: What is a living organism?

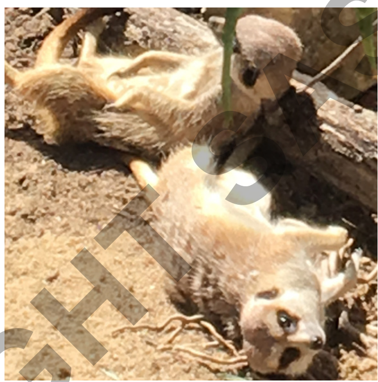
It is common for there to be a misunderstanding on what would be considered to be living and what is not! Living organisms are capable of undertaking all processes without the assistance of any other organism. Living organisms respire, reproduce, grow, move, excrete, synthesise and respond to their environment independently.

Earth is so far unique in that it is the only known planet in the solar system that has recognised life. The diversity of life is remarkable from the smallest of organisms not able to be seen without a microscope to towering trees one hundred metres tall and many other organisms of different shapes and sizes in between (Figure 1.1). All capable of undertaking life's processes successfully in their given niches within the vast diversity of places where life can be found.

Figure 1.1: A variety of living organisms.



Bacteria stained with an immunofluorescent marker



Meerkats enjoying the sun

Giant sequoia trees in Sequoia National Park, California

DID YOU KNOW: REMRING (Respiration Excretion Movement Reproduction Inhibition Nutrition Growth) or MRS GREN (Movement Respiration Stimulus Growth Reproduction Excretion Nutrition) are ways for students to remember the characteristics associated with every living thing.

Table 1: Comparison of the features of Prokaryotic cells and Eukaryotic cells.

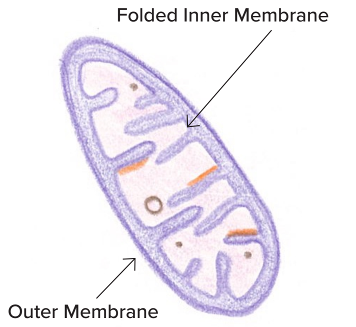
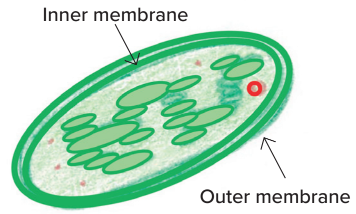
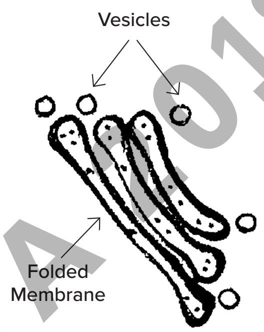
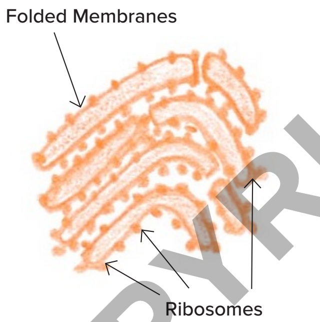
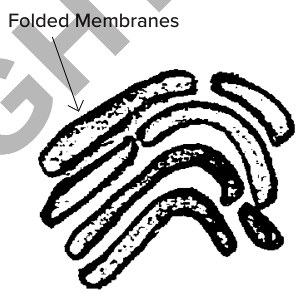
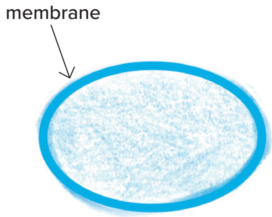
FEATURE	PROKARYOTIC CELLS	EUKARYOTIC CELLS
Cell size (µm)*	Approx. 1-10	Approx. 10-100
Structure of chromosomes	circular	linear
Number of chromosomes	single	multiple
Cell membrane	yes	yes
Internal membranes	no	mitochondria, chloroplast, Golgi body, rough endoplasmic reticulum, smooth endoplasmic reticulum, vacuole
Nucleus	no	yes
Ribosomes	yes	yes
Cell division	binary fission	mitosis (and meiosis)

** cell size is approximate, based on the typical organisms in each cell type*

DID YOU KNOW? While eukaryotic cells and prokaryotic cells both have ribosomes made up of a number of molecules of ribosomal RNA (rRNA) and proteins without a surrounding membrane, they are structurally different yet capable of doing the same job in the cells of binding to messenger RNA (mRNA) during protein synthesis! Eukaryotic ribosomes are larger in size compared to prokaryotic ribosomes. Eukaryotic ribosomes are described as 80S particles and prokaryotic ribosomes as 70S particles. The S stands for the unit, Svedbergs used to describe how quickly the ribosomes can be separated from other cellular components by centrifugation. Because Eukaryotic ribosomes are larger, they sediment faster than prokaryotic ribosomes.

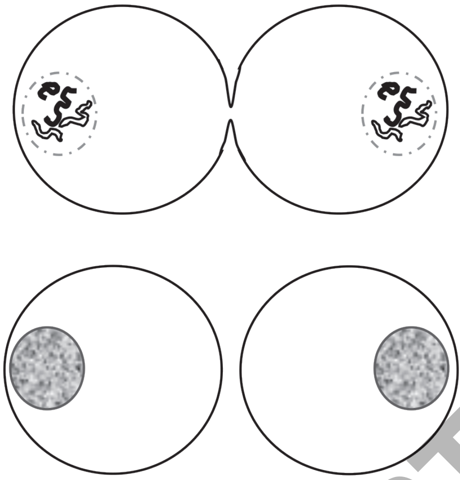
Distinguishing Features:
Organelles - Membrane Bound In Eukaryotic Cells

Below are a series of diagrams to show the features of some of the membrane bound organelles found in eukaryotic cells. Organelles have specialized functions within the cell. It enables these functions to be regulated and controlled within the organelle. Organelles can be considered to be compartments within the cell which is defined by the cell membrane.

		
MITOCHONDRIA	**CHLOROPLAST**	**GOLGI BODY**
Site of the later stages of aerobic respiration	Site of Photosynthesis	Site of packaging, modification and secretion
		
ROUGH ENDOPLASMIC RETICULUM	**SMOOTH ENDOPLASMIC RETICULUM**	**VACUOLE**
Site of protein synthesis	Site of lipid synthesis	Storage

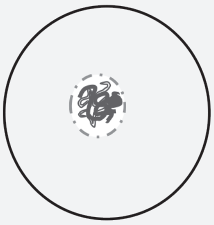
Cytokinesis occurs after telophase in the cell cycle (Figure 1.10). Cytokinesis concludes the cell cycle, and involves the division of the cytoplasm to produce the two genetically identical daughter cells (Figure 1.11).

Figure 1.11: Cytokinesis: the formation of 2 genetically identical daughter cells



DID YOU KNOW? That scientists often describe smaller steps within each phase of mitosis. This is so that each event within each phase can be represented, as they do not necessarily happen simultaneously. For example, prophase can be divided into early and late prophase.

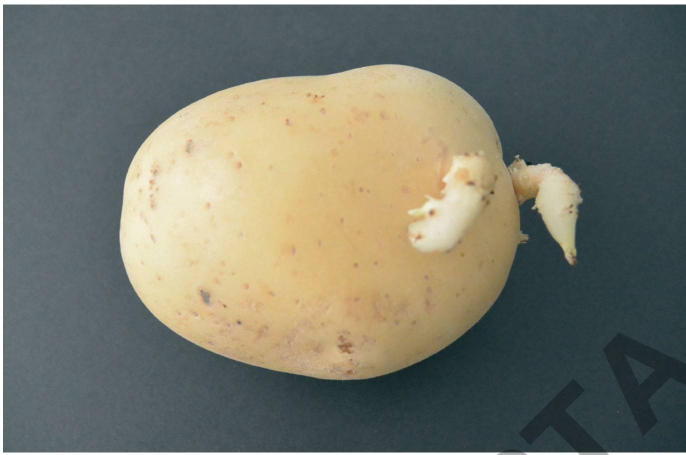
Table 5: Early and Late Prophase during mitosis.

PHASE	DIAGRAM	FEATURES
Early Prophase		Chromosomes start to become visible. Nuclear membrane has not yet broken down.
Late Prophase		Chromosomes have moved to the equator and spindle fibres are attached. The chromosomes are not fully condensed.

Tubers

Form underground from stems that thicken and form buds, from which new plants can arise. Potato varieties are well known examples of plants that form tubers, but other root vegetables, like carrots and beets can also form tubers. Tubers are typically high in starch.

Figure 1.14: Potato with a tuber.

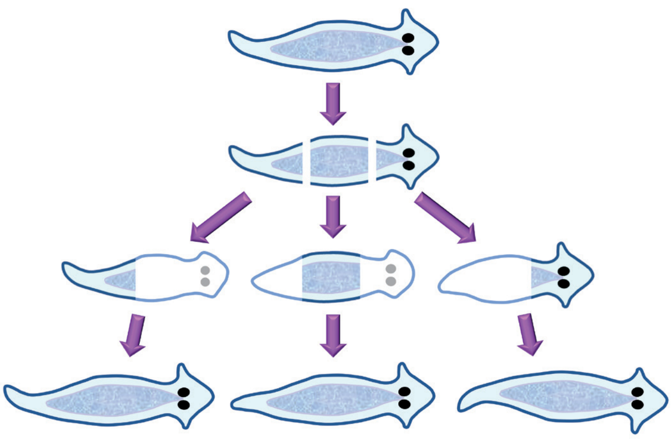


DID YOU KNOW? That starch is a storage macromolecule, a polysaccharide which enables glucose to be stored. Starch is usually stored as granules (in organelles called amyloplasts) inside of the plant cell. Using iodine solution to stain banana and potato cells enables the starch granules to be seen using a light microscope.

Fragmentation

Occurs in lower order animal species, where the parent organisms fragments into at least two parts. Each part of the fragmented organism regenerates to form mature organisms, genetically identical to the parent. Examples of organisms that can undergo fragmentation include: Planaria, some species of Hydra, starfish and algae.

Figure 1.15: Schematic diagram of fragmentation occurring in the organism, Planaria.



1.4: Energy in Cells

Cells of an organisms must obtain all their requirements for their survival from the environment to be able to grow, maintain their internal environment, synthesise molecules and undertake repair.

There are two groups of organisms, Autotrophs (further classified as Photo-autotrophs and Chemo-autotrophs) and Heterotrophs (further classified as consumers and decomposers) that obtain these requirements from different origins.

Figure 1.17: The different types of organisms based on feeding types.

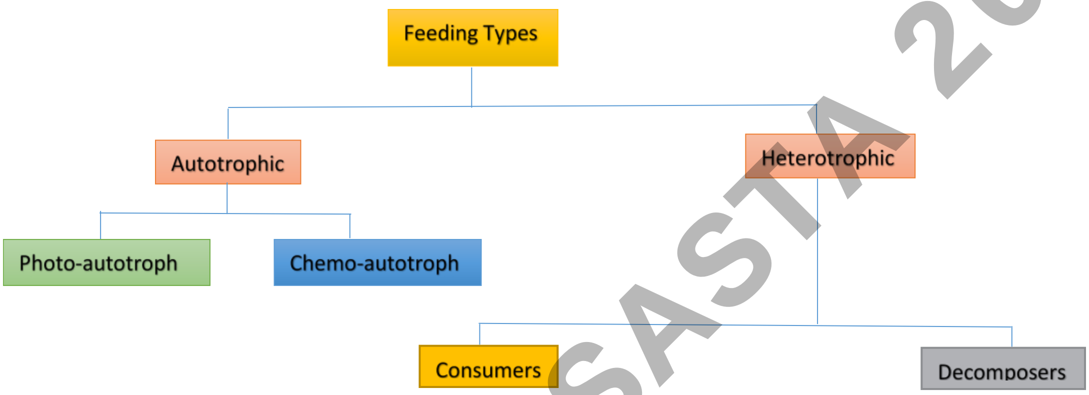
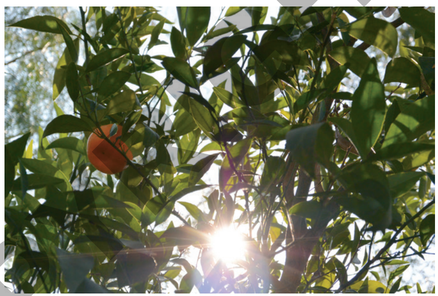


Figure 1.18: A photograph of a fruit tree, a photo-autotroph and a couple of Tasmanian Devils (*Sarcophilus harrisii*) which are heterotrophs.



Autotrophs, the primary producers of any food web, are capable of synthesizing their own food from simple inorganic substrates through the conversion of energy. These organisms generally do not consume other organisms. However, they are consumed by the second group of organisms: Heterotrophs.

Photo-autotrophs, the most common of the autotroph group use light energy through photosynthesis to convert light energy into chemical energy, synthesizing glucose and oxygen (as an important by-product) from carbon dioxide and water. The glucose produced is then used in various metabolic processes, to enable the photo-autotrophs to produce more complex molecules (such as proteins, polysaccharides, lipids) needed by their cells.

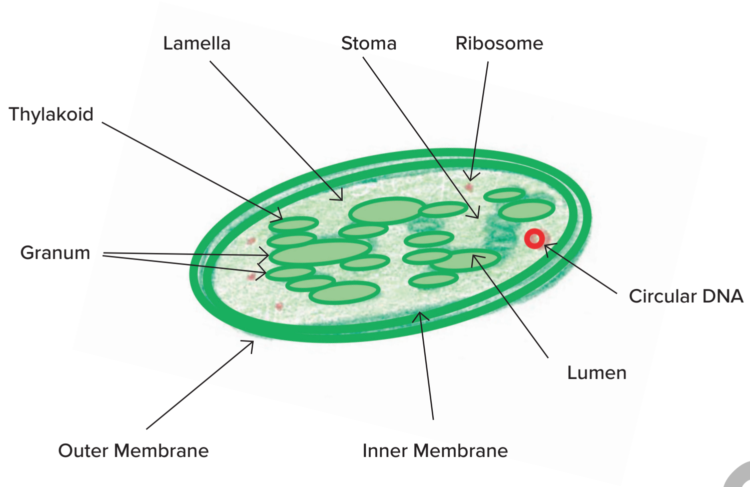
Chemo-autotrophs, are not as common as photo-autotrophs and are able to produce their food from carbon dioxide through oxidation reactions to convert simple inorganic (such as hydrogen sulphide, ferrous iron, or ammonia) molecules into organic molecules. Chemo-autotrophs are typically bacteria and other microorganisms that live in harsh environments and are the primary producers for their food webs. Examples of these organisms include nitrogen fixing bacteria in soil, these organisms play a role in the nitrogen biogeochemical cycle (*See Chapter 4*) or sulphur oxidizing bacteria located in deep sea thermal vents.

The second group of organisms, ***Heterotrophs*** occupy the remaining trophic levels of any food web. These organisms consume autotrophs (primary consumers) or eat other heterotrophs (e.g. secondary consumers) to obtain their food sources, including glucose, protein, and lipid. Heterotrophs are not able to synthesis their own food from energy sources such as light. Decomposers, another group of heterotrophs feed on once living organisms and play a pivotal role in returning matter to the environment. Table 7 compares the characteristics of autotrophs and heterotrophs.

Table 7: Comparison of characteristics of Autotrophic and Heterotrophic organisms.

FEATURE	AUTOTROPHIC		HETEROTROPHIC
	Photo-autotrophic	***Chemo-trophic***	
Energy Source	Light	Chemical	Chemical: through consumption of other organisms
Process used to convert energy	Photosynthesis	Oxidation (Chemosynthesis)	N/A
Pigment used	Chlorophyll in most. Other pigments used if organism is not green	No pigment.	No pigment.
Raw Materials	Carbon dioxide and water	Carbon dioxide and various inorganic molecules	Consumption of other organisms to obtain complex organic molecules containing carbon
Position in Food Chains/Webs	Producer First Trophic Level	Producer First Trophic Level	Consumers Second trophic level and above Decomposers
Waste materials produced	Carbon dioxide Oxygen Nitrogenous waste, Water Tannins, essential oils, gums	Carbon dioxide Nitrogenous waste Water	Carbon dioxide Nitrogenous waste Water
Examples of organisms	Plants, algae. Photosynthetic bacteria, Phytoplankton	Deep sea bacteria, Thermophilic bacteria	Animals, Fungi, Protista, Bacteria

Figure 1.19. Chloroplast



SHE Alert: Energy availability is one the most important issues facing humans in the future. With the past dependence of fossil fuels being questioned, and this discussion being *influenced* from both a supply perspective and the effect the burning of these fuels has on the environment has driven the need to find alternative and renewable ways to obtain energy for all purposes including transport and electricity. New technologies, stemming from research that started in the 1970's around artificial photosynthesis, are being investigated with the hope of using these to solve global warming as well as energy problems including the ever increasing demand for more energy.

Useful resources: https://futureoflife.org/2016/09/30/artificial-photosynthesis/ and https://www.technologyreview.com/s/610177/the-race-to-invent-the-artificial-leaf/

Respiration and Fermentation

Cellular respiration is an essential process that occurs in all living cells. It enables energy captured in the bonds of the glucose molecule to be transformed by coupled reactions into usable forms of energy such as Adenosine tri-phosphate (ATP). Cellular respiration can occur in both the presence (aerobic) and absence (anaerobic) of oxygen.

The process of aerobic respiration is relatively conserved in all organisms that undergo this process. The metabolic pathway, a complex set of reactions catalysed by enzymes that are conserved across a broad array of organisms, from bacteria to humans. It is for this reason, that the genes involved in the production of the enzymes for aerobic respiration are used to determine evolutionary relationships between organisms (Table 8).

Table 9: Common bacterial genus' that are classified as lactic acid bacteria.

GENUS	DESCRIPTION
Lactobacillus	Commonly used in yoghurt making
Lactococcus	Commonly used in cheese making
Enterococcus	Can cause spoiling of fermented products. Some species can cause hospital acquired infections and are often multi-drug resistant.
Streptococcus	Some species are pathogenic to humans and cause pneumonia, Otis media and meningitis.

SHE Alert: Probiotics. The debate continues as to whether probiotics provide beneficial health benefits to humans. Certainly, there is some preliminary evidence that taking probiotics can restore important intestinal flora, after a dose of antibiotics or for sufferers of irritable bowel syndrome but its benefits seem to not be consistent for all. Scientists suggest that the inconsistent result of probiotics may be because there are so many different probiotics available using many different strains of bacteria that it has not been yet established which ones are providing benefit and which ones do not. Probiotics are big business, a multi-billion dollar industry. The sale of probiotics with the message that they will benefit human health *influences* people in society to buy the product without fully understanding how they work and if it will benefit them or indeed cause harm.

Comparison of aerobic and anaerobic respiration

In both aerobic and anaerobic respiration the release of energy in the breakdown of glucose, is shuffled to a coupled reaction where adenosine tri-phosphate (ATP) can be produced by the cell. The ATP synthase enzyme which catalyses' the formation of ATP from ADP (adenosine di-phosphate) and inorganic phosphate is highly conserved among organisms. It Is ATP, as the primary energy molecules in the cell, that can be used by the cell to undertake energy requiring processes such as those involved in the synthesis of molecules, the transport of molecules across the cell membrane, as well as for growth and maintenance.

1.5: Cell Membrane

The structure of the cell membrane over the past 75 years has changed as scientists have developed methods and utilized new technologies to gain a better understanding of the structure and function of the feature that defines a living cell.

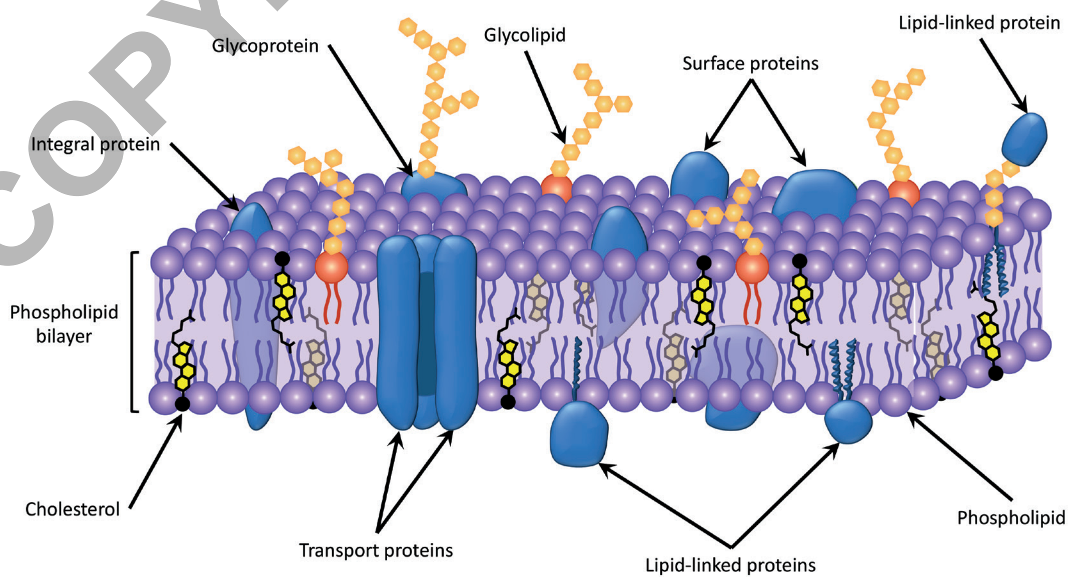
The current model of the cell membrane is described by the Fluid Mosaic Model proposed by S.J.Singer and Garth L. Nicolson in 1972. The cell membrane is often also described as a semi-permeable layer that allows some molecules to pass through, while others are too large or are charged and cannot. It is this semi-permeable layer that helps to distinguish the cell's internal environment from its external environment. It also determines how much of a substance will enter the cell.

The cell membrane consists of a phospholipid bi-layer, where the hydrophobic (water repellent) tails and hydrophilic (water soluble) heads are arranged with the lipid tails facing inward (Figure 1.22). The fluid nature of the membrane is determined by the phospholipid content and by other lipid derivatives embedded in the bi-layer such as cholesterol in animal cells and sterols in plant cells.

Each phospholipid molecule in the membrane is composed of glycerol, fatty acid chains and a phosphate. Glycerol is a three carbon molecule. 2 fatty acid chains are attached to the first two carbons and the phosphate to the third carbon (Figure 1.23).

The mosaic component of the model refers to the proteins that are embedded into the phospholipid bilayer. These proteins play various roles for the cell including transport, recognition and communication. Enzymes can also be embedded or associated with the membrane, to catalyse those reactions that occur at the membrane, in particular, in prokaryotic cells.

Figure 1.22: The cell membrane.



1.10: Applications of Lactic Acid Fermentation

Cheese making

Different types of cheese use different microbes to develop the characteristic of that cheese whether fetta, cheddar or camembert varieties. Some varieties also use moulds to further develop the distinctive tastes of the cheese. The way the milk is processed, the bacteria used and the storage of the cheese during maturation will determine its shelf-life.

The lactic acid-producing bacteria used in the cheese making process use the lactose sugar in the milk to produce lactic acid. This occurs at specific temperatures under anaerobic conditions, and decreases the pH of the milk, resulting in the milk protein (casein) denaturing, to form the curds (cheese). It is this decrease in pH that also helps to preserve the cheese, as the pH conditions are not favourable to the growth of other bacteria, including food spoilage bacteria.

Figure 1.33: Flow diagram of the general process of cheese production

Milk temperature raised and maintained at appropriate temperature for cheese type.

↓

Specific bacteria added to the milk.

↓

Lipase, an enzyme to breakdown fats is added to the mixture.

↓

Rennet, an enzyme is added for curd formation.

↓

After the curd forms, the cheese is put into a salt solution.

↓

Cheese stored as appropriate for the type of cheese.

If cheese is maintained at a suitable temperature, it will last for months to years, depending on the type of cheese made. It is when it becomes exposed to air and is handled, that food spoilage microbes, usually mould cause the cheese to spoil.

Figure 1.34: A photograph of cheese with mould.

2.0: Types of Diseases: Infectious, Genetic and Lifestyle diseases

All organisms are susceptible to disease. The causative agents of these diseases are sometimes very clear, however, at other times why and how the disease progresses is a mystery. Medical research aims to investigate and find treatment solutions to these diseases, to improve the lives of those that are affected. The effect of these diseases can be direct, where an individual has the disease and health consequences or the disease could indirectly affect an individual, for example by infecting a crop or animal stock, thereby affecting the food supply of a community and the potential income of the farmer.

SHE Alert: There are many factors that influence why some diseases are researched more thoroughly than others. Economic influences determined by pharmaceutical companies and governments, social influences determined by individuals passionate about a cause seeking to raise the profile of a disease (think Love my Sister, Beanie for Brain Cancer, MS cold bucket) and increase public support and fundraising or cultural influences, where either the disease or medical intervention to treat the disease are not approved or accepted. These influences, often shape the way society view different diseases and hence how governments and other authorities react and respond to an outbreak or increase in prevalence of a disease in a population. (Influence)

There are many ways that diseases in humans (and other organisms) can be classified, in this chapter diseases have been characterized into infectious diseases, genetic diseases (both hereditary and non-hereditary) and lifestyle diseases. Table 1 below compares these disease types in humans. Disease can also be simply classified as communicable or non-communicable; a disease that is able to be passed or spread from one individual (either directly or indirectly) to another due to an infectious agent is a communicable disease.

Infectious diseases were the leading cause of deaths of humans worldwide. Today, however, infectious diseases are of greater issue in developing nations, where access to medical treatment is sometimes inadequate. Western nations, with their access to medications, the latest medical treatments, and relatively high vaccination rates no longer have infectious diseases as the number one cause of death. However, new emerging infectious diseases, such as the Ebola virus and new influenza virus strains, pose the greatest threat for future disease outbreaks that could affect millions of people worldwide.

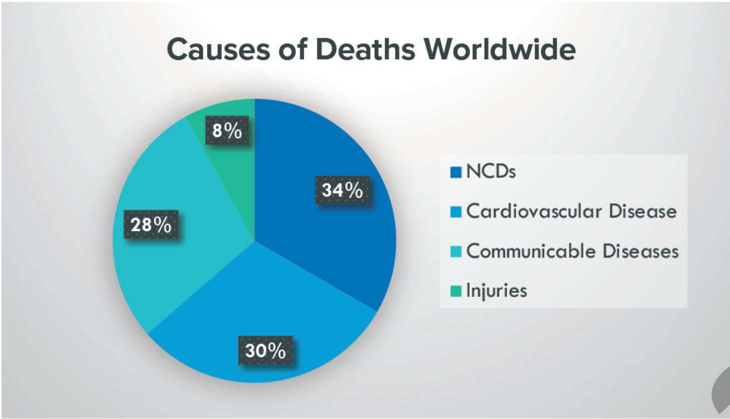
Table 1: Comparison of Infectious, Genetic and Lifestyle Diseases of Humans.

DISEASE	DESCRIPTION
Infectious	The result of an infection, presence and growth of a pathogenic biological agent in a host organism. Pathogenic agents include bacteria, viruses and prions. Communicable Disease.
Genetic	Disease caused by a genetic mutation. Some of these mutations can be passed onto offspring (hereditary disease) while others occur randomly in an individual (non-hereditary). Type I Diabetes, autoimmune diseases, asthma and cancer are examples of non-hereditary genetic diseases. Cystic Fibrosis, sickle cell anemia, Fragile X syndrome, thalassemia and haemophilia are examples of inherited genetic diseases. Non-communicable disease.
Lifestyle	Any disease that appears to increase in frequency due to lifestyle choices, Risk factors include lack of exercise or poor diet choices and/or use of drugs. Individuals with particular genetic predispositions may trigger disease due to their lifestyle choices. Heart disease is often referred to as an example of a lifestyle disease. Non-communicable disease.

Lifestyle diseases associated with poor diet, lack of exercise and excess and inappropriate drug usage, are now trending as the highest cause of disease in western nations, including Australia (Figure 2.1). The statistics are concerning:

- It is estimated that 180 million people in the world have diabetes, with up to 95% being attributed to Type II diabetes, a lifestyle associated disease.
- Cardiovascular disease, another lifestyle associated disease claims approximately 17 million people each year accounting for 30% of all deaths worldwide. These cardiovascular diseases have no geographical, gender or socioeconomic boundaries, although the statistics show that more people in western nations are affected than from developing countries.
- Add this to the number of people affected by the various forms of cancer, approximately 1.1 million deaths per year, many of which are lifestyle related (e.g. smoking and the link to lung cancer), it is clear that lifestyle diseases are a significant issue.

Figure 2.1: A pie graph representing the proportion (%) of human deaths attributed to different causes worldwide: 2011-2016. Lifestyle related diseases such as cardiovascular disease and other non-communicable diseases (NCDs, such as diabetes and other genetic diseases) represent the highest cause compared to infectious disease (communicable disease).



Genetic diseases are any medical condition that results from a DNA abnormality, arising from a range of mutations including a single base change in the DNA sequence or to the complete loss or gain of a chromosome. Genetic diseases can be inherited, or they can occur randomly in any cell within the body, but unless they occurred in an egg or sperm cell, the random mutation will not be passed onto any offspring. Environmental factors, such as exposure to radiation, mutagenic chemicals or viruses may increase the chances of developing a mutation that leads to genetic disease in individuals and/or their offspring. When inherited, the genetic disease is passed from parent(s) to offspring, and the disease may be dominant, recessive or X-linked (*see glossary for a definition of these terms*).

In non-inherited genetic diseases, an individual acquire mutations that will only affect them (e.g. cancer). These mutations may have occurred due to errors in DNA replication, exposure to environmental factors causing completely random errors in DNA sequence or other unknown causes. Some individuals may develop these diseases as they have a genetic pre-disposition to the disease and hence have genes that may increase the risk of developing the disease in particular circumstances.

SHE Alert: Could a virus be causing obesity? The distinction between the different types of diseases is sometimes difficult to know. Recent research indicates that some lifestyle diseases and conditions may in fact be caused by infectious agents. As the scientific community increases their knowledge about how viruses infect human cells and act in various disease states, more causative agents will be discovered. Utilising other technologies, such as DNA sequencing, immunological screening, and tissue culture, will further develop scientific knowledge on how viruses may be involved in various diseases and conditions such as obesity. Work by scientists in laboratories at various universities around the world that has recently been published shows a possible connection between adenovirus-36 and obesity. Will there one day be a vaccine for virus induced obesity? (Development)

2.3: Disease control

When a disease outbreak occurs it is essential to ensure that the spread through the population is minimized and that future outbreaks are prevented if at all possible. The goal of disease control is to eradicate the pathogen from the community. A disease outbreak occurs when there is an increase in the number of cases at a particular place and time. An outbreak may involve as few as a couple of people or at the other extreme, thousands to millions of people. There are 4 different types of disease outbreaks: sporadic, endemic, epidemic and pandemic (Table 8). The way the disease spreads through a population, the number of people infected and the pattern of infection can be used to determine the best control measures and to determine the potential source of the disease.

Table 8: Types of disease outbreaks.

TYPE OF DISEASE OUTBREAK	DESCRIPTION
Sporadic	Occurs infrequently or in an irregular pattern. Random occurrence of the disease in a population.
Endemic	Occurs persistently in a particular place or population. The level of infection can be persistently low or high.
Epidemic	Many people are infected with the same pathogen at the same time. It may occur in one community or several.
Pandemic	When an epidemic disease outbreak occurs and spreads throughout the world.

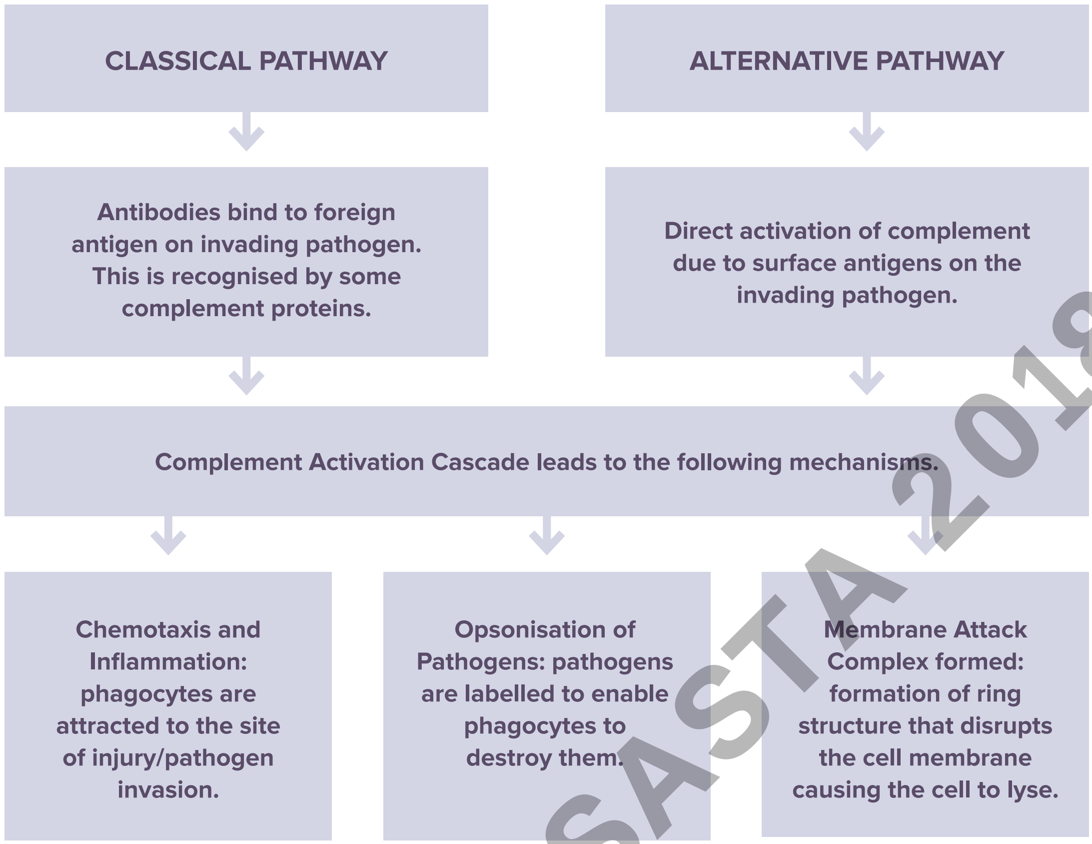
Any disease outbreak has the potential to turn into a pandemic, where it spreads and infects people across the world if not appropriately controlled. Pandemics in the past have had detrimental effects on the human population, for example the Spanish Influenza outbreak in 1918 killed up to 50 million people, and the HIV/AIDS pandemic has killed approximately 35 million people, to date. Therefore it is essential to prevent the spread of disease. A number of factors will affect how a disease is controlled:

- Has the source been identified?
- Is there a vaccine or effective treatment?
- How fast is it being transmitted?
- How is the pathogen being transmitted?
- Mortality rate of the infection.
- Ethical considerations over the need to protect communities and prevent spread.

Disease can be controlled by numerous mechanisms, including:

- controlling the carriers.
- quarantining the carriers of disease.
- screening and quarantining of hosts.

Figure 2.6: The Classic and Alternative Complement Pathways.



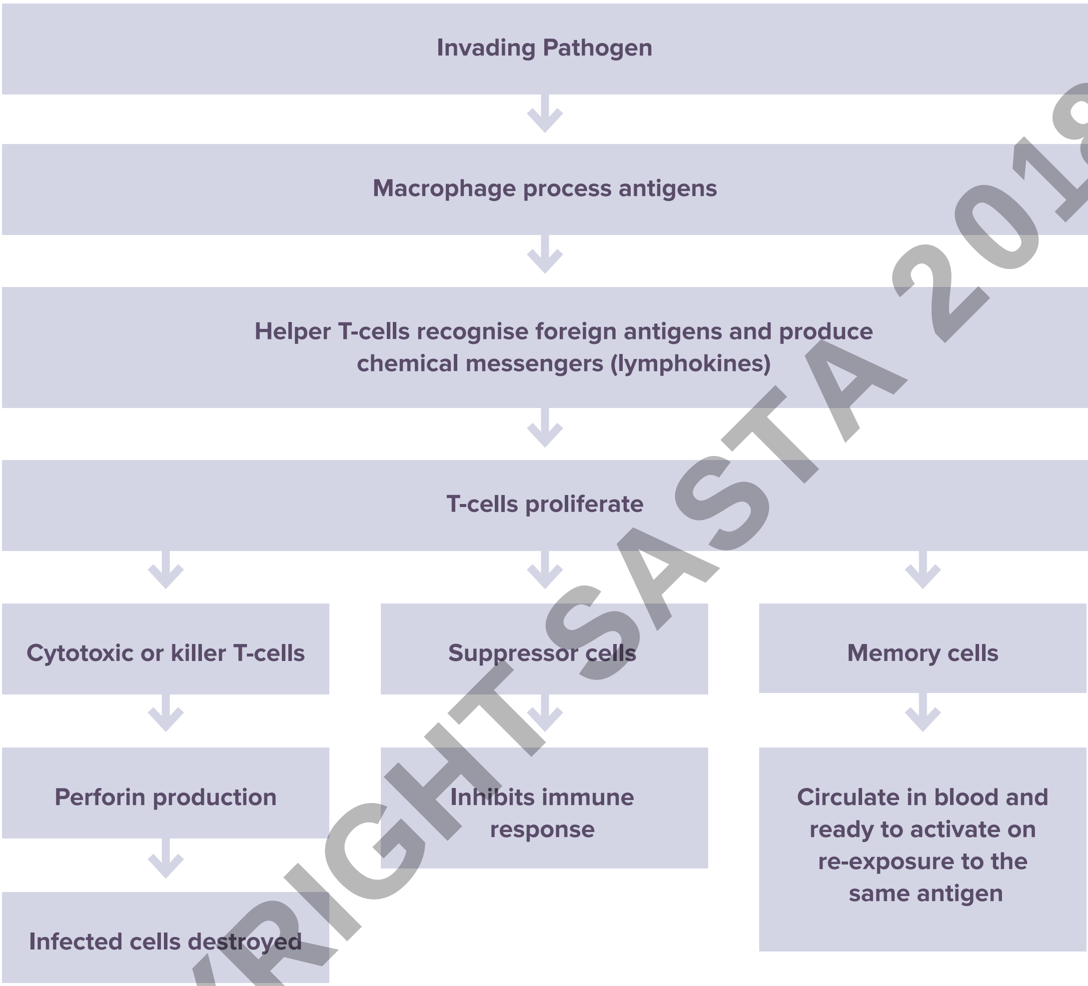
DID YOU KNOW? There is in fact a third pathway that can activate the complement proteins to cause pathogens to be destroyed. It is known as the Mannan-Binding lectin pathway. Mannose sugars on the surface of the pathogen bind to lectin. This causes the activation of serine proteases, which activate the complement proteins leading to the same responses as seen in Figure 2.6 above. A number of potential pathogens have mannose on their surfaces including yeasts, bacteria and protozoans. Two well-known pathogens *Mycobacterium tuberculosis* (causes tuberculosis) and *Mycobacterium leprae* (causes leprosy) use the mannose on their surface to enter phagocytic cells, via specific receptors where they reside, to hide from the immune system of the infected individual.

Natural Killer (NK) Cells

Natural killer cells are responsible for looking for an individual's own body cells that are damaged, and are an important cell of the innate immune system. NK cells are a type of lymphocyte that are not activated by specific foreign antigens. Damaged cells detected by natural killer cells include virus infected cells and cancerous cells, where the surface proteins of these cells have been altered. The NK cells will specifically destroy these cells by releasing cytotoxins.

Figure 2.12 shows an overview of how T-cells are activated in the cell mediated response to invading pathogens. Memory T-cells are also produced to increase response time to the same pathogen in the event of re-infection.

Figure 2.12: An overview of the mechanisms involved in the cell mediated immune response.

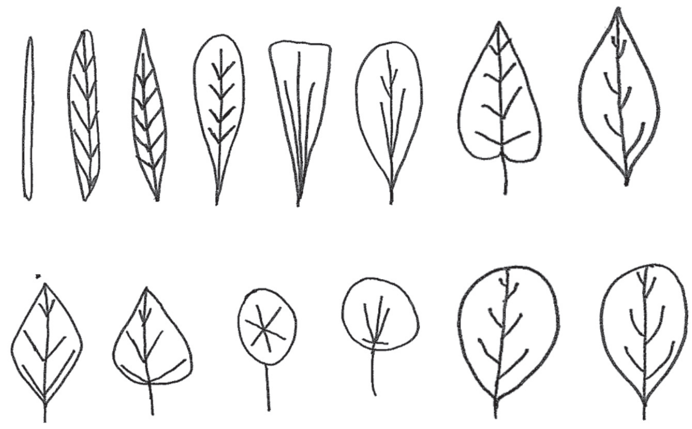


General Immune Response to Bacteria and Viruses

The generalised response to bacteria and viruses is described below:

Bacteria: Upon entry a bacterium will bind to a macrophage via its toll-like receptors. This causes the macrophage to engulf and breakdown the bacterium and present the bacterial antigens in the MHC class II molecules on the surface of the macrophage. The presentation of bacterial antigen stimulates helper T-cells and subsequently B-cells. Helper T-cells activate B-cells and promote their proliferation and differentiation into plasma cells that will produce antibodies that will specifically tag the bacterial antigen and enable identification and destruction of the bacteria by macrophages and neutrophils.

Figure 3.11: Some of the different leave shapes of plants.

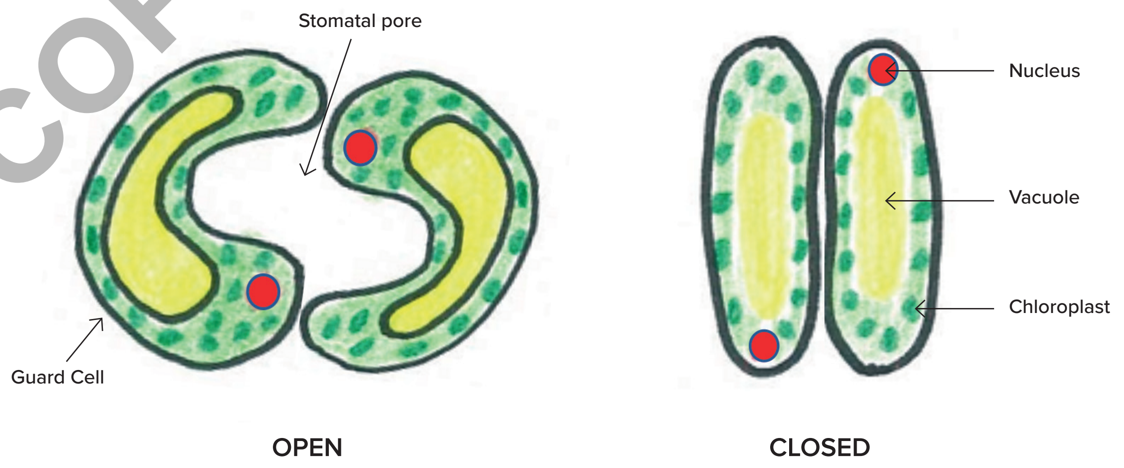


The leaf is an important organ and is vital for plant growth but also as a source of food for animals. Herbivores, animals that consume only plant material rely on plants as their source of food. Leaves also produce oxygen an essential molecule, as a by-product of photosynthesis, which is released into the air. This replenishment of atmospheric oxygen is important, as oxygen is essential for the survival of most organisms that rely on aerobic respiration to transform energy into useable forms (*see Chapter 1, for more detail on aerobic respiration and ATP*).

In the outer epidermis layers of the leaf there are specialized cells found in pairs called guard cells (Figure 3.12). These cells form stomata (or stoma, plural) which form a pore into the leaf that is able to open and close. These pores are important to ensure enough carbon dioxide is available for photosynthesis and to release oxygen into the atmosphere. These pores also enable water to be lost to the environment through the process of transpiration (*see later in this chapter for more information*).

The opening and closing of the stoma occurs in response to light, the availability of water and the concentration of potassium in the cells. In most plants the stoma are located on the lower epidermis layer (underside of the leaf) but can be found in the epidermis of other parts of the plant such as the stem or even fruit.

Figure 3.12: Stomata in the open and closed position.



3.3.5: Excretory Systems of Animals

Nitrogenous waste due to the breakdown of proteins must be removed from the body of animals as it is potentially toxic to cells. The type of nitrogenous waste produced by animals include uric acid, urea and ammonia. Figure 3.20 shows different groups of animals and the types of nitrogenous waste produced. Hence, different animal groups have different specialized cells and structures that are responsible for the excretion of the nitrogenous waste. A summary of these different systems can be found in Table 12. Later in this chapter, some of these systems will be described in more detail and compared to the human excretory system which uses kidneys.

Figure 3.20: Organisms that produce different nitrogenous waste.

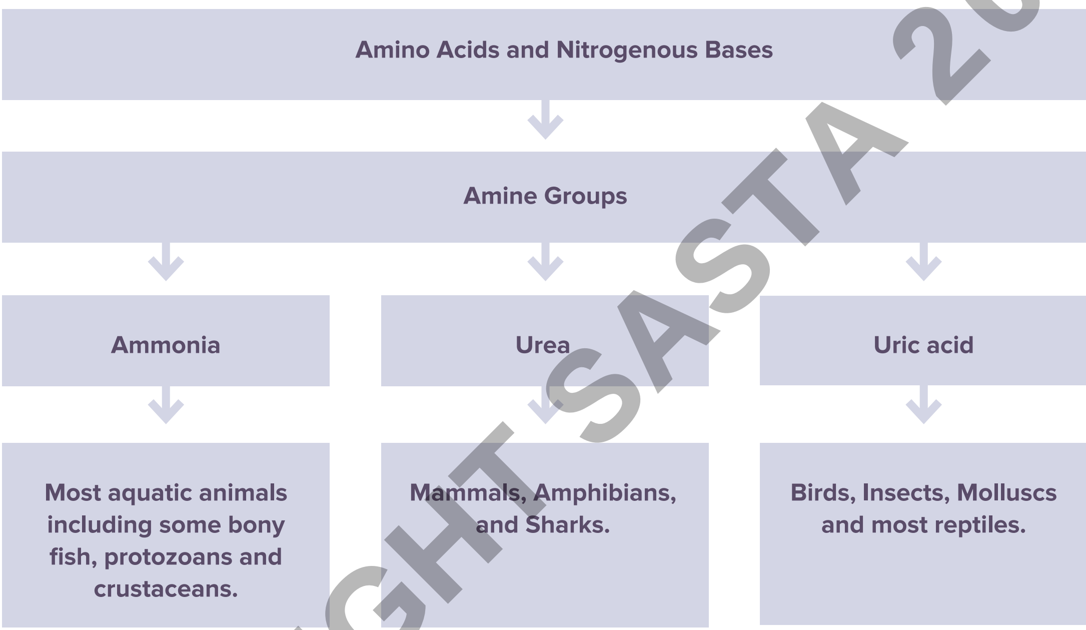


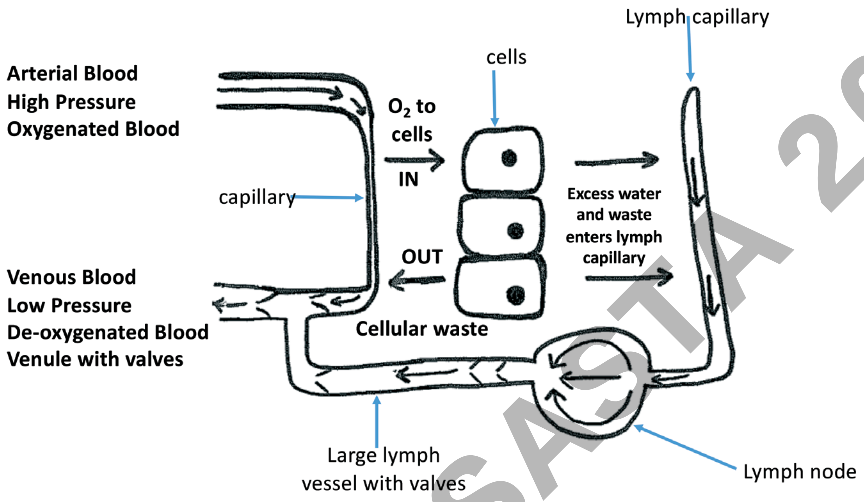
Table 12: Types of excretory systems in different organisms.

ORGANISM	MAIN COMPONENT (ORGAN) OF THE EXCRETORY SYSTEM
Human	Kidneys
Reptiles, Birds and other Mammals	Kidneys
Insects	Green glands and Malphighian tubules
Annelids: e.g. ringed worms Echinoderms: e.g. sea urchins	Nephridia
Flatworms e.g. planaria	Flame cells

Delivery of Oxygen and Removal of Wastes

Figure 3.26 summarises how materials are exchanged between the fluid surrounding cells (interstitial fluid) and the blood and lymph in the capillaries of the circulatory and lymphatic systems of humans. Substances in the blood and interstitial fluid move in simple terms due to blood pressure, the leaky walls of the capillaries, osmotic pressure and concentration gradient.

Figure 3.26: Exchange of materials between the interstitial (tissue) fluid and the circulatory and lymphatic systems of the human body.



DID YOU KNOW? Foetal haemoglobin has a higher affinity for oxygen than adult haemoglobin. The foetus developing in its mother's uterus relies on obtaining oxygen through the blood that travels from the placenta through the umbilical cord. If the haemoglobin of the foetus did not have a higher affinity for oxygen, there would not be enough oxygen available for the baby to grow as it would all be used by the mother.

SHE Alert: The close link between the structures of the circulatory systems has led scientists to explore the possibility of using organs from other animals for transplantation. Xenotransplantation, however, has both supporters and many critics, and sparks much public debate. With a growing need for organs, especially heart and lung organs, with a diminishing donor list new solutions are needed. There are significant issues with using organs from another species: rejection, infection (including zoonosis) and consideration of whether or not it is ethical to use animals in this way are just some of the ongoing issues. Rejection is the biggest hurdle to overcome. New DNA technologies may make it possible to program these animal organs such that the modified organ when transplanted will not be recognized by the recipient's immune system.

Review Questions: Check your understanding.

53. What is the function of the circulatory system?
54. What are the various functions of the lymphatic system?
55. Compare the structure of blood capillaries with lymph capillaries.
56. Draw a simple diagram to show the 4 chambers of the heart and the blood vessels associated with each.
57. Explain why the heart is often described as “two pumps that act as one”?
58. Explain how substances are exchanged between blood and the tissue fluid surrounding the cells of the human body.
59. Explain why the human circulatory system is described as a double circulatory system.
60. Describe the structure of the heart found in fish species and compare it to the heart found in reptiles.
61. Explain, using examples the difference between an open circulatory system and a closed circulatory system.
62. What two tissues are found in vascular bundles?
63. Describe the function of xylem.
64. Describe the function of phloem.
65. Compare the characteristics of the xylem and phloem.

4.3: Adaptations

Adaptations are characteristics that are found within the populations of a species that provide the individuals with traits that enable them to survive in their habitats. These characteristics are associated with the presence of particular genes in these individuals. These genes and hence the adaptations can be such an advantage to the species that over time due to the process of natural selection these characteristics increase in frequency in the gene pool that the population has "adapted" to the environmental change that occurred. Populations are continually adapting to the changes in their habitats to ensure the survival of the species. The basis for adaptation is, however, the presence of a variety of genes (genetic diversity) in the population prior to any change. Individuals cannot adapt by acquiring new characteristics, however, the species as a whole can. As the number of individuals with characteristics better suited to the changed environment survive and reproduce, they pass the genes encoding these favourable characteristics to their offspring, eventually outnumbering those that are less suited to the new environment.

DID YOU KNOW? Natural Selection, is a theory proposed and published independently by two scientists, Charles Darwin and Albert Wallace in 1859. It attempts to explain how species become better suited to changes in their environment. These changes, called selective pressures favour individuals in the population that are more suited to these changes. These individuals are more likely to reproduce and pass on their favourable characteristics to their offspring. Over numerous generations, in the presence of the selective pressure the populations' gene pool changes to have a higher frequency of individuals with the favourable characteristic. Natural selection with geographical isolation is the basis for the mechanism of (allopatric) speciation, where species evolve from a common ancestor.

There are three different types of adaptations that organisms may have to increase their chance of survival.

- Behavioural
- Physiological
- Structural (or anatomical)

Behavioural Adaptations

Behavioural adaptations relate to the way an organism acts. This could include inherited or learnt characteristics. It would include behaviours such as living in groups, displaying particular vocal demonstrations and conserving energy by resting during the day.

Figure 4.10: Behavioural Adaptation: Fish swim in schools to protect themselves from predators.

Physiological Adaptations

Physiological Adaptations are those that involve the way the organisms body or cells work. This would include adaptations that reduce water loss, temperature regulation or the production of venom or toxins.

Figure 4.11: Physiological Adaptation: Sea urchins produce venom.

Structural Adaptations

Structural adaptation are the physical characteristics of an organism and would include the shape of the animal, length of any limbs or presence of hair or fur.

Figure 4.12: Structural Adaptation: Stingray camouflages against the ocean floor.

Animals and plants have different requirements for survival and hence the types of adaptations within the populations of these organisms is different.

Adaptations in the animal kingdom

There are examples of all adaptation types across the multitude of animal species. In this section a number of common and unique adaptations in the animal kingdom are provided.

ANIMAL EXAMPLE	ADAPTATION TYPE	EXPLANATION
Meerkat *(Suricata suricatta)*	Behavioural	Live in communities and take turns to watch for predators.
Desert Hopping Mouse *(Notomys alexis)*	Physiological	Do not need to drink water, they extract water from the seeds consumed. They also produce very concentrated urine to reduce water loss.
Notothenioid fish	Physiological	Able to make their own "antifreeze" proteins to survive in the cold waters surrounding Antarctica. The proteins are able to bind to ice crystals that form in the blood, preventing the blood from freezing.
Cuttlefish *(Sepia officinalis)*	Behavioural	Using camouflage by changing colour to avoid predators and to aid in hunting prey.
Okapi *(Okapia johnstoni)*	Physiological	Okapi have three important physiological adaptations: • have scent-glands on their feet to mark their territory. • have infrasonic calls, which allows them to communicate with their calves without predators hearing their call. • have large ears to enable them to detect predators.
Emu *(Dromaius novaehollandiae)*	Structural	The small pad beneath the three toes help the emu to stride over Australia's difficult terrains.
Echidna *(Tachyglossus aculeatus)*	Structural	Has short and stout legs that help it dig underground. Has backward facing hind legs which is a unique physical features that push the dirt out of the way when burrowing.

Adaptations in Australia's Arid Zone

In Australia, 70% of the area of the land mass consists of an arid ecosystem. The plants and animals that live there have adapted to life in a hot, dry, windy and sunlit environment. Australia's desert environment, known as the Arid Zone (consisting of both arid and semi-arid zones) is unique in its abiotic and biotic features. The arid zone is characterized by less than 250mm of rain, and the semi-arid zone has an average rainfall in the range of 250-350mm in a year. These unique factors has meant that both animals and plants have adapted to live in this low water environment. Australia's arid regions are different to other desert environments and has the following characteristics:

- extreme fluctuations in weather conditions.
- rainfall occurs in extremes: from drought conditions to floods, making rainfall unpredictable.
- the flooding of the arid zones and the water run-off that occurs is responsible for producing pockets of fertile alluvial soils, with nutrients to support new plant growth.
- large areas of poor soils that are highly weathered and nutrient poor.
- fire is an important factor in the maintenance of the arid ecosystem, through nutrient recycling, creation of space and for the germination of some plant species.
- availability of obtaining food determines animal distribution not the availability of water. Many animals that live in the arid zone obtain water from their food source.

Figure 4.13: Left: Storm over Uluru, NT. Right: Water cascading down Uluru, NT after the rain.

It is this combination of features that has shaped the types of plant and animal species that call the arid zone of Australia home. These species have adapted to these extremes, and have such highly adapted characteristics that they continue to survive in this harsh environment, even when water is so scarce, and when food supplies may diminish. The following table compares some of the typical adaptions of plants and animals that live and reproduce in the arid/semi-arid zone of Australia.

Figure 4.14: Cooper Pedy, SA. The desert ecosystem before and after the rain.

Table 2: Comparison of some adaptations found in plants and animals in Australia's Arid Zone.

PLANT ADAPTATIONS	ANIMAL ADAPTATIONS
Physiological: Photosynthesis in stems because they have no leaves, which reduces water loss by transpiration	Physiological: production of concentrated urine
Structural: shallow roots	Structural: large ears to enable heat loss
Structural: deep roots	Behavioural: rest in the shade during the hottest parts of the day Burrow to avoid temperature fluctuations. Nocturnal behavior to feed and hunt in the night, to avoid high day time temperatures.
Physiological: Flowers open at night when its cooler	Physiological: Dormancy during droughts. Reduce metabolic activity and movement. Relies on stored energy sources and water.
Structural: no leaves, or very thin needle like leaves (modified structure)	Structural: light coloured fur to reflect light and heat.

DID YOU KNOW? The arid regions of the Australia can have creeks beds that are dry for years, and then suddenly flowing with water 3 to 5 metres high. The arid zone is normally dry, in a condition of drought. Frogs have adapted to these conditions, and one in particular commonly known as the water-holding frog (*Cyclorana platycephalus*) can bury itself and aestivate (go dormant) for months to years waiting for the next rains and flooding event which will deliver it food. To survive in this state, the frog burrows itself to avoid temperature fluctuations and survives on energy stored (as lipids) in its tissues.

Figure 4.15: A flooded creek near Oodnatatta, SA.

Review Questions: Check your understanding.

16. Why do organisms have particular adaptations?
17. Name and describe the three different types of adaptations? Use an example to support your description.
18. Why do some organisms not have behavioural adaptations?
19. Explain why organisms that live in the Australian arid zone may have different adaptations to organisms that live in other desert ecosystems around the world.
20. Describe one adaptation that an organism may have to:
    a. live in the understory of a rainforest.
    b. survive extended periods of time without rain.
    c. evade predators.
    d. avoid the hot day time temperatures
21. Characterise the adaptations of the Tarrkawarra, also known as the spinifex hopping mouse as structural, physiological or behavioural.
22. Even though the mulga tree and saltbush plants have different adaptations they are both able to survive in the arid zone. Explain.
23. Explain why plants that are in the understory of a rainforest have different adaptations to the plants in the canopy of the rainforest.
24. Describe the types of adaptations you would expect an animal would need to live in a cold, snowy environment, such as a tundra?
25. This is a fish that lives in the coral reefs in the south pacific. Explain why its colour may be an adaptation that increases the chance of survival.

26. Explain the type of adaptation observable in the following photograph.

27. Explain why the characteristics of this kangaroo are not well suited to the Australia arid ecosystem.

SHE Alert: Renewable energy: A cleaner future?

The development of more efficient and renewable energy alternatives to fossil fuels is a growing industry. As the cost of this technology decreases for the consumer this will *influence* the further development of these emerging technologies. In addition, as the benefits for the environment (including maintenance of ecosystems and the organisms that live there) become more evidence based and the public demand for species protection, cleaner air to breathe, with less pollution, and a solution to the increasing number of natural disasters, more renewable technology will be used by governments and industry, which will make it more accessible for others, including households.

The Nitrogen Cycle

Nitrogen is the most abundant element in the atmosphere and is vital for life as it is required for the formation of nucleic acids and proteins. The nitrogen in the atmosphere, however, is not in a useful form. Most living things, with the exception of a specialised group of bacteria, are not capable of using atmospheric nitrogen (N_2). The nitrogen cycle is therefore a complex cycle where nitrogen is converted into a number of different forms suitable for different living things.

There are numerous stages to the nitrogen cycle (Figure 4.23). As mentioned atmospheric nitrogen is not usable and needs to be converted in a form of nitrogen that can be taken up by plants. This reaction requires specialised groups of organisms including nitrogen fixing bacteria. The nitrogen enters the soil through rain. Nitrogen fixing bacteria living in a mutualistic symbiotic relationship with plants, have the necessary enzymes capable of converting nitrogen into ammonia (NH_3).

Figure 4.23 also shows that nitrogen can also be fixed by lightening, where high energy input converts the nitrogen into ammonia and nitrates. However, only a small amount can be made with this process and is not sufficient to support plant life.

Some plants are able to use ammonia, but many are not able to and the ammonia can in fact be toxic. Another group of bacteria, nitrifying bacteria convert the ammonia into nitrite (NO_2^-) and then into nitrate (NO_3^-).