NASCA WORKBOOK
NATURAL SCIENCES

Table of Contents

COMPONENT 2 BIOLOGY

Introduction

Biology is the scientific study of living organisms from the molecular level to their interactions with one another and their environment. Biology as a school subject is usually selected from molecules and cells, genetics and heredity, evolution and diversity, structure and function of animals and plants, and ecology. In the NASCA curriculum we chose to focus on the topics Evolution and diversity, linking them with genetics and heredity. These topics are the most important concepts in modern biology.

Biology Content Structure

Topic Heading	Sub-Topic (with Approximate Instructional Time)
1. Biodiversity	1. Biodiversity and the biomes of South Africa (8 hours) 2. Principles of classification (7 hours) 3. The history of life (1 hour)
2. Evolution	1. The theory of evolution by natural selection (7 hours) 2. Evidence supporting evolution (7 hours)
3. Genetics and Heredity	1. Patterns of inheritance (13 hours) 2. DNA structure and function (15 hours)

Topic 1. Biodiversity

Introduction

Biodiversity is the scope of variation among organisms. Biodiversity can be studied at three different levels:

1. The diversity of genes in a species,
2. The diversity of species living in an area;
3. The diversity of ecosystems in a particular area.

We focus here on diversity of ecosystems and diversity of species.

South Africa is fortunate to have enormously rich biodiversity. We hope to make you aware of South Africa's biodiversity by exploring the major ecosystems, called biomes of South Africa, and the variety of species in the country. We also consider threats to biodiversity and conservation efforts.

Diversity of species can be organised according to a hierarchical classification scheme, based on similarities and differences between species and groups of species. We introduce you to the Linnaean classification system, which is still used at present. The highest level of organisation in the Linnaean system is the Kingdom. We study the distinguishing characteristics of the five Kingdoms or life: Bacteria, Protista, Fungi, Plantae and Animalia. We end by illustrating the history of the major groups of living organisms.

Sub-topic 1. Biodiversity and the Biomes of South Africa

Content:

Unit 1: Definitions of the biosphere and biomes

Unit 2: Factors defining biomes

Unit 3: Exploring the biomes of South Africa

Unit 1. Definitions of the biosphere and biomes

Learning outcomes:

When you have completed this unit, you should be able to:

- Define the biosphere as all parts of the Earth on which life can exist;
- Define a biome as an area with a characteristic climate and main types of vegetation.

1.1. The biosphere

Activity 1.1: What do you already know about biodiversity in South Africa?

Expected outcome: Learners will be aware of their knowledge of the environment.

1. Circle all the names that you recognise in this list:

Elephant, cycad, mushroom, cow, vulture, yellowwood tree, protea, rhinoceros, vygie, wildebeest, python, halfmens, tortoise, sunbird, crab, earthworm, shark, hyaena, butterfly, snail, pangolin.

2. How many did you recognise? These are all organisms that occur in South Africa.

The **biosphere** is defined as all parts of the Earth where life exists. Life has been found below the earth's surface, on the earth's surface, in freshwater rivers and dams, in the oceans, and even in the air.

Life can exist almost anywhere on Earth, even in the frozen north and south poles, in very hot volcanoes and in deep caves.

The biosphere depends on energy from the sun. The process of photosynthesis allows living organisms such as plants to store energy in complex molecules. The plants use the stored energy to drive their life processes.

Animals eat the plants, and use the stored energy in plants to keep them alive. Eventually, all living organisms die. Bacteria and fungi break down the complex molecules, recycling their components in the environment.

Apart from the energy input from the Sun, the biosphere is a closed system. All the molecules necessary for life are recycled continuously.

[New word: Biosphere: all parts of the Earth where life can exist]

> MAIN IDEA: The biosphere is all parts of the Earth where life can exist. The biosphere receives energy from the Sun, but all other requirements for life are recycled within the biosphere.

1.2 Defining biomes

A **biome** is a region that is defined by the main type of plant life. The type of plant life may be grass in the Grassland biome, tall trees in the Forest biome, or **succulent** plants in the Succulent Karoo biome.

The type of plant life is controlled by the **climate** of the biome. Therefore, a biome is defined by the main type of plant life AND the climate of the region.

[New words: **Biome**: a region of the biosphere that has a particular type of plant life, controlled by the climate of the region

Succulent: plants that have fleshy leaves and/or bulbs and fleshy roots.

Climate: the average weather conditions of an area over many years].

MAIN IDEA: A biome is a region that has a particular type of plant life, which is controlled by climatic conditions.

Unit 2 Factors defining biomes

Learning outcomes:

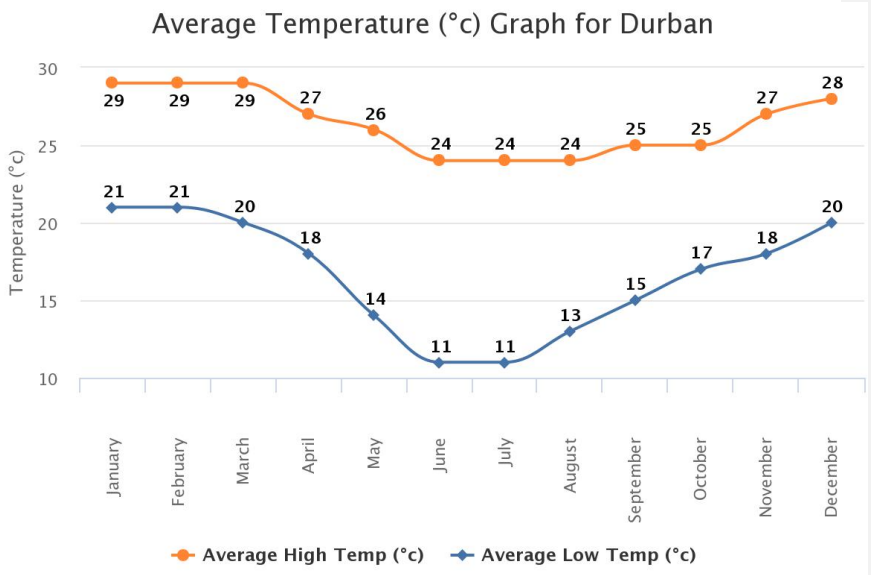
When you have completed this unit, you should be able to:

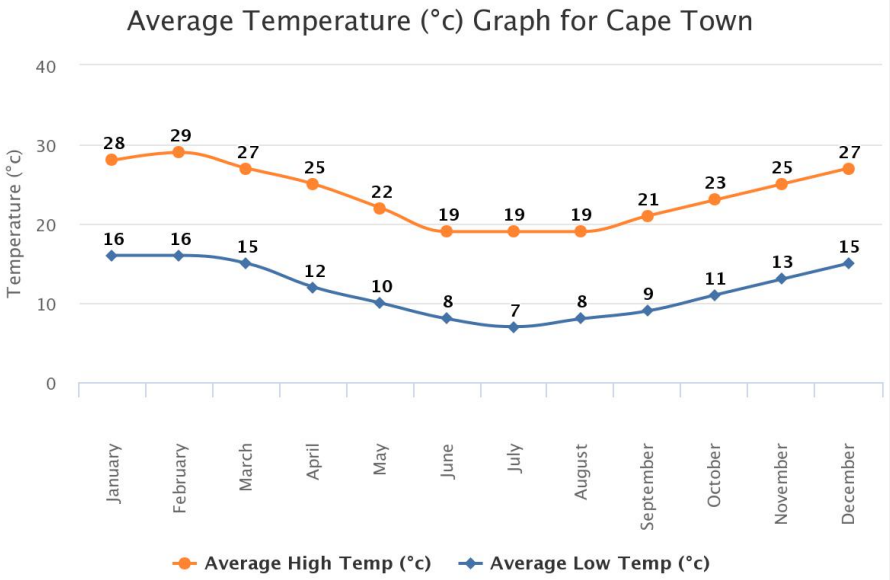
- identify the major terrestrial biomes of South Africa on a map of South Africa;
- identify the major differences between the terrestrial biomes with reference to climate, soils and main vegetation;
- explain the concept of adaptation, with reference to at least one example of a plant from each biome.

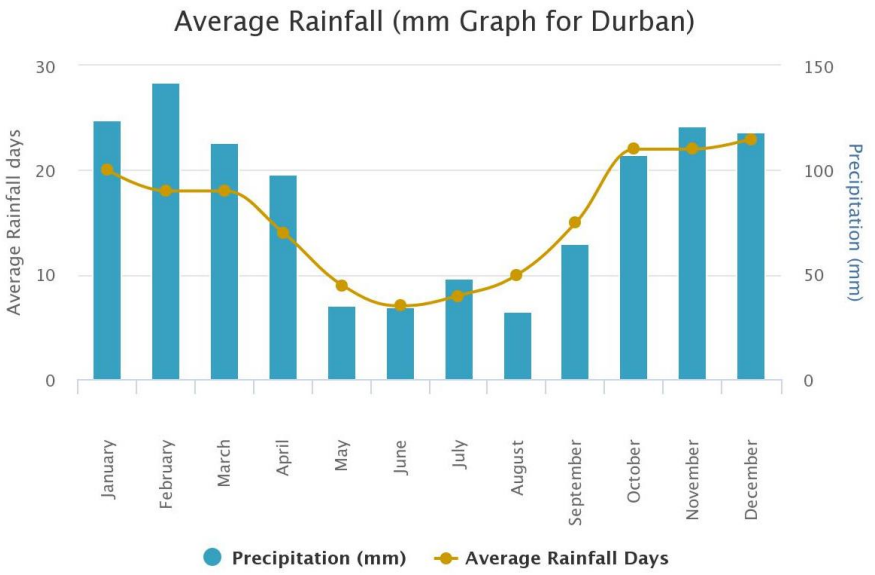
2.1 Introduction

The **climate** controls the type of **vegetation** in a biome. Two important climatic factors are the amount of moisture received and temperature.

For example, the graphs below show rainfall and temperature in Durban (east coast) and Cape Town (west coast).


Average Temperature (°c) Graph for Durban
Temperature (°c)
30
25
20
15
10
29 29 29 27 26 24 24 24 25 25 27 28
21 21 20 18 14 11 11 13 15 17 18 20
January
February
March
April
May
June
July
August
September
October
November
December
Average High Temp (°c)
Average Low Temp (°c)


Average Temperature (°c) Graph for Cape Town
Temperature (°c)
40
30
20
10
0
28 29 27 25 22 19 19 19 21 23 25 27
16 16 15 12 10 8 7 8 9 11 13 15
January
February
March
April
May
June
July
August
September
October
November
December
Average High Temp (°c)
Average Low Temp (°c)



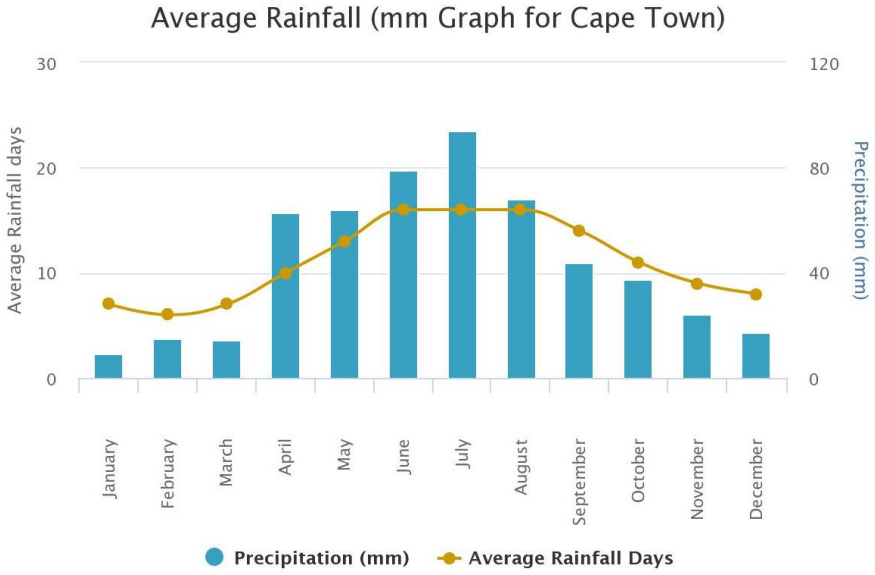


Figure 2.1 Graphs showing rainfall and temperature in Durban and Cape Town.
[Graphs from www.worldweatheronline.com]

Look carefully at the graphs and notice that

- Durban receives more rainfall than Cape Town.
- Rain falls in the winter in Cape Town, and in summer in Durban.
- In summer, Durban is about as hot as Cape Town during the day.
- In winter, Durban is hotter than Cape Town during the day.
- The average minimum temperatures are higher throughout the year in Durban than in Cape Town.

South Africa's climate varies across the country from west to east and from north to south. We also have coastal plains and high mountains, with a high plateau across the centre of the country. The varied climatic conditions mean that we have a large diversity of biomes. Some of the climatic variations are:

- The eastern parts of the country receive more rainfall than the west;
- The eastern part of the country receives summer rainfall, while the west receives rain in winter;
- Temperatures in the mountains and the central plateau are more extreme than temperatures in lower-lying coastal areas.

Soil type also plays an important role in the vegetation of a biome. Soils that are poor in nutrients have fewer and smaller plants than soils that are rich in nutrients. South Africa has a variety of different soil types.

MAIN IDEA: Climate and soil control the type of vegetation that grows in a biome. South Africa has great diversity of climate and soil types across the country.

2.2 The major terrestrial biomes of South Africa

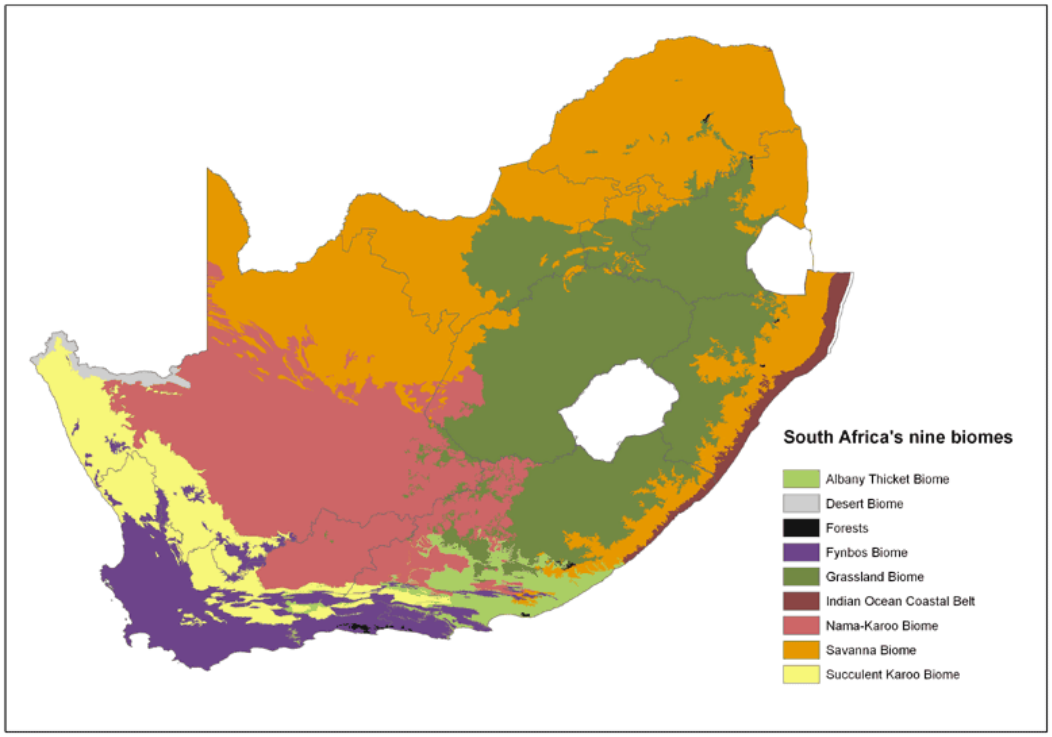
http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/intro.htm#2

There are nine major terrestrial biomes in South Africa:

- Fynbos
- Succulent Karoo
- Desert
- Nama Karoo
- Grassland
- Savanna

- Albany Thicket
- Indian Ocean Coastal Belt
- Forest.

Some textbooks include Desert in the Succulent Karoo biome, and Indian Ocean Coastal Belt in Albany Thicket. However, the most recent classification of the biomes shows the nine biomes listed above.



[Caption: Figure 2.2: The major terrestrial biomes of South Africa]

http://redlist.sanbi.org/imgs/stats/biomes.png

Activity 2.1: Find the biomes on a map of South Africa.

Expected outcome of activity: Identify the major biomes of South Africa on a map.

1. Study Figure 2.2.

1.1 Locate each biome using the colour key on the map.

1.2 Find approximately where you live on the map. In which biome do you live?

1.3 Name the three biomes that are the largest biomes in South Africa. (3)

1.4 Name two biomes that occur only in the western and southern part of the country. (2)

MAIN IDEA: South Africa has nine major biomes.

2.3 Climate, soils and main vegetation in each biome of South Africa.

1. Fynbos

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/fynbos.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

Caption: Figure 2.3: Fynbos has a great diversity of plants. From plantzafrica.com

Distribution

Fynbos occupies the mountains and coastal lowlands of the Western Cape, and coastal portions of the Eastern Cape Province, to the west of Port Elizabeth.

Climate

Fynbos is found in the winter rainfall region of South Africa. The biome has cool, wet winters and hot, dry summers. Annual rainfall varies through the fynbos biome. There are high winds throughout the year. Fire is an important component of this biome and there are intense fires about every 15 years that help maintain the plant community composition.

Soils

Fynbos soils are extremely poor. They are low in nutrients, lacking minerals and organic matter. Soil type, together with interactions between climate and fire, determine the boundaries of the fynbos biome.

Vegetation

The name fynbos (meaning "fine bush") refers to the large number of small-leaved evergreen shrubs in this biome. Fynbos vegetation includes many types of protea, erica and restio. The fynbos has extremely high plant diversity (with almost 9 000 species), approximately 70% of which are endemic.

[New word:

endemic species: a species that occurs in one particular place and is found nowhere else in the world.

[end word box:]

2. Succulent Karoo

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/succulentkaroo.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

[Caption: Figure 2.4: Yellow vygies flowering in the succulent karoo. (my own photograph)]

[New word:]

Distribution

The Succulent Karoo occurs along the western coast of South Africa, and inland along the northern border of the Fynbos biome. The Succulent Karoo biome occurs in the dry winter rainfall region of the country.

Climate

The Succulent Karoo experiences low winter rainfall, with only 20 to 290 mm of rain per year. Winters are cool but frost rarely occurs in this biome. It is extremely hot and dry in summer, with temperatures frequently over 40°C. Fog occurs along the coast, and this is an important source of water for organisms in the Succulent Karoo. Hot, dry winds blow throughout the year.

Soils

The soils of the Succulent Karoo are rich in lime and occur in a thin layer on top of a rock base. They contain little organic matter and are therefore not very fertile.

Vegetation

[Caption: Figure 2.5: Botterboom plants are adapted to the climate of the Succulent Karoo. (own photo)]

The Succulent Karoo is a hotspot of plant diversity. Over 6 300 species of plants have been recorded, of which 38% are endemic. This biome is characterised by dwarf succulent shrubs, including vygies and stone plants. These succulent plants have thick, fleshy leaves that store water. Grasses grow in the sandy areas.

Many annual plants such as daisies flower in the spring. Annual plants survive the dry period in the form of seeds and only germinate after rainfall. This biome is an area of outstanding natural beauty because of the mass flowering of plants in the spring after rains. Many tourists visit the Succulent Karoo biome to see the spring flowers.

[New words: Annual: a plant that lives for only one season

Hotspot: a region with a high level of biodiversity, particularly endemic species]

3. Desert (included in Succulent Karoo in some books)

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

[Caption: Figure 2.6: The desert biome. http://wp.roadstoroam.co.za/wp-content/uploads/2014/03/Richtersveld-National-Park-Springbokvlakte-viewpoint.jpg]

Distribution

Although much of South Africa is arid or semi-arid (environments with very little water), only a very small area is classified as true desert. The Desert biome of South Africa occurs in the Northern Cape Province along the lower Orange River valley. This biome includes sandy plains along the Atlantic coast. Further inland, the Desert biome includes the Richtersveld, a rocky and mountainous habitat that is the only arid biodiversity hotspot on Earth.

Climate

The Desert biome has a harsh climate. In the summer, temperatures can reach up to 53°C in the daytime, while at night the temperatures are very low. The western portion of the desert biome falls within the winter rainfall zone of South Africa, while the eastern portion is in the summer rainfall zone. Mean annual rainfall ranges from approximately 10 mm in the west to 80 mm inland. Thick fog is an important feature of this biome. The fog is critical for maintaining the high level of biodiversity found in the Desert biome.

Soils

The soils in the desert biome of South Africa are not very fertile due to the fact that there is little organic matter. They vary from sand in the west to thin soils on a rock base in the east.

Vegetation

The vegetation of the desert biome includes many annual plants – especially grasses – that survive through dry periods in the form of seeds. When rain falls, the seeds of the annual plants germinate and they complete their life cycle quickly before dying.

Perennial plants (those that live for more than two years) are also present. The perennial plants that grow in the desert have adaptations that allow them to survive with very little water. Many of the perennial plants in deserts are succulent, with special structures that allow them to store water in their leaves or roots. One plant species that occurs only in the Richtersveld is the Halfmensboom. Literally translated, the name "half-person tree" because it looks like a human.

4. Nama Karoo

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/namakaroo.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

[Caption: Figure 2.7: Nama Karoo vegetation] From plantzafrica.com

Distribution

The Nama Karoo is found on the central plateau of the western half of South Africa. This biome falls within the summer rainfall zone and its distribution is determined primarily by rainfall.

Climate

The Nama Karoo is an arid to semi-arid region. Rainfall varies between about 200 mm per year in the west to over 400 mm per year in the north-east. Rivers in the Nama Karoo only have water in them immediately after rains have fallen. It is very hot in the summer and cold in the winter, with frequent frost.

Soils

The soils of the Nama Karoo are rich in lime but form only a thin layer on top of a rock base. They contain little organic matter and are therefore not very fertile.

Vegetation

The vegetation of the Nama Karoo consists mostly of grasses and small shrubs. Trees occur only along watercourses. There is relatively low plant diversity in this biome and fires are rare.

5. Grassland

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/grassland.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

Figure 2.8: Grassland biome (own photograph)

Distribution

Grassland occurs mainly on the high central plateau and the inland areas of KwaZulu-Natal and the Eastern Cape. The biome extends from sea level to altitudes greater than 3 000 m, with landscapes that vary from flat plains to mountains.

Climate

Grassland is found within the summer rainfall zone. Heavy thunderstorms and hail occur during the rainy season. Rainfall ranges from 400 mm to more than 1 200 mm per year. Temperatures are also highly variable throughout the biome. Some areas experience frost and snow during the winter, while other parts are frost-free.

Soils

The soils that occur in grasslands tend to be deep and rich in nutrients. Grassland areas are frequently used for agriculture.

Vegetation

Grasslands are dominated by grasses and other low-growing plants, including many showy flowers that survive dry periods as underground bulbs. Trees occur only along rivers and protected valleys. Frost, fire and grazing maintain grass dominance and prevent trees from growing in other areas. Plant diversity is high in this biome, with approximately 3 400 plant species occurring in the central grassland region.

6. Savanna

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/savanna.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

Figure 2.9: The savanna biome

https://room42.wikispaces.com/file/view/savanna_geography.jpg/33724861/savanna_geography.jpg

Distribution

Savanna covers about one-third of South Africa. Savanna is found in northern regions of the country, including the lowveld and Kalahari, as well as in parts of KwaZulu-Natal and the Eastern Cape.

Climate

Savanna occurs in the summer rainfall zone. Summers are wet and winters are dry. This biome receives from 235 mm per year in the west to 1 000 mm per year in the east. The climate is tropical to subtropical, with higher temperatures than the grassland biome. Fires occur frequently.

Soils

Savanna soils vary greatly depending on the location. In the dry Kalahari region, soils are sandy and deep. Areas of savanna with higher rainfall tend to have more shallow soils. Soil fertility is generally low.

Vegetation

Savanna vegetation consists of a lower layer dominated by grasses, with scattered shrubs and trees. Thorn trees grow throughout the savanna, with baobab and mopane trees in the north. There is high plant diversity, with 3 800 species in the moist savannas and 3 300 in the dry savannas. Climate, fire and grazing maintain the characteristic grass-tree structure of the savanna biome.

7. Albany Thicket

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/albanythicket.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

[Caption: Figure 2.10: Albany thicket vegetation. From: Pza.sanbi.org]

Distribution

Albany Thicket occurs in semi-arid parts of the Eastern and Western Cape provinces. Thicket is sometimes considered part of the savanna biome but recent vegetation classifications have identified it as a distinct biome.

Climate

The Albany Thicket biome is found at the transition zone between the winter and summer rainfall regions of South Africa. Rainfall occurs throughout the year, although rain is unpredictable and the totals are relatively low (200 to 950 mm per year). Inland areas experience temperatures exceeding 40˚C in the summer and have frost in the

winter. The ocean moderates the extreme temperatures in the coastal parts of this biome. Fog in coastal regions maintains the rich lichen community. Fire is not an essential component of this biome and many of the succulent plant species found here are resistant to burning.

Soils

The soils in Albany Thicket vary across the biome, from sand dunes along the coast to deep sandy soils further inland. The soils are typically poor in nutrients.

Vegetation

The vegetation of the Albany Thicket is generally dense, with succulent, woody and spiny plants that grow to a height of 2-3 m. Characteristic plant species include euphorbias, aloes and spekboom. Plant diversity is high, with many endemic species.

8. Indian Ocean Coastal Belt (included in Albany Thicket in some books)

Figure 2.11: Indian Ocean Coastal Belt vegetation. [my own photograph]

Distribution

The Indian Ocean Coastal Belt runs from the South Africa-Mozambique border in the north to the mouth of the Great Kei River (near East London) in the south. This biome occupies a narrow coastal strip that extends from sea level to an altitude of approximately 600 m inland. Indian Ocean Coastal Belt has a distinctive vegetation structure and climate that separates it from other biomes.

Climate

Indian Ocean Coastal Belt has a subtropical climate. It falls within the summer rainfall zone of the country but there is some rainfall throughout the year. Annual precipitation ranges from 800 to 1 300 mm per year, making it the biome with the highest average rainfall. Summers are very hot, while winters are warm and mild. Fires are rare in this biome.

Soils

The soils of the Indian Ocean Coastal Belt are generally sands with poor soil development. Many parts of this biome occur on sand dunes or the coastal plain.

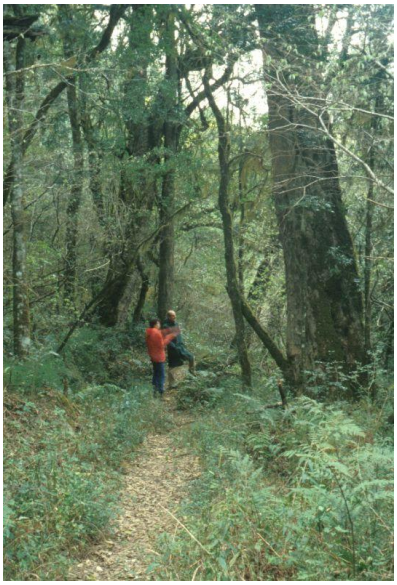
Vegetation

The Indian Ocean Coastal Belt is a component of the Maputaland-Pondoland-Albany biodiversity hotspot, including both the Maputaland and Pondoland Centres of Endemism. The vegetation includes coastal forest, dwarf shrubland, thicket and grassland. Important plant species include cycads, red-hot pokers, bitter aloe, and bird-of-paradise flower.

9. Forest

http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/forest.htm

http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus



[Caption: Figure 2.12: Forest in the Hogsback. From plantzafrica.com]

Distribution

Forest is the smallest biome in South Africa. Forests have a patchy distribution along the eastern Escarpment from the Soutpansberg in the north to the Cape Peninsula in the south. South African forests are naturally quite small and fragmented and most cover areas less than 1 km^2. Some of the best-known examples of South African forests include the Knysna and Tsitsikamma forests in the southern Cape and Ongoye forest in KwaZulu-Natal.

Climate

Forests occur in both the winter and summer rainfall zones, with some forests receiving rainfall throughout the year. The climate is generally temperate, with fairly small changes in temperature between winter and summer. Fires are rare in South African forests because they have high humidity.

Soils

The soils of forests are generally fertile, with high amounts of organic matter.

Vegetation

Almost all the indigenous trees found in South African forests are evergreen, meaning that they hold on to their leaves year-round. Forests have many different layers. Very tall trees form a canopy; shorter trees form a sub-canopy; and low shrubs, ferns and herbaceous plants grow at ground level, forming the understorey layer. Some of the most important tree species found in forests include yellowwoods and black stinkwood. Although the forest biome is quite small, it has the second richest plant species diversity

Activity 2.2: Have you understood your reading?

Expected outcome of the activity: Students should be able to associate climate, soil and vegetation with the correct biomes.

The biomes of South Africa are: Fynbos, Succulent Karoo, Nama Karoo, Desert, Forest, Savanna, Grassland, Albany Thicket, Indian Ocean Coastal Belt.

1. Choose the biome or biomes that match each of the following descriptions. The first one has been done for you.

1.1 Most rain falls in the winter.

Answer: Fynbos, Succulent Karoo, Desert.

1.2 Fire plays an important part role in these biomes.

1.3 Winter is very cold with frequent frost.

1.4 Soils are fertile.

1.5 Vegetation consists of grass with scattered trees and shrubs.

1.6 Famous for the colourful flowers in spring.

1.7 Rain falls mostly in the summer.

1.8 Mostly in the highveld areas that experience frost in the winter.

1.9 Fog plays an important role in these biomes.

1.10 Vegetation consists of evergreen, succulent, spiny trees and shrubs.

1.11 Annual rainfall is 10 mm – 80 mm. (10)

per unit area, after fynbos.

MAIN IDEA: Each biome has characteristic climate, soils and vegetation.

2.4 Adaptations of plants to the different biomes.

Adaptations are special features of organisms that help them to survive in their environment. Plants are adapted to the climate and soils of the biome in which they live.

[New word: Adaptation: Any special feature of an organism that helps it to survive in its environment]

Fynbos

Plants of the fynbos biome are adapted to winter rainfall, hot dry summers, poor soils, and fire. Plants are adapted to save water and survive fire.

- The reeds and grass of the fynbos biome have small leaves or no leaves and tough, wiry stems.
- Many of the shrubby plants have small, narrow, rolled leaves (http://pza.sanbi.org/sites/default/files/Fynbos6.jpg).
- The proteas have broad leaves and thick bark. The thick bark helps proteas to survive fires. (http://pza.sanbi.org/sites/default/files/fynbos5%20keerpomsberg.jpg).

Succulent Karoo Biome

Plants of the Succulent Karoo are adapted to low rainfall, and very hot, dry summers. The main plants are small succulent shrubs. Vygies are a good example. They have fleshy leaves that store water. Figure 2.3 shows yellow-flowered vygie.

Nama Karoo Biome

Plants of the Nama Karoo biome are adapted to little rain, hot summers and cold winters. Frost affects the plants in winter. Most plants are low shrubs and grasses. Many plants lose their leaves when rain does not fall. This is an adaptation to the dry climate. See a photograph of typical Nama Karoo plants at this website:

http://pza.sanbi.org/sites/default/files/nkdoleriteneartafelkop3.jpg

Grassland

Plants of the Grassland biome are adapted to winter frost, fire and grazing. Grasses are well adapted to these conditions. They have an underground stem that can survive fire, frost and grazing. The leaves die off in winter, enabling the plants to survive frost. You can see photographs of grasslands by searching for "Grassland biome South Africa" and selecting "Images".

Desert Biome

Plants of the desert biome are adapted to very harsh climatic conditions. Desert plants are mostly annual. The most common plants are grasses. They survive the dry conditions as seeds. After rain, the seeds germinate quickly and the plant completes its life cycle in a few weeks. You can see a photograph of the desert biome with a few dead grass plants at this website:

http://pza.sanbi.org/sites/default/files/desert1.jpg

Savanna

Plants of the Savanna biome are adapted to low rainfall and fire. Acacia (Thorn) trees are common in South African savanna. They have small leaves that help reduce water loss. The thorns discourage animals from eating them. Some acacias have thick bark that enables the plants to survive fire. You can see a photograph of an acacia tree in the savanna biome at this address:

http://pza.sanbi.org/sites/default/files/savanna3.jpg

Albany Thicket Biome

Plants in the Albany Thicket Biome are adapted to fairly low rainfall. A typical plant of Albany Thicket is the spekboom. It has succulent leaves that store water. Read more about spekboom at the following website:

http://www.kariega.co.za/blog/happy-earth-day

Forest biome

Unlike most of the biomes of South Africa, forests receive high rainfall, no frost, and rare fires. Forest plants compete for light. Trees such as yellowwood trees grow very tall to reach the light. The trees have a sturdy trunk to support the height of the tree. The leaves are dense on the branches. Search for photographs of yellowwood trees using the key words "Yellowwood tree South Africa" and selecting "Images".

Indian Ocean coastal belt

The Indian Ocean coastal belt biome is a mixture of grasslands, forest and thicket. Close to the sea, the vegetation is affected by salt spray and wind. A plant that is typical of this biome is the Natal wild banana. It has enormous leaves that tear in the wind. It forms clumps, each plant growing from its underground stem. The clumps protect the plants from the wind.

See photographs and read more about the Natal wild banana at this website:

http://www.plantzafrica.com/plantqrs/strelitznichol.htm

MAIN IDEA: Plants are adapted to the climatic conditions of each biome.

Activity 2.3: Have you understood your reading?

Expected outcome of activity: Students should be able to identify environmental features and adaptations of a plant.


ws two halfmens plants.

https://www.plantzafrica.com/plantnop/plimagesnop/pachynam.jpg

Choose statements from the list below that apply to the photograph.

1.1 The photograph shows the forest biome.

1.2 The plants grow amongst rocks.

1.3 The biome where these plants are found experiences heavy rain in the summer.

1.4 The plants have many broad leaves.

1.5 The plants have succulent stems that store water.

1.6 These plants grow in the Desert biome.

1.7 The plants have few leaves at the tips of branches.

1.8 The plants have thick bark that protects them from fire.

1.9 The stems are covered in spines that discourage herbivores. (5)

Unit 3 Exploring the biomes of South Africa

Learning outcomes:

When you have completed this unit, you should be able to:

- select one South African biome for detailed study (preferably the biome in which you live), collect climatic data, type of soils, altitude, main vegetation and animal life in the biome from Internet sources such as PlantZAfrica.com or books;
- describe threats to and conservation of the biome;
- write a comprehensive report on the biome, including drawings, photographs, and graphs showing precipitation and temperature records;
- explain the classifications of plant species used in the Red List, and illustrate the classifications with reference to the chosen biome (search for Red List on the SANBI website);
- explain the concept of sustainability, and investigate one plant in South Africa that is used by humans, and how it should be used sustainably (search for sustainable use of plants on the SANBI website).

3.1 Researching a biome in South Africa

Follow the instructions and complete assignment 1.

Assignment 1: Carry out research on one biome of South Africa.

Expected outcome of the assignment: Students should produce a comprehensive report on one biome of South Africa, including drawings, photographs and graphs showing rainfall and temperature records for the biome.

1. Select a biome that you would like to study. It should preferably be the biome in which you live. Please note that there is not much information available about the Indian Ocean Coastal Biome.

1.1 Collect data about the climate, soils, and altitude of the biome. Some resources you can use are:

- Knobel, J. & Bredenkamp, G. 2006. The Magnificent Natural Heritage of South Africa. Roggebaai: Sunbird Publishers.
- http://planet.botany.uwc.ac.za/nisl/bdc321/ekapa%20cape%20towns%20lowlands/biomes/intro.htm#2
- http://pza.sanbi.org/vegetation
- http://www.everythingmaths.co.za/science/lifesciences/grade-10/08-biosphere-to-ecosystems/08-biosphere-to-ecosystems-03.cnxmlplus

1.2 You can find tables showing annual rainfall, average minimum and maximum temperatures on the following website:

https://worldweatheronline.com

Enter the name of a town in your chosen biome. Some examples are: Durban (Indian Ocean Coastal); Grahamstown or East London (Albany Thicket); Knysna (forest); Johannesburg or Bloemfontein (Grassland); Polokwane or Nelspruit (savanna); Cape Town (fynbos); Upington (nama karoo); Springbok (succulent karoo); Alexander Bay (desert).

Select the icon on the left of the screen that shows a bar graph. After a short wait, you will see line graphs showing the average minimum and maximum temperatures per month for 2000 – 2012. Scroll down, and you will see a bar graph showing the average monthly rainfall for the same period.

1.3 Collect information about the main plants growing in your biome and the animals that are found in the biome. Use the sources listed under 1.1

1.4 Collect information about threats to your biome, and conservation efforts. You will find suitable information in the first three references listed for question 1.1.

1.5 Write a comprehensive report on the biome you have chosen. Use your own words. (50)

3.2 Classification of plant species according to the Red List.

The Red List is a scientific system designed to measure a species' risk of extinction. Its purpose is to identify species that most need conservation. South Africa uses 14 categories of the Red List, ranging from **Extinct** to **Least Concern**.

- **Extinct** species no longer live. They may be extinct from the whole planet, **extinct in the wild**, but living in cultivation, or **extinct in a region** where they previously occurred.
- **Threatened** species are those that face a high risk of extinction.
- **Species of conservation concern** are all those categorised as extinct in the wild or extinct in a region through to those where there is insufficient data to categorise them.
- **Species** are classified as **Least Concern** when they are at low risk of extinction**.** They do not require conservation.

[New word: Extinct: A species that no longer exists alive.

Threatened: Species that face a high risk of extinction.

Conservation concern: species that must be conserved]

In the 2015 survey, almost 75% of South Africa's plant species were classified as **least concern**, 0,2% were **extinct**, 13,4% were **threatened**, and 11,8% were of **conservation concern**. Most species that need conservation are in the fynbos and succulent karoo biomes, followed by grassland and savanna biomes.

The Red List is important when new developments are planned. Before a development can go ahead, the natural vegetation is evaluated to make sure it does not affect a threatened species.

The most important threat to plant diversity is loss of habitat, when the natural vegetation is destroyed. Reasons for habitat loss are:

- Developments such as mining, agriculture, urbanization, roads and forestry;
- Overgrazing;
- Fires that burn the habitat too frequently or at the wrong time of the year;
- Invasive alien plant species that grow faster than indigenous plants;
- Harvesting plants for medicinal purposes and for gardens or collectors;
- Pollution;
- Climate change.

Main idea: The Red List is used to identify organisms that are threatened with extinction and therefore need special conservation measures.

Activity 3.1: Have you understood your reading?

Expected outcome of activity: Learners will be able to classify organisms according to the main Red List categories.

1. Say whether each of the following statements indicates extinct, threatened, or least concern species.

1.1 Seventeen of the 243 mammal species in South Africa face a high risk of extinction.

1.2 The quagga is an animal that looks like a zebra. No living quaggas exist anywhere on earth.

1.3 The hadedah ibis is a bird that is increasing in urban habitats.

1.4 Cape vultures are decreasing in number because of poisoning by farmers and the muthi trade.

1.5 Baboon colonies are increasing in parts of South Africa.

1.6 "Halfmens" plants are decreasing in the desert biome because of plant collecting.

1.7 Pepperbark trees are very valuable for traditional medicine. There are no longer any pepperbark trees growing in the wild in South Africa.

1.8 The Common Hook Thorn tree is widespread throughout South Africa. (8)

3.3 Sustainable use of plants

South Africa has a rich diversity of plant and animal life. The Red List shows that more and more species are becoming threatened or near to extinction. The reasons why so many species are becoming threatened are given in the previous section.

One way that we can help to save our biodiversity is through sustainable use of plants. Sustainable use means that we use those resources at a rate that enables the species to recover, grow and reproduce. If humans destroy habitats and use plants and animals too quickly, those species will become extinct. We must preserve habitats and not use up plant and animal resources too quickly.

Over 2 000 plant species are used in the traditional medicine trade in South Africa. Most (97,4%) of medicinal plants are classified in the Red List as "Least Concern". They are being harvested sustainably. The remaining species are classified in the Red List as threatened, near extinction, or extinct.

Among the threatened species are the 24 species of cycads that occur in South Africa. These plants grow slowly, and have a very slow reproductive rate. Cycads are threatened by the trade in medicinal plants, but even more threatened by people who collect them to sell to the overseas market or to grow them in their own gardens. Because of their slow growth and reproductive rates, harvesting cycads is not sustainable.

Figure 3.1 Cycads are not being used sustainably in South Africa

https://www.sanbi.org/sites/default/files/images/encephfridguil2.jpg

Main idea: Sustainable use of plants means that we use the plants at a rate that allows the plants to recover, grow and reproduce. If we do not use plants sustainably, many species will become extinct.

Summary of key learning:

- The biosphere is all parts of the Earth where life can exist. The biosphere receives energy from the Sun, but all other requirements for life are recycled within the biosphere.
- A biome is a region that has a particular type of plant life, which is controlled by climatic conditions.
- Climate and soil control the type of vegetation that grows in a biome.
- South Africa has great diversity of climate and soil types across the country.
- South Africa has nine major biomes.
- Each biome has characteristic climate, soils and vegetation.
- Plants are adapted to the climatic conditions of each biome.
- The Red List is used to identify organisms that are threatened with extinction and therefore need special conservation measures.
- Sustainable use of plants means that we use the plants at a rate that allows the plants to recover, grow and reproduce. If we do not use plants sustainably, many species will become extinct.

Assessment: Subtopic 1

1. Give the correct scientific term for each description. Choose the term from the list below:
   Extinct; Biome; Threatened; Adaptation; Least Concern; Habitat; Sustainable; Biosphere
   1.1 All parts of the Earth where life can exist.
   1.2 An area that has a characteristic climate and type of vegetation.
   1.3 A special feature of an organism that allows it to survive in a particular climate.
   1.4 Species that face a high risk of extinction.
   1.5 Species that no longer exist in an area where they used to live.
   1.6 Species that maintain healthy populations.
   1.7 A way of using organisms so that they can recover, reproduce and continue to exist on Earth. (7)

2. Match the biome in Column A with the correct description in Column B.

Column A	Column B
2.1 Fynbos	A Characteristic vegetation is grassland with scattered trees.

2.2 Forest	B Winter rainfall area, with great diversity of plants.
2.3 Desert	C Area with summer rainfall; mostly at high altitude.
2.4 Albany Thicket	D Winter rainfall area along the west coast of South Africa.
2.5 Savanna	E Summer rainfall area along the east coast of South Africa.
2.6 Nama Karoo	F Area with rainfall all year round and thick bush.
2.7 Succulent Karoo	G Sandy area that receives very little rainfall.
2.8 Grassland	H Small patches of large trees in areas with fertile soils.
2.9 Indian Ocean Coastal Belt	I Semi-desert biome with small shrubs and grasses

(9)

3. Explain what each of the following statements means:
3.1 Pepperbark trees are extinct in the wild.
3.2 Fynbos plants are adapted to their climatic conditions.
3.3 The white rhinoceros is classified as Threatened. (6)

Subtopic 2: Principles of classification

[Note to editor: Unless otherwise indicated, Figures used in this Subtopic were taken from Platinum Life Sciences Grade 10, which was unpublished. It was commissioned by Pearson South Africa.]

Content:

Unit 1: Extent of biodiversity

Learning outcomes

At the end of this unit, learners should be able to:

1.1.1 demonstrate awareness of the extent of biodiversity in South Africa;
1.1.2 represent biodiversity of the most abundant groups of plants and animals in the form of graphs and charts;
1.1.3 define a species using the biological species concept;

Unit 1: The extent of biodiversity

1.1 The biological species concept

For thousands of years, people have divided living organisms into groups that make sense to them. Scientists recognised that certain groups of organisms look alike and are able to breed together. They cannot breed with other groups of organisms. If they did interbreed with another group of organisms, the offspring were weak and died early, or they were infertile. These observations led to the **biological species concept**:

A species is a group of individuals that can breed together and produce viable offspring.

The biological species concept applies to species that reproduce sexually. There are many species, such as bananas, that do not reproduce sexually. A different definition was needed for organisms that do not reproduce sexually. A species can also be defined as follows:

A species is a group of individuals that look alike and live in the same area.

[New word: viable: organisms that survive and are able to reproduce]

Species: A group of organisms that share many characteristics, and can breed successfully.]

Figure 3.2 Giraffe are a species because they look alike, and can breed together. http://thebiomes.yolasite.com/resources/subequatorial-climate-tanzania.jpg.opt993x595o0,0s993x595.jpg

Main idea: Species are groups of organisms that share many characteristics and can reproduce successfully

1.2 Biodiversity in South Africa

The biodiversity of an area is the number of different species in that area. South Africa has greater biodiversity than most countries. This is largely because of the fact that we have nine different biomes in South Africa. We have different climate across the country from west to east and from north to south. We have a variety of land forms, such as mountains, high altitude plains, low altitude plains, swamps, lagoons, and coastal areas.

South Africa covers about 1% of the total land surface of the world, but about 10% of the known bird, fish and plant species in the world.

Most reference books give data for southern Africa, which includes all countries south of the Zambezi and Cunene Rivers. Southern Africa includes South Africa, Namibia, Botswana, Zimbabwe and the southern part of Moçambique. This area has:

- 20 300 species of flowering plants. The fynbos biome is classified as a Floral Kingdom because of its high level of biodiversity of plants.
- 354 mammal species.
- 951 bird species.
- 517 reptile species.
- 115 amphibian species.
- Over 80 000 insect species.

Indigenous, endemic and exotic species

Indigenous species belong to a particular area. They have not been brought from anywhere else. Many animals and plants that ae indigenous to South Africa also occur in other parts of Africa. For example, elephants, lions and giraffe are indigenous to South Africa, but they also occur in other African countries. Bugweed is a plant that was introduced to South Africa from South America. It is **exotic** to South Africa.

Figure 3.3 Bugweed is an exotic species in South Africa.

http://www.weedbusters.org.nz/resizer/w=800&h=700&zc=3~/uploads/images/Gallery/_weeds/solanum-mauritianum/DSCF0801.JPG

Endemic species belong to a particular area, but they do not occur anywhere else on earth. Each biome that you studied in Subtopic 1 has a number of endemic plant species. For example, the halfmens plant is endemic to the desert biome. The fynbos biome has a large number of plant species that are endemic to that area.

[New words: biodiversity: the number of different species in an area.

Indigenous: Species that occur naturally in a particular area.

Endemic: Species that occur naturally in a particular area and nowhere else on earth.

Exotic: Species that have been introduced to an area from another part of the world.]

Main idea: Biodiversity is the number of different species in an area. Indigenous species belong to a particular area. Exotic species have been introduced from another area. Endemic species belong to a particular area and are not found anywhere else in the world.

1.3: Displaying biodiversity

Activity 1.2: Displaying biodiversity

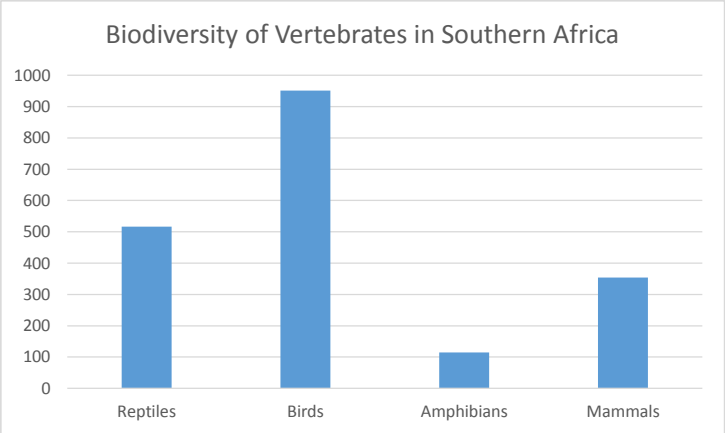
Expected outcome of activity: Learners will be able to interpret Tables and graphs showing biodiversity

Vertebrates are animals that have a backbone. There are four groups of vertebrates that live on land: Mammals, Birds, Reptiles and Amphibians. Southern Africa has a rich biodiversity of each group of Vertebrates.

Table: Biodiversity of each group of vertebrates in southern Africa

Reptiles	517
Birds	951
Amphibians	115
Mammals	354

We can show the same information in the form of a bar graph.



1. Answer the questions that follow:

1.1 Which group of vertebrates has the greatest biodiversity? (1)

1.2 Which group of vertebrates has the least biodiversity? (1)

1.3 One axis has numbers on it. It is called the y-axis. What do the numbers show? **(1)**

1.4 What is a vertebrate? (2)

2. The table below shows the diversity of four groups of plants that are common in South Africa.

Table showing the diversity of four plant groups in Southern Africa	
Aloe	150 species
Acacia	56 species
Protea	29 species
Fig	34 species

2.1 Draw a bar graph, similar to the bar graph for diversity of vertebrates, for the four plant groups. (10)

Unit 2: Taxonomic levels

Learning outcomes

At the end of this unit, learners should be able to:

- apply the nested hierarchical classification system to classify species according to genus, family, order, class, phylum (animals) or division (plants), kingdom;
- Correctly use the binomial system of naming species.

2.1 What is classification?

Classification is sorting objects into groups according to their similarities. When early scientists began to observe large numbers of organisms, they placed them into groups that shared key similarities. Classification allows us to create order out of the large number of living organisms on the Earth.

[New word: Classification: sorting objects into groups according to features they share.

Similarity: Aspects of two objects that are alike.]

Activity 2.1: Classifying everyday objects.

Expected outcome of activity: Learners will realise how they use classification in their everyday lives.

Figure 2.1: Sort Maite's clothes

1. Maite must pack her clothes into four drawers. Sort her clothes into four groups. Say what is **similar** in each group.
2. Sort the underwear into two groups. Say what is similar in each group.

Main idea: Classifying means grouping objects that share certain similarities. Classification allows us to create order out of large numbers of objects.

2.2 Classifying living organisms.

Scientists use a classification scheme called a nested hierarchy. Think of a nested hierarchy as being like a box within a bigger box, within an even bigger box up to the largest box of all. Each box contains more and more organisms up to the biggest box of all, which is all living things on earth.

- The smallest unit of a nested hierarchy is a **species**. All members of a species share many characteristics. They can breed together.
- Two or more species share a number of characteristics. They are placed in the same **Genus**. Species of the same genus cannot breed together.
- Two or more Genera (plural of genus) share some characteristics. They are placed in the same **Family**.
- Two or more Families share some characteristics. They are placed in the same **Order**.
- Two or more Orders share a few characteristics. They are placed in the same **Class**.
- Two or more Classes share a few key characteristics. They are placed in the same **Phylum**. Plants have **Divisions** instead of **Phyla** (plural of Phylum).
- Two or more phyla share some key characteristics. They are placed in the same **Kingdom**.

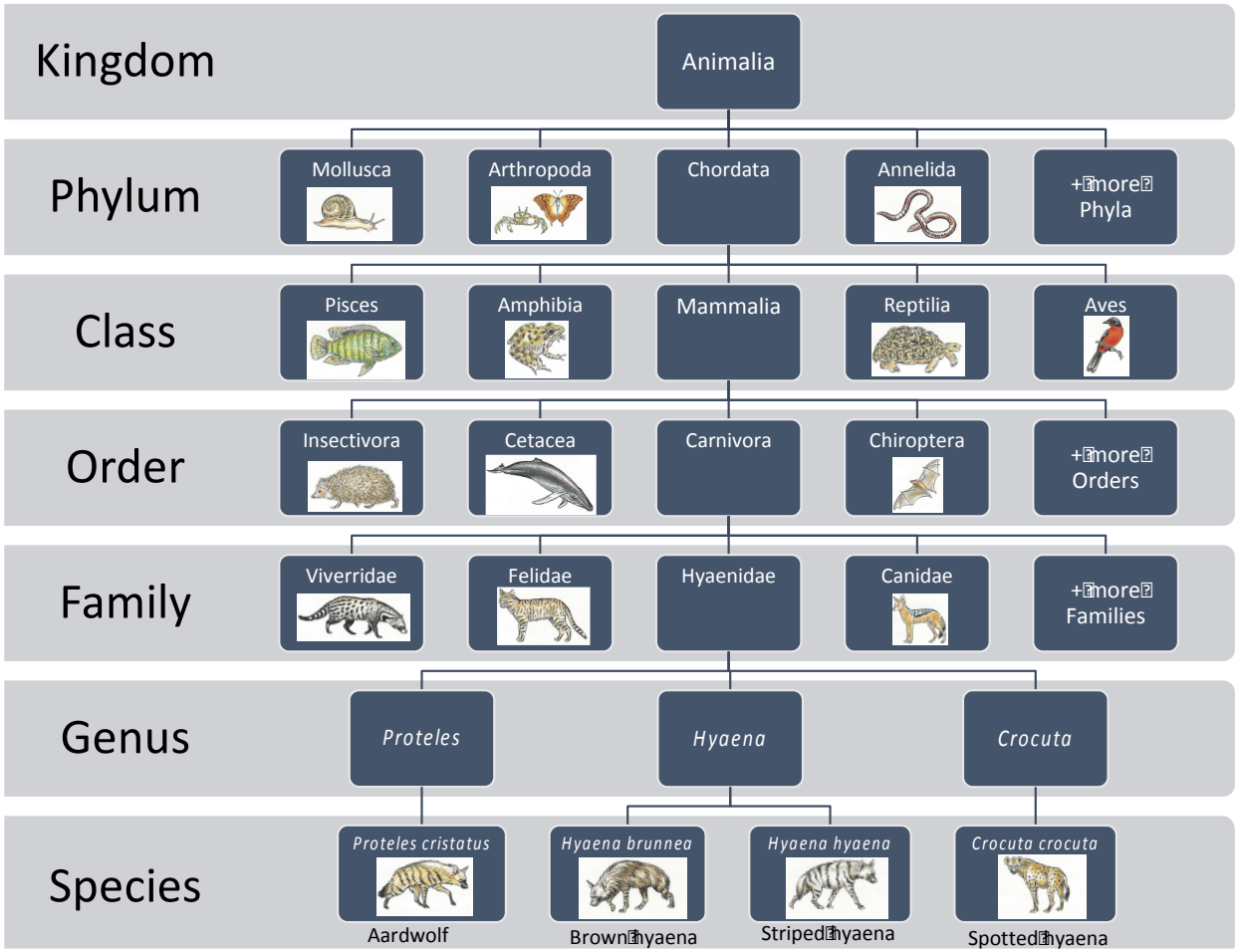


Figure 2.2: Classification of four species of hyaena using the main classification groups

We can illustrate the nested hierarchy as a tree diagram. Figure 2.2 shows a classification tree for animals. We can use the classification tree to give the full classification for the Spotted hyaena. Follow the steps on Figure 2.2. Start at the bottom of the tree to get the correct idea.

- The spotted hyaena, *Crocuta crocuta,* is a species that belongs to the genus *Crocuta.*
- The genera *Crocuta, Proteles* and *Hyaena* belong to the Family Hyaenidae.
- The families Hyaenidae, Viverridae, Felidae, Canidae and other families belong to the Order Carnivora.
- The orders Carnivora, Insectivora, Cetacea, Chiroptera and other orders belong to the Class Mammalia.
- Classes Mammalia, Pisces, Amphibia, Reptilia and Aves belong to the Phylum Chordata.
- Phylum Chordata, Arthropoda, Mollusca, Annelida and other phyla belong to the Kingdom Animalia.

The names of the levels of classification are written in Latin. This is done so that everyone in the world will use the same names. The scientific way of writing the full classification of a species is from the largest category to the smallest. The scientific classification of a spotted hyaena is therefore:

Kingdom: Animalia

Phylum: Chordata

Class: Mammalia

Order: Carnivora

Family: Hyaenidae

Genus: *Crocuta*

Species: *Crocuta crocuta*

Main idea: The classification scheme for living organisms is a nested hierarchy. It has seven main levels: Kingdom, Phylum, Class, Order, Family, Genus and Species.

Activity 2.2: Interpret the classification of hyaenas.

Expected outcome of activity: Learners will be able to interpret a classification tree.

1. Use Figure 2.2 to fill in the missing words in these sentences. The first one has been done for you.
   1.1 The brown hyaena and the striped hyaena belong to the same Genus *Hyaena.*
   1.2 The Genus *Hyaena*, Genus *Crocuta* and Genus *Proteles* belong to the Family …….. (1)

1.3 The Family Hyaenidae belongs to the Order Carnivora. Three other Families that belong to the Order Carnivora are ……., ……. and ……. (3)
1.4 The Order Carnivora belongs to the Class ……. (1)
1.5 Figure 2.2 shows five classes of the Phylum Chordata. They are: ……., ……., ……., ……., ……. (5)
1.6 The phylum Chordata belongs to the Kingdom ……. (1)
1.7 Complete the classification of the Aardwolf:
Kingdom: Animalia
Phylum: …….
Class: …….
Order: …….
Family: ……..
Genus: ……..
Species: ……. (6)

2.3 The binomial naming system

Did you notice that each of the hyaena species has two names? The first name is the name of the Genus, and the second name is the name of the species. The full scientific name of each hyaena is:

- Aardwolf: *Proteles cristatus*
- Brown hyaena: *Hyaena brunnea*
- Striped hyaena: *Hyaena hyaena*
- Spotted hyaena*: Crocuta crocuta*

Did you notice that the Genus name and the species name are both written in italics? If you write the names by hand, you MUST underline the names.

There are two rules for writing the scientific name of a species:

1. The genus name must begin with a capital letter. The species name must begin with a lower case letter.
2. The name must be written in italics or it must be underlined.

Main idea: Each species has two names: first the name of the genus, and second, the name of the species. This is called the binomial naming system.

Activity 2.3: Have you understood your reading?

Expected outcome: Learners will be able to apply their knowledge.

Correct the scientific names of each species that are written incorrectly.

Common name	Scientific name
Giraffe	*Giraffa Camelopardis*

African elephant	Loxodonta africana
Southern African Python	*Python* natalensis
Natal cycad	*encephalartos Natalensis*
Ostrich	*Struthio camelus*

(4)

Unit 3: Characteristics of the five kingdoms.

[Note to editor: Illustrations for this Unit are taken from an unpublished book: Platinum Series Life Sciences Grade 10. The book was developed by Pearson Publishing, but never published]

Learning outcomes:

At the end of this unit, learners should be able to:

- distinguish among the five kingdoms according to shared characteristics of organisms within each kingdom:
    - Monera: prokaryotic, unicellular, autotrophic, heterotrophic or saprotrophic;
    - Protista: eukaryotic, unicellular or simple multicellular, autotrophic or heterotrophic;
    - Fungi: eukaryotic, having chitin in the cell walls, unicellular or simple multicellular, saprotrophic;
    - Plantae: eukaryotic, having cellulose in the cell walls, multicellular, most having differentiated tissues, autotrophic;
    - Animalia: eukaryotic, with no cell walls, multicellular, most having differentiated tissues, heterotrophic.

3.1 Classification systems

The earliest classification system separated all living organisms into two Kingdoms: Plantae and Animalia. As more information was discovered, scientists realised that many organisms did not fit neatly into either the Plant Kingdom or the Animal Kingdom.

In the early 1970s, Robert Whitaker proposed that there are actually five Kingdoms. The five-kingdom system is based on

- the structure of the cells,
- the way of feeding,
- whether the organisms consist of one cell or many cells, and
- where they live (in water or on land).

Other characteristics are also useful in placing organisms into kingdoms. New techniques such as DNA analysis make classification clearer.

Whitaker identified five kingdoms:

- Monera (bacteria)
- Protista
- Fungi
- Plantae
- Animalia

[Note: The most recent classification system divides all species into three Domains. The Kingdom Monera is divided into two Domains, and all other species belong to the third Domain]

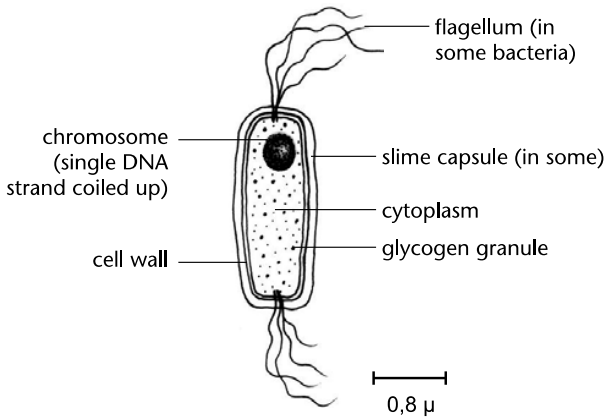
Monera Protista Fungi Plantae Animalia

[Caption: Figure 3.1 Examples of Whitaker's five kingdoms.]

3.2 Distinguishing characteristics of the five kingdoms.

Kingdom Monera

The kingdom Monera consists of single-celled microscopic organisms. They can only be seen with a microscope. We call these organisms **bacteria**. They have simple cells, with no organelles. They have one chromosome that is a ring of DNA. There is no membrane around the chromosome. The cells are called **prokaryotic**.



[Caption: Figure 3.2 Structure of a Monera]

Sometimes, bacterial cells form long chains, but each cell can survive on its own. They feed in many different ways.

- Some Monera contain membranes that carry out photosynthesis. They are **autotrophic**.
- Some Monera feed by secreting enzymes into the food and absorbing the digested material. They are **saprotrophic**.
- Some Monera are **parasites** living on or in other organisms. They are **heterotrophic**.

[New words: Monera: The kingdom to which bacteria belong.

Organelles: Structures in a cell that perform a particular function. Examples are the nucleus, chloroplasts and mitochondria.

Prokaryotic: cells that have no membrane surrounding the chromosome.

Autotrophic: An organism that is able to manufacture its own food.

Saprotrophic: An organism that feeds on living or dead organic matter.

Heterotrophic: An organism which consumes food for nutrition.

Parasite: An organism that lives in or on another organism and feeds on another it.]

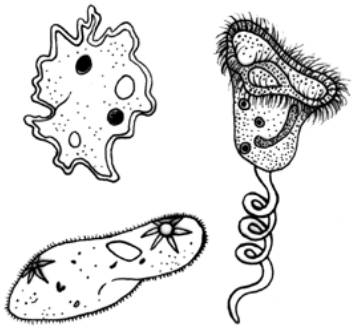
Kingdom Protista

The kingdom Protista consists of single-celled or simple **multicellular** organisms. The Protist cell has a **nuclear membrane** around its chromosomes, and it has organelles such as mitochondria. A cell that has a nuclear membrane and organelles is called a **eukaryotic** cell.

Protists range from single-celled organisms to large multicellular algae (seaweeds). They vary in size, shape and functioning, but all have a simple structure with no specialised **tissues**. Some scientists say a protist is any eukaryotic organism that is *not* a fungus, plant or animal!

Most protists live in water or damp environments. They have a variety of ways of obtaining food.

- Some species are autotrophs, e.g. algae (seaweed).
- Some species are heterotrophs, e.g. Protozoa such as *Amoeba*.
- Some species are saprotrophs (e.g. slime moulds).
- Some species are parasites that can cause serious diseases in animals including humans (e.g. malaria, sleeping sickness).



[Caption: Figure 3.3: Three different types of single-celled Protista]

[New words: Eukaryotic: Cells that have a nuclear membrane around the chromosomes, membranes and organelles.

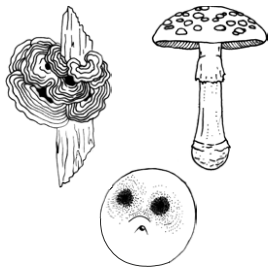
Multicellular: an organisms that consists of many cells.

Tissue: a group of cells that perform a particular function, e.g. muscle tissue]

Kingdom Fungi

Fungi are multicellular organisms that have **chitin** in their cell walls. Their cells are eukaryotic. Some fungi are single-celled organisms (e.g. yeast), while others are multicellular (e.g. mushrooms). The body of a fungus is made of microscopic threads called **hyphae**.

Fungi live on land or in water. Most species are saprotrophs, which play an important role in decomposing dead organisms. Some species are parasites that feed on living organisms. Athlete's foot and ringworm are examples of parasitic fungi that affect humans.



[Caption: Figure 3.4: Bracket fungus growing on a dead log, a mushroom, and mould growing on an orange]

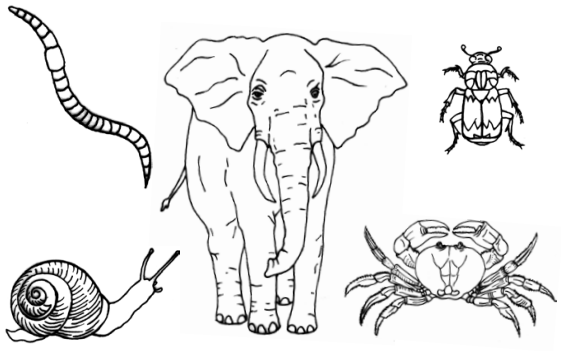
[New word: Hyphae: the threads that make up the body of a fungus.

Chitin: a substance that strengthens the cell walls]

Kingdom Animalia

Animals are multicellular organisms. They have eukaryotic cells with no cell wall. The cells are organized into different tissues, such as muscles, skin, and nerves.

Some animal species live on land, while others live in water. All species of the Kingdom Animalia are heterotrophic. Most animals can move from one place to another.

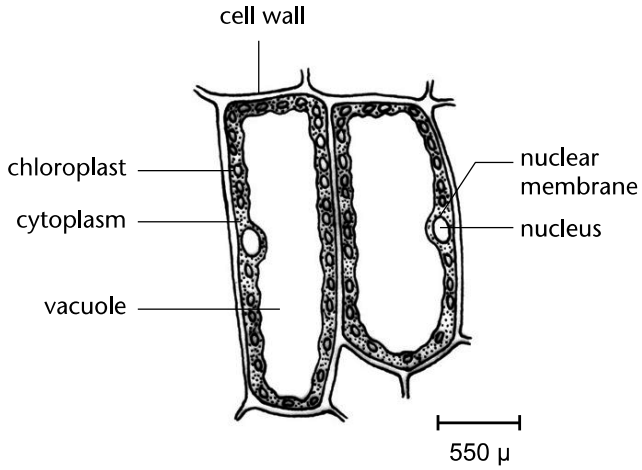


[Caption: Figure 3.5: Worms, snails, elephants, beetles and crabs belong to the Kingdom Animalia]

Kingdom Plantae

Plants are multicellular organisms. The cells are organized into tissues such as skin, conducting tissue and storage tissue. The cells are eukaryotic and have a cell wall composed of cellulose.

Most plants live on land. All species of the Kingdom **Plantae** are autotrophic and make their food by photosynthesis. Plants cannot move from one place to another.



[Caption: Figure 3.6: Plant cells are eukaryotic]

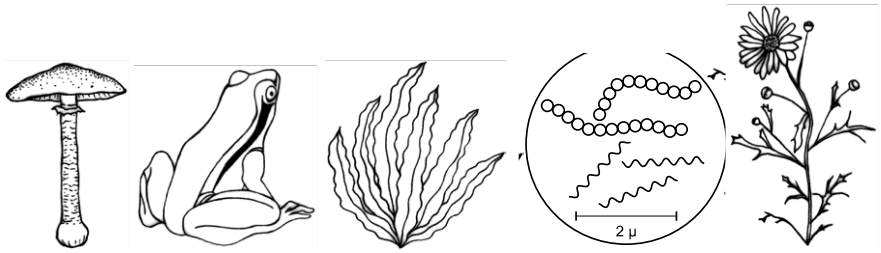
[Caption: Figure 3.7: A variety of plants growing on the banks of a stream]

Main idea: All living organisms can be classified into one of five Kingdoms: Monera, Protista, Fungi, Animalia or Plantae.

Activity 3.1: Have you understood your reading?

Expected outcome of activity: Learners will be able to classify organisms to their correct kingdoms.

1. Place each organism shown below in its correct Kingdom.



Mushroom Frog Seaweed Bacteria Daisy

(5)

2. Each description in Column B fits one or more of the Kingdoms. Choose the Kingdoms that match each description. The first answer has been done for you.

Kingdoms: Plantae, Monera, Protista, Animalia, Fungi

Descriptions
2.1 Includes autotrophic organisms. (3)
2.2 Organisms that have eukaryotic cells. (4)
2.3 Photosynthetic organisms that live on land. (1)
2.4 Unicellular organisms that have no nuclear membrane. (1)
2.5 Eukaryotic organisms that have no tissues. (1)
2.6 Prokaryotic one-celled organisms. (1)
2.7 Bodies are made up of hyphae. (1)
2.8. Multicellular organisms that can move around. (1)
2.9. Includes some saprotrophic organisms. (2)

(12)

Summary of key learning:

- Species are groups of organisms that share many characteristics and can reproduce successfully
- Biodiversity is the number of different species in an area.
- Indigenous species belong to a particular area.
- Exotic species have been introduced from another area.
- Endemic species belong to a particular area and are not found anywhere else in the world.
- Classifying means grouping objects that share certain similarities.
- Classification allows us to create order out of large numbers of objects.
- The classification scheme for living organisms is a nested hierarchy. It has seven main levels: Kingdom, Phylum, Class, Order, Family, Genus and Species.
- Each species has two names: first the name of the genus, and second, the name of the species. This is called the binomial naming system.
- Monera are prokaryotic, unicellular organisms that are autotrophic, heterotrophic or saprotrophic organisms.
- Protista are eukaryotic, unicellular or simple multicellular organisms that are autotrophic or heterotrophic.
- Fungi are eukaryotic organisms that have chitin in their cell walls. They are unicellular or simple multicellular, saprotrophic organisms.
- Plantae are eukaryotic organisms that have cellulose in their cell walls. They are multicellular, and most plants have tissues. They are autotrophic.
- Animalia are eukaryotic organisms with no cell walls. They are multicellular, and most animals have tissues. They are

Assessment Subtopic 2

1. Refer to Figure 2.2 when you answer this question. The first one has been done for you.
   1.1 The striped hyaena, the hedgehog and the tortoise belong to the same ……..

   Answer: Phylum

   1.2 The brown hyaena and the striped hyaena belong to the same ……..
   1.3 The aardwolf, the cat and the whale belong to the same …….
   1.4 The spotted hyaena and the aardwolf belong to the same ……..
   1.5 The frog, the aardwolf, the bat and the butterfly belong to the same …….
   1.6 The brown hyaena and the jackal belong to the same …….. (5)
2. Choose the correct answer for each of the following questions.

2.1 What does “classification” mean to biologists?

A Naming organisms.
B Sorting organisms into groups that share certain similarities.
C Identifying organisms.
D Describing organisms.

2.2 The scientist who introduced the five-kingdom classification system was ..

A Charles Darwin
B Carolus Linnaeus
C Carl Woese
D Robert Whitaker

2.3 The correct order of taxonomic categories from largest to smallest is .....

A Species, genus, family, order, class, phylum, kingdom

B Genus, species, kingdom, class, order, family, phylum

C Phylum, order, class, kingdom, genus, family, species

D Kingdom, phylum, class, order, family, genus, species

2.4 The correct way of writing the scientific name for a spotted hyaena is …

A *Crocuta crocuta*
B *Crocuta Crocuta*
C Crocuta crocuta
D *Crocuta* crocuta

2.5 *Encephalartos natalensis* and *Encephalartos princeps* are two types of cycads. The two cycads belong to the same:

A Species

B Ecosystem

C Genus

D Biome (10)

3.Explain the difference between each pair of terms.

3.1 Indigenous and endemic

3.2 Prokaryote and eukaryote

3.3 Extinct and Threatened

3.4 Monera and Protista (8)

Subtopic 3: The History of Life

[Note to editor: The photographs are taken with permission from Life Etched in Stone, by Colin Macrae. They were used in the unpublished book Platinum Life Sciences Grade 10, commissioned by Pearson South Africa]

Content:

Unit 1: Life has an extremely long history.

Learning outcomes

At the end of this unit, learners should be able to:

- Construct a timeline showing key events in the history of life on earth.

Unit 1: Life has an extremely long history

So far in this Topic, we have focussed on biodiversity at the level of the diversity of biomes in South Africa, and the diversity of species living on Earth at present. Diversity has another dimension: time.

The diversity of living organisms we see around us at present is about 10% of the biodiversity that has existed in the past. We know that different species existed in the past, because their remains are preserved as fossils.

Fossils are the preserved remains of once-living organisms, or preserved traces left behind by living organisms. Examples of fossils are fossilized bones, wood, footprints, and even faeces. Fossils tell us about the kinds of life that existed in the past.

A B

[Caption: Figure 1.1: A Fossilized leaves; B fossilized dinosaur skull. Both fossils were found in South Africa]

How old is life on Earth?

Scientists have found ways of measuring the age of fossils. We know that the Earth formed about 4,6 billion years ago. The oldest fossils of living organisms are between 3,3 and 3,5 billion years ago. They are bacterial cells.

For the next 2 billion years, bacteria were the only life forms on Earth. Eukaryotic cells evolved about 1,4 billion years ago. At first, life existed only in the oceans. From about 540 million years ago, diversity expanded. The first fish evolved about 460 million years ago. The first land plants evolved about 420 million years ago. We know this, because there are no fossils of fish that are older than 420 million years ago.

Table 3.1 shows some significant events in the history of life on Earth. It shows the approximate dates that various groups of organisms evolved.

[New word: Fossil: the preserved remains of an organism, or preserved traces of organisms that lived a long time ago.]

Assignment 3.1: Make a timeline

Expected outcome: Students will construct a timeline showing some major events in the history of life.

Table 3.1 shows the timing of some important events in the history of life.

Table 3.1: Some important events and when they occurred in the history of life	
Event	**Time in millions of years ago (mya)**
First bacteria	3 500 mya
First eukaryotes	2 100 mya
First fish	460 mya
First land plants	420 mya
First amphibians	370 mya
First reptiles	340 mya
First mammals	230 mya
First birds	195 mya
First flowering plants	141 mya
First pre-humans	5 mya

1. Make a timeline to show the history of life on Earth. Your timeline must be drawn to scale.

Hint: Single ply toilet paper comes in rolls that are divided into sections called sheets. Each roll has 500 sheets of toilet paper. If you make one sheet = 5 million years, one toilet roll will give you 2 500 million years of history. Since most of the history of life took place in the last 500 million years, you can unroll 100 sheets, and leave the rest of the paper rolled up. You can attach the toilet paper to a long wall with sticky tape or Prestik. You will need some large sticky labels as well.

1. The first sheet is the last 5 million years of the history of life. Attach a label to the sheet: "5mya: first pre-humans".
2. Count in 5's from the first sheet until you reach 140-145 mya. This sheet is the time at which the first flowering plants evolved. Label the sheet: "141 mya: first flowering plants".
3. Count in 5's from the 140 mya to the 195 mya mark. The first birds evolved about 195 mya. Label that sheet: "195 mya: first birds".

4. Keep working in this way until you have labelled all the events shown in Table 3.1, except the first eukaryotes and the first prokaryotes. Stick a label on a toothpick near the beginning of the toilet paper to mark the first eukaryotes. The first prokaryotes would be a long distance before this mark.
5. Submit a photograph of your completed timeline, together with the names of your team members. If you are studying at a community college, ask your tutor to evaluate your timeline. (20)

Main idea: Living organisms have existed on earth for 3 500 million years.

Summary of key learning:

- Living organisms have existed on earth for 3 500 million years.

Suggested sources of additional information

https://www.youtube.com/watch?v=2es4Xdg7zHw is a good Youtube video on the savanna biome of South Africa.

https://www.youtube.com/watch?v=H0rYdoD3aV8 is a good review of the five-kingdom classification system.
https://www.youtube.com/watch?v=NRVJyUZoQow shows the levels of classification in a bit more detail that you need for this course.
https://www.youtube.com/watch?v=H2_6cqa2cP4 is a very short video showing the history of life on earth.
https://www.youtube.com/watch?v=57merteLsBc is a long video (1 hour 30 min) but it is well worth watching for an explanation of the history of life on the Earth.

My Notes

Use this space to write your own questions, comments or key points.

Topic 2 Evolution

Introduction

In Topic 1, you made a timeline showing the history of life. Topic 2 studies how life changes over time. Life evolves from previously-existing life-forms by a process of natural selection. Evolution by natural selection is supported by evidence from the fossil record, comparative anatomy and biogeography. Artificial selection illustrates natural selection.

Sub-topic 1. The Theory of Evolution by Natural Selection

Content:

Unit 1: Development of the theory of evolution by natural selection.

Unit 2: The theory of evolution by natural selection.

Unit 3: Natural selection in action, e.g. antibiotic resistance.

Unit 4: Mechanisms of speciation and reproductive isolation

Activity 1.1: What do you already know about evolution?

1. Write down at least THREE things you associate with evolution.
2. Discuss your list with other students.

Unit 1. Development of the theory of evolution by natural selection.

Learning outcomes:

When you have completed this unit, you should be able to:

- Describe the contributions of Charles Darwin and Alfred Wallace to the development of the theory of evolution.

The theory of evolution by natural selection was presented to the scientific world by Charles Darwin and Alfred Wallace. This unit describes the history of how they jointly arrived at the same theory completely independently.

1.1 Charles Darwin's early life

Charles Darwin (1809-1882) was the son of a doctor. As a young boy, he loved spending time in nature, collecting bird's eggs and beetles. He studied Theology at University, but spent a great deal of time collecting, plants and animals and studying rock formations in Britain.

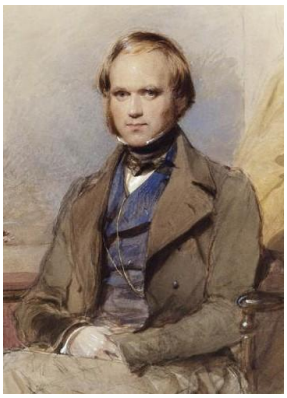
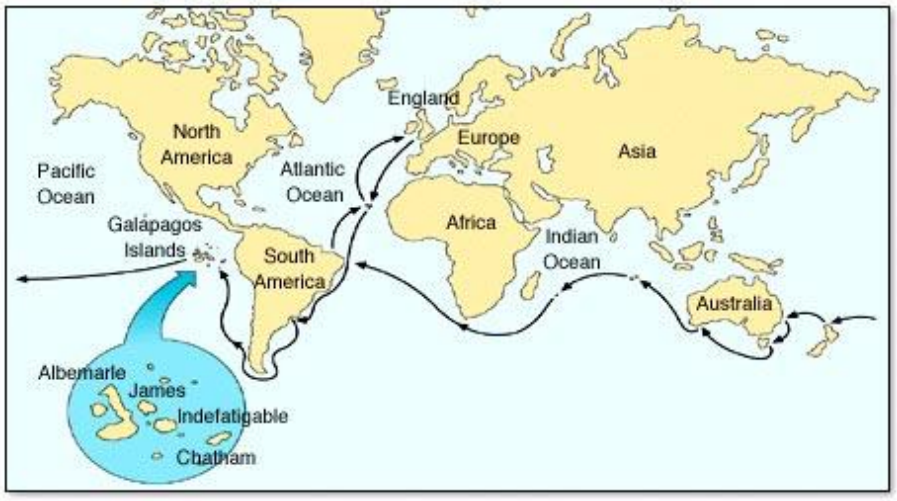


Figure 1.1 Charles Darwin as a young man [This image is from Getty images, but it is widely available]

1.2 The Voyage of the Beagle

After completing his studies, Darwin joined an expedition to map the coastline of South America. The ship on which he travelled was the HMS Beagle. The voyage took 5 years, and had a deep effect on Darwin's later ideas. The ship travelled around the southern hemisphere, visiting South America, New Zealand, Australia and South Africa. The ship also stopped at various islands along the way.

While he was travelling, Darwin collected many plant animal specimens, including fossils. These were carefully labelled, preserved and sent back to various naturalists for identification. During the voyage, Darwin read a book called "Principles of Geology", which suggested that the Earth changed slowly over long periods of time. The same geological processes that are happening today could explain the past.

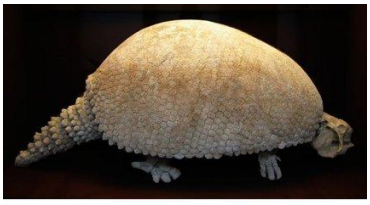


[Caption: Figure 1.2: The voyage of HMS Beagle]

http://www.mhhe.com/biosci/esp/2001_gbio/folder_structure/ev/m1/s3/assets/images/evm1s3_1.jpg

1.3 Darwin's observations on the journey

- In South America, Darwin found fossils of giant animals that were named "glyptodonts". They resembled the smaller armadillos that were found in the same area. Darwin wondered if the small armadillos had evolved from the glyptodonts.



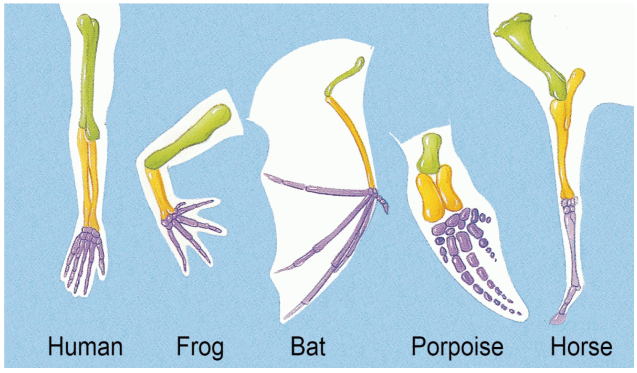
Glyptodon - lived 2,500,000 to 10,000 years ago

Armadillo - lives presently in the Americas

[Caption: Figure 1.3: Extinct Glyptodont and living armadillo.]

https://upload.wikimedia.org/wikipedia/en/b/bc/Glyptodon-Armadillo.jpg

- He discovered layers of fossilised seashells high up on a cliff face. He interpreted this as evidence that sea levels have changed over long periods of time.
- He noticed that every continent had its own types of plants and animals, most quite different from other continents. He wondered why, if the earth had been created at one time, there was so much diversity.
- The HMS Beagle stopped at the Galapagos Islands. These are volcanic islands about 1 000 km off the west coast of South America. He discovered that the islands were inhabited by small birds such as finches and mocking birds that were different from those on the mainland. Different species occurred on different islands. He also found tortoises on these volcanic islands. He wondered if the birds and tortoises of the Galapagos had evolved from those on the mainland.
- Darwin noticed that the same set of bones could be found in all vertebrate forelimbs. He wondered if all vertebrates had descended from one ancestor.



[Caption: Figure 1.4: Vertebrate forelimbs are made up of the same set of bones.
https://online.science.psu.edu/sites/default/files/biol011/Fig-8-5-Vertebrate-Limbs.gif]

- Darwin's observations of rock formations that he saw on the journey convinced him that Lyell was correct: the Earth has changed and is still changing over long periods of time. The Earth is in fact very old.

1.4 Back home again

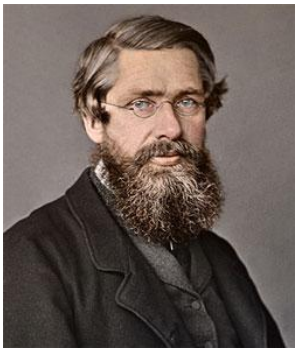
After the five-year journey, Darwin set about organising his specimens and revising his thinking. He was convinced that the life presently on Earth had evolved from previous life forms, but he did not know how the process of evolution takes place.

Darwin was strongly influenced by an essay written by Thomas Malthus. Malthus argued that humans were increasing in number. As human populations increased, they were competing with each other to survive. The

competition resulted in famine, disease or war. The winners were healthier and wealthier than the losers.

Darwin began to think that the same principle could apply to all species. He called his idea "natural selection". He was convinced that evolution occurred by natural selection. He began writing a book about his ideas, but never completed the book.

1.5 Alfred Wallace



[Caption: Figure 1.5: Alfred Wallace (1823-1913)
http://dl0.creation.com/articles/p046/c04670/Alfred-Wallace.jpg]

Alfred Wallace was a naturalist who had been studying plants and animals in the Amazon basin and the Malay islands. He also read Thomas Malthus' essay. He wrote a paper in which he explained the diversity of life in terms of evolution by natural selection. His essay presented exactly the same theory as Charles Darwin!

In 1858, the theory of evolution by natural selection was presented at a scientific meeting. Charles Darwin and Alfred Wallace were co-authors of the paper, but neither was present at the meeting.

Darwin published his book "On the Origin of Species by Natural Selection" in 1859, 25 years after he started writing the book. It is an argument that draws on evidence from a variety of sources. Evolution was soon accepted by the scientific community, but they were not so sure about natural selection. The theory of natural selection was only fully accepted after genetics had been discovered.

Main idea: Charles Darwin and Alfred Wallace developed the theory of evolution by natural selection independently.

Activity 1.2: Have you understood your reading?

Expected outcome of activity: Learners will be able to sequence events described in the lives of Charles Darwin and Alfred Wallace.

1. Put these sentences in the correct order to represent the development of the theory of evolution by natural selection.

1.1 In 1831, Darwin set out on a five-year journey around the world in the HMS Beagle.
1.2 The theory of evolution by natural selection was immediately accepted by most scientists.
1.3 The Beagle visited South Africa.
1.4 Darwin noticed fossils of giant extinct animals in the area where similar species now exist in South America.
1.5 Darwin and Alfred Wallace were influenced by an essay written by Thomas Malthus.
1.6 Darwin published a book called "On the Origin of Species by Natural Selection".
1.7 Darwin observed strange animals in Australia, that occurred nowhere else in the world.
1.8 Darwin and Wallace jointly presented the theory of evolution by natural selection to a science society.
1.9 Darwin visited the Galapagos Islands.
1.10 Alfred Wallace sent a paper he had written outlining a theory of evolution by natural selection to Charles Darwin. (10)

Unit 2 The theory of evolution by natural selection

Learning outcomes

By the end of this unit, you will be able to:

- Describe the theory of evolution by natural selection.

The theory of evolution by natural selection is actually two theories. **Evolution** is a change in a line of descent. It means that all present organisms are descended from now-extinct species, which themselves evolved from even older extinct species. It means that all species that have ever lived were not created at the same time. There have been long chains of species, extending back 3,5 billion years to the first life on Earth. Remember the timeline you created in Topic 1. It shows the evolution of life since the very first cells.

Natural selection is the mechanism by which evolution occurs. Darwin and Wallace based the theory of evolution by natural selection on five propositions:

1. Organisms tend to produce more offspring than are needed to replace themselves when they die.
   For example, a single maize plant can produce hundreds of seeds in one season. A female leopard can produce 15 cubs in her lifetime.
2. Individuals belonging to a species vary in characteristics such as their appearance, resistance to disease or their ability to survive drought. The variation is inherited, that is, they pass it on to their offspring.
3. The individuals in an overcrowded environment compete to survive.
   Maize seedlings compete with each other for light and water, and leopard cubs compete for food and shelter.

4. Only the best-adapted individuals survive and reproduce. Individuals that are less well-adapted die before they reach reproductive age.
5. Over time, more and more individuals in the population have the most favourable adaptations. The population has evolved from its original form.

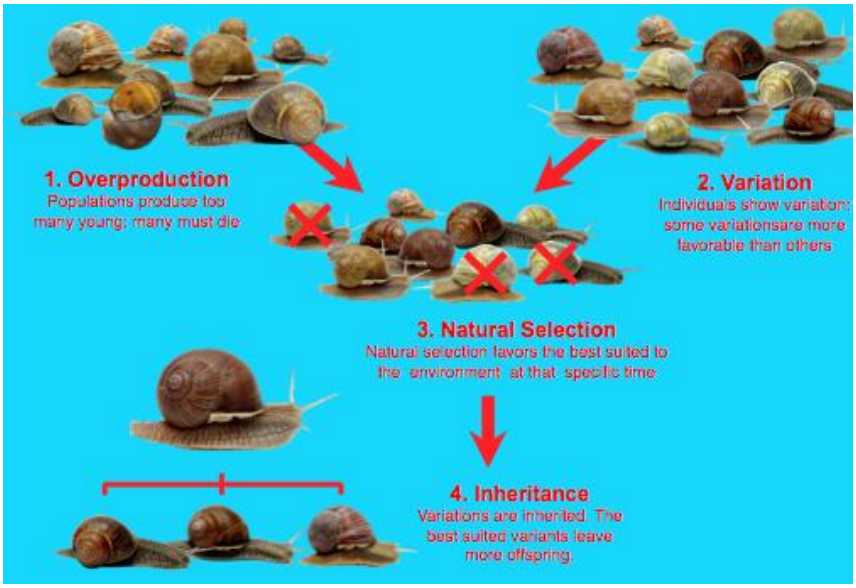


Figure 2.1: A summary of natural selection
https://classconnection.s3.amazonaws.com/878/flashcards/663878/png/screen_shot_2011-09-06_at_5.26.59_pm1315301241192.png
[New words: Evolution: A change in the line of descent.

Natural selection: The differential survival and reproduction of individuals of a population based on differences in heritable characteristics.]

Main idea: Natural selection is the process by which evolution takes place. Individuals with the best adaptations leave more offspring than other individuals. The number of individuals with the best adaptations increase in the population.

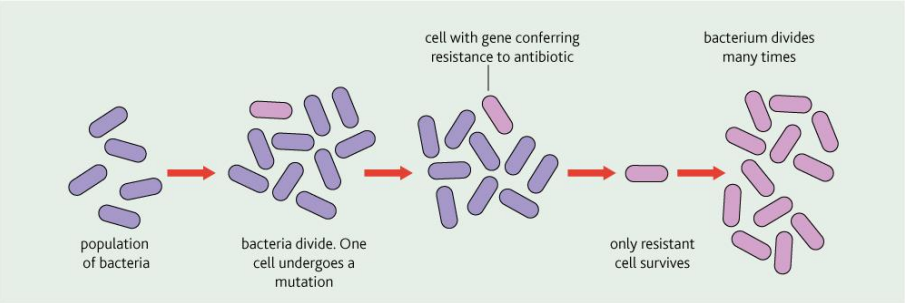
Unit 3: Natural selection in action: antibiotic resistance.

Learning outcomes:

By the end of this unit, you will be able to:

- Exemplify natural selection using the example of antibiotic resistance.

Antibiotic resistance is an example of natural selection in action. Antibiotics treat bacterial infections such as pneumonia and tuberculosis (TB) very effectively. However, if they are not used correctly, some bacteria may develop a mutation that makes them resistant to antibiotics. Using antibiotics correctly means taking the medicine regularly, and completing the course.



[Caption: Figure 3.1: Development of antibiotic resistance in a population of bacteria]

https://y12hb.files.wordpress.com/2013/03/antibiotic-resistance.png

Suppose a TB patient starts a **first-line** course of antibiotics. He has to take the antibiotics for six months. After two weeks, he is feeling better, so he stops taking his antibiotics. Two months later, he is feeling ill, so he starts taking his antibiotics again. This time the antibiotics don't make him feel better. He might have multi-drug resistant TB.

Antibiotics help the body to kill all the bacteria that cause TB. If the patient takes the antibiotics correctly, most of the bacteria will be killed within the 2-3 weeks. Treatment continues for six months to make sure that all the bacteria have been killed.

If a patient forgets to take his medication regularly, the few bacteria left in his body have time to develop a mutation that makes them resistant to the antibiotic. The resistant bacteria survive and multiply. They have a **selective advantage** over normal bacteria, because they are resistant to antibiotics. Figure 3.1 illustrates how antibiotic resistance develops by natural selection.

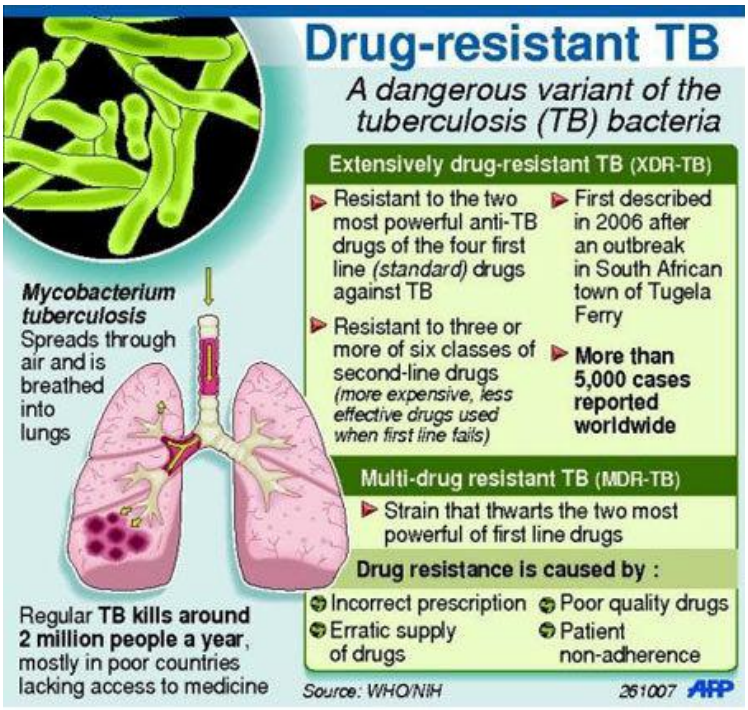
Eventually, the whole population of bacteria causing TB in the patient are resistant to the first-line antibiotics. The patient is very ill again. The patient has to change to different antibiotics and take them strictly for the full six months.

[New words: Antibiotic: a drug that treats bacterial infections.

First-line antibiotics: Antibiotics that are prescribed when a person is first diagnosed with TB.

Selective advantage: characteristic of an organism that enables it to survive and reproduce better than other organisms in the population]

Main idea: Antibiotic resistance in bacteria arises due to natural selection.



[Caption: Figure 3.2: TB poster]

https://www.sott.net/image/s4/91554/full/Drug_resistant_TB.jpg

Activity 3.1: Interpret the poster about drug-resistant TB

Expected outcomes of the activity: Learners will demonstrate that they understand the different types of drug resistance.

1. Study the poster about drug-resistant TB, and answer the questions that follow.
   1.1 What is the scientific name of the bacteria that causes TB? (1)
   1.2 How does TB normally spread from one person to another? (2)
   1.3 How many people die from TB each year? (1)
   1.4 Explain what is meant by "first-line" drugs against TB. (2)
   1.5 The word "thwart" means to "reduce the effectiveness of" something. What is the effect of the multi-drug resistant strain of TB? (2)
   1.6 Where was Extremely drug-resistant TB first discovered? (1)
   1.7 List four causes of drug resistance. (4)
   1.8 Explain how a mutation can cause antibiotic resistance. (2)

Unit 4: Mechanisms of speciation and reproductive isolation

Learning outcomes:

When you have finished this unit, you should be able to:

- illustrate how geographical isolation gives rise to speciation, with specific reference to Galapagos finches;
- explain mechanisms of reproductive isolation including temporal, ecological, and behavioural isolation, gamete incompatibility and hybrid sterility.

1.1. Speciation

Natural selection explains how a population can adapt to its environment. Now we turn our attention to how natural selection can give rise to new species. **Speciation** is the process whereby one species gives rise to two or more new species.

Remember from Topic 1 that a species is defined as a group of organisms that look alike and can breed successfully together. We have studied natural selection and how the proportion of well-adapted individuals in a population increases until the whole population is well-adapted. Speciation requires that natural selection goes further: the well-adapted population must eventually stop breeding with its parent and sister populations. It has become a new species.

Allopatric speciation

Allopatric speciation occurs after two populations have been separated by a physical barrier. It is the most common method of speciation.

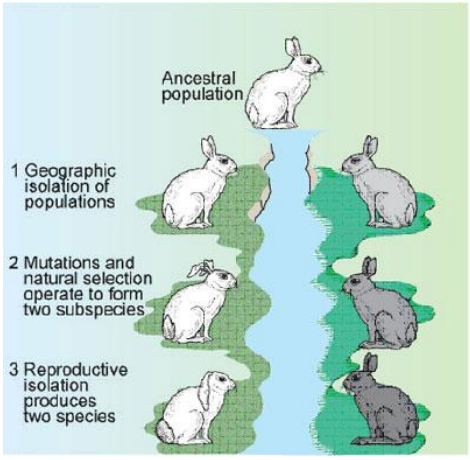


Figure 4.1 Allopatric speciation

http://larryfrolich.com/Evolution/ch5c.jpg

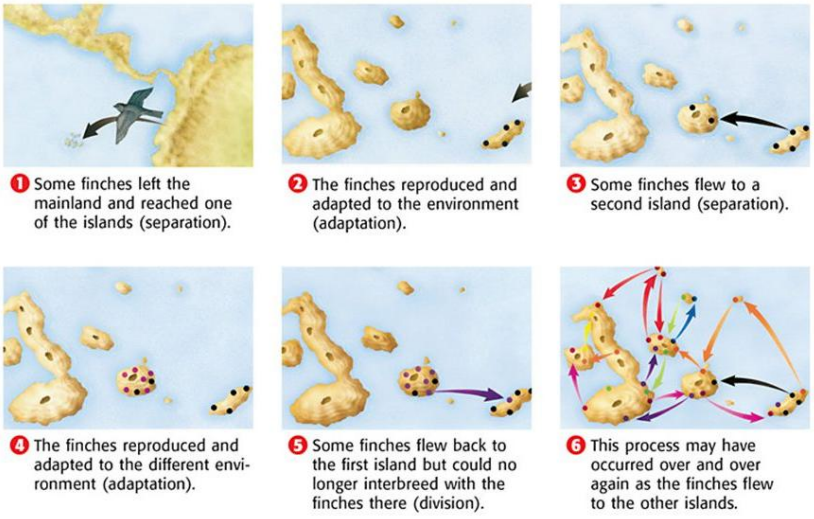
Study Figure 4.1 to see how allopatric speciation may occur. A single **ancestral** population of rabbits exists in an area. The ancestral population separates into two populations by a physical barrier. We say they are **geographically isolated**. In Figure

4.1, the physical barrier is a large dam. The two populations change due to natural selection in their different environments. This period may take 2 000 years. Eventually, even if they meet, they cannot breed successfully because they have changed so much. We say they are **reproductively isolated**. Two new species have evolved, where previously there was one.

Speciation of finches on the Galapagos Islands

Charles Darwin observed the results of speciation on the Galapagos islands. The finches on the islands resemble finches on the mainland, but not enough to say they are all one species. The islands are about 1 000 km away from the mainland. The islands are volcanic, the oldest being about 5 million years old.

Even within the Galapagos Islands, certain finch species occur on only a few neighbouring islands. The finches are adapted to different ways of feeding. There are 14 different species on the islands.



[Caption: Figure 4.2: Speciation in Darwin's finches.]

http://images.slideplayer.com/10/2752683/slides/slide_10.jpg

Figure 4.2 shows how Darwin's finches could have evolved from one ancestral species into may species.

- The ancestral finch species lived on the mainland of South America. The birds are too small to fly 1 000 km to the Galapagos Islands. However, storms often blow flocks of small birds out into the ocean. A few finches must have landed on the Galapagos Islands. They were geographically isolated from the mainland finches.

- The small flock of finches reproduced. Through natural selection, they became adapted to the island environment.
- Some finches flew to a second island, where they were geographically isolated from the first species. Through natural selection, the finches on the second island became adapted to the food available on that island.
- After a long period of isolation, the finches on different islands could no longer interbreed. They could not interbreed with the mainland finch species. They are new species.
- This process may have occurred many times as finches flew between islands. It has resulted in 14 finch species.

Watch the following video. It explains speciation very clearly.
https://youtube/8yvEDqrc3XE

[New words: Speciation: The evolutionary process in which new species arise.

Allopatric speciation: Speciation that results from a population being separated into two or more separate populations by a physical barrier.

Geographic isolation: Separation of two or more populations by a physical barrier.

Ancestral species: A species that produces descendant species.

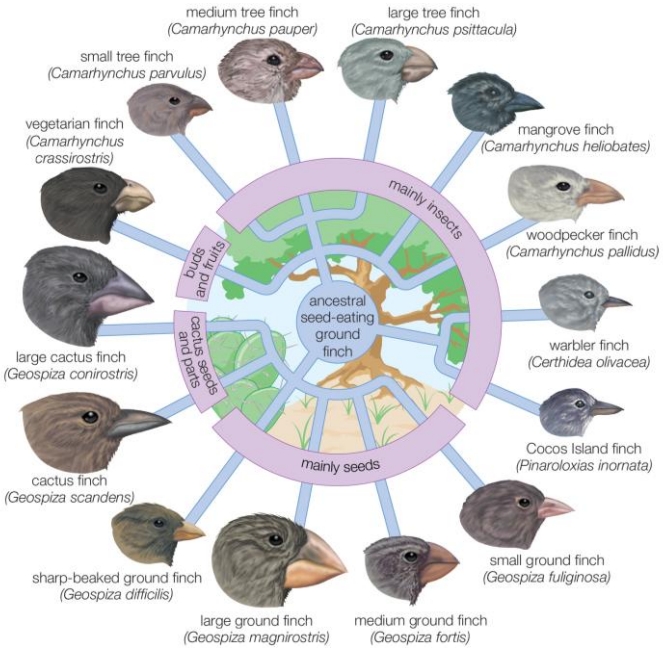
Reproductive isolation: Populations that cannot breed successfully together.]

Main idea: Allopatric speciation explains how speciation occurs in geographically isolated populations. The finches on the Galapagos Islands illustrate allopatric speciation.

Activity 4.1: Interpret a diagram showing speciation in Darwin's finches.

Expected outcome of activity: Learners will demonstrate understanding of speciation in Darwin's finches.

1. Study Figure 4.3 and answer the questions that follow.



[Caption: Figure 4.3: Adaptive radiation in Darwin's finches]

http://media-1.web.britannica.com/eb-media//11/54911-050-0E225E16.jpg

1.1 All 14 finch species are descended from one ancestor. What is the ancestor called? (1)

1.2 How many finch species have adapted to eating mainly seeds? (1)

1.3 Write the scientific name of the species that has adapted to eating buds and fruits. (1)

1.4 The 14 species belong to four genera. Name the four genera. (4)

1.5 What do all except one species of the genus *Camarhynchus* have in common? (1)

1.6 Study the diagrams of the finches that eat mainly seeds. Name the species that is adapted to eating **large, hard** seeds. Say why you have chosen this species. (2)

4.2 Methods of reproductive isolation

Reproductive isolation is the end of inter-breeding between two populations. Once reproductive isolation is established, the two populations are two separate species.

Once the two populations are separate species, interbreeding is detrimental. Mistakes sometimes happen, such as when a horse breeds with a donkey. The offspring (mules) are almost always sterile.

The most efficient mechanisms of reproductive isolation happen before two individuals meet and mate. Three examples are described below.

1. **Temporal isolation** means that the two species breed at different times of the day or the year. One plant species may flower in spring and its sister species in autumn. The chances of inter-breeding is reduced.
2. **Ecological isolation** means that the two species occupy different parts of an ecosystem. One butterfly may live and breed in the canopy of trees, while another lives in the understorey plants. They are ecologically isolated from each other.
3. **Behavioural isolation** means that the two species use different signals to attract a mate. Male frogs use mating calls to attract females. Different species have different mating calls. The females respond only to the calls of their own species. The two species are behaviourally isolated.

Sometimes a male and female of different species meet when they are sexually receptive. They mate, but reproductive isolation mechanisms prevent fertilisation, or ensure that the hybrid offspring do not reproduce. Two examples are described below.

4. **Gamete incompatibility** means that the sperm cannot fertilise the eggs. Pollen is easily transported from a flower of one species to a flower of another species. The pollen grain does not fertilise the eggs of the wrong species. The sperm does not penetrate the egg of the wrong species. The gametes are incompatible.
5. **Hybrid sterility** means that, even if interbreeding occurs and an offspring is produced, it is sterile. In some cases, the hybrid offspring are weak and die early before they can reproduce. Some hybrids survive to adulthood, but they are sterile. Mules are sterile hybrids of inter-breeding between a horse and a donkey.

Main idea: Species are reproductively isolated by temporal ecological, and behavioural isolation. They are also isolated by gamete incompatibility and hybrid sterility.

Activity 4.2: Have you understood your reading?

Expected outcome of activity: Learners will be able to assign specific examples to mechanisms of reproductive isolation.

1. Five mechanisms of reproductive isolation are: temporal isolation, ecological isolation, behavioural isolation, gamete incompatibility and hybrid sterility.

   Say which type of reproductive isolation is illustrated by each of the following examples.

1.1 Four closely-related flower species produce different scents and attract different pollinators.
1.2 Sheep sometimes mate with goats, but the offspring are usually stillborn.
1.3 Black wildebeest and blue wildebeest are closely related. Black wildebeest prefer Grassland and Nama Karoo biomes. Blue wildebeest prefer the edge of the Savanna biome.
1.4 Two butterfly species can mate, but females' eggs are never fertilised.

1.5 In two bird species, males attract their mates by courtship dances and song. The dances and songs are different in the two species.
1.6 Two vygie species grow near each other in the Succulent Karoo. One flowers in late July and August, while the other flowers in September. (6)

Summary of key learning:

- Charles Darwin and Alfred Wallace developed the theory of evolution by natural selection independently.
- Natural selection is the process by which evolution takes place. Individuals with the best adaptations leave more offspring than other individuals. The number of individuals with the best adaptations increase in the population.
- Antibiotic resistance in bacteria arises due to natural selection.
- Allopatric speciation explains how speciation occurs in geographically isolated populations. The finches on the Galapagos Islands illustrate allopatric speciation.
- Species are reproductively isolated by temporal ecological, and behavioural isolation. They are also isolated by gamete incompatibility and hybrid sterility.

Assessment Subtopic 1

Question 1

Match each description in Column A with the correct term in Column B.

Column A	Column B
1.1 A pond dries up during a drought to make two smaller ponds.	A Natural selection
1.2 One frog species breeds in March, while a related frog species breeds in May.	B Hybrid sterility
1.3 Tortoises with long necks survive and breed on an island with tall shrubs growing on it.	C Geographical isolation
1.4 Pollen from a lily lands on the stigma of a daisy.	D Artificial selection
1.5 The offspring of a zebra and a donkey cannot reproduce.	E Behavioural isolation

1.6 Pigs are crossbred to produce more meat.	F Ecological isolation
1.7 The courtship dance of the rock pigeon is different from that of an olive pigeon.	G Gamete incompatibility
	H Temporal isolation

(7)

2. State whether each of the following statements is TRUE or FALSE. If False, give the corrected version of the statement.

2.1 The theory of evolution states that species change over time.

2.2 Darwin proposed that artificial selection is the way evolution takes place.

2.3 Each generation produces just enough offspring to replace itself.

2.4 Alfred Wallace developed the idea of evolution after a 5-year voyage on the ship. HMS Beagle.

2.5 Natural selection is based on differences in reproductive success of individuals that have favourable adaptations. (5)

3. The table below gives information about an investigation of survival in four varieties of mice, each having a different fur colour. The mice live in a desert area where the sand is a golden colour. They are active only at night. Their main predators are owls. The Table shows the average results for 10 mice of each variety.

Table: Average results for four types of female mice in a desert environment.				
Variety of mouse	A	B	C	D
Fur colour	Dark brown	Gold	Red-brown	White
Average age at death (months)	3	10	4	9
Average number of offspring produced	5	12	6	10

3.1 Which variety of mouse (A.B. C or D) is best adapted to its environment? (1)

3.2 Give TWO reasons, based on the Table, to support your choice. (2)

3.3 Explain the results in terms of natural selection. (7)

Sub-topic 2. Evidence supporting evolution

Content:

Unit 1: Artificial selection.

Unit 2: Fossil record.

Unit 3: Comparative anatomy.

Unit 4: Biogeography

Activity 1.1: What do you already know about the evidence supporting evolution?

1. Write a sentence for each of the content topics showing what you know about that topic.
2. Discuss your list with other students.

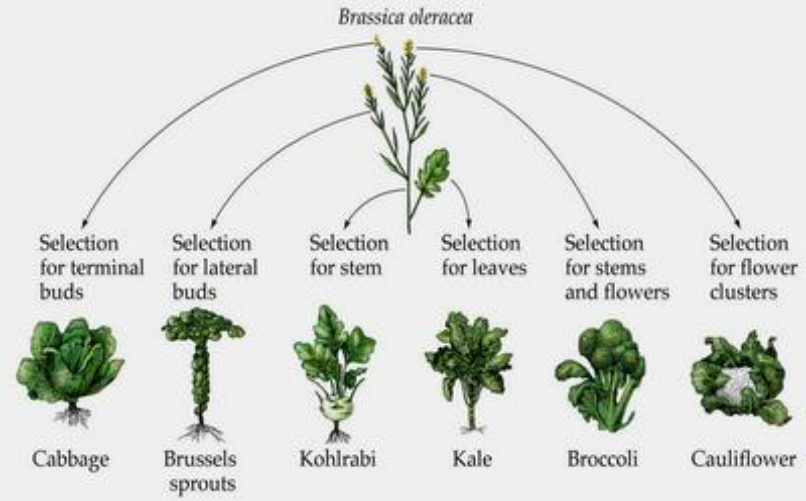
Unit 1: Artificial selection.

Learning outcomes

When you have completed this unit, you should be able to:

- Explain how artificial selection mimics natural selection, giving examples of artificial selection.

In his book "One the Origin of Species by Natural Selection", Darwin used the example of artificial selection to illustrate how a species can change through selective breeding. Artificial selection involves a human choosing which individuals will breed the next generation. If the breeding programme continues for many generations, the resulting individuals may look quite different from the original parents.



[Caption: Figure 1.1: Artificial selection and vegetables]

http://65.media.tumblr.com/103e5c3e6dd283721f37b6885f4fc013/tumblr_moxn48L0k21r8ebyno1_400.png

Figure 1.1 shows how many different vegetables are varieties of one plant, called *Brassica oleracea*. Plant breeders have artificially selected a certain characteristic. They carefully cross-pollinate plants with that characteristic. They collect the seeds and germinate them. They select the parent plants from the next generation, and repeat the process.

After many generations, we have different vegetables such as cabbage, cauliflower, broccoli and kale. This example illustrates how selecting the parents who will breed can lead to change in a line of plants.

[Caption: Figure 1.2 Artificial selection and cattle. A. The original Auroch cow. B. A modern dairy cowPlease delete Auroch. Add labels A (left cow) and B (right cow)]

http://joshuabloom.co.uk/assets/img/blog/Veganism/cow%20vs%20cow.png

All different breeds of cattle are descended from the original Auroch cattle. Figure 1.2 shows an Auroch cow, and its descendant, a modern dairy cow.

Cattle have been bred for different purposes: beef cattle for meat, dairy cattle for milk, breeds that are resistant to disease, cattle that can survive in dry conditions, and cattle that have particular coat patterns. In every case, the animal breeder breeds only from the bull and cows that have the best qualities that he wants. Over many generations, he achieves the result he wants.

Charles Darwin used artificial selection to illustrate that a species can change over many generations. Artificial selection is similar to natural selection. The agent of artificial selection is the breeder, whereas the agent in natural selection is the environment. Natural selection generally acts more slowly on a population.

Main idea: Artificial selection illustrates that populations can change over time, due to selective breeding. Artificial selection demonstrates that natural selection is possible.

Unit 2: Fossil record

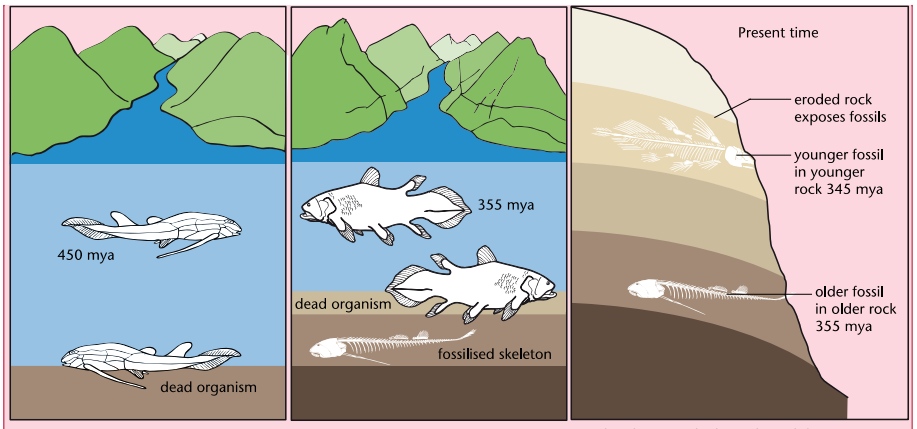
Learning outcomes

When you have completed this unit, you should be able to:

- Explain how the fossil record supports evolution

A fossil is the remains of extinct organisms preserved in rock, or traces left behind by those organisms. Fossils make us realise that life has existed on earth for an extremely long time (3,5 billion years), and life forms have changed over that very long period of time. Remember the timeline you made in Topic 1, which showed when certain key events took place in the history of life.

2.1 Fossil formation



Commented [d1]: Error in the label "older fossil in older rock 355 mya" – should be "older fossil in older rock 450 mya"

[Caption: Figure 2.1 How fossils form in sedimentary rock]

{From: Platinum Life Sciences Grade 10. Unpublished by Pearson South Africa.]

Figure 2.1 shows how fossils form in a type of rock called **sedimentary rock**. It shows fish swimming in the ocean 450 million years ago. One fish dies and sinks to the seabed. It is quickly buried by sediment washed down by the river. The soft parts of the fish decay, leaving the hard parts in the sediment. Over time, minerals from the sediment replace the hard parts. The bones still keep their original shape and size, but they are turned into stone.

About 1 million years later, different fish are swimming in the ocean. One dies and sinks to the seabed. Its remains also turn into stone in a layer above the first fish.

Many millions of years later, the rock has risen above sea level. It starts to erode. One fossil is exposed. If scientists discover the fossil, they may find the older fossil in a lower layer in the sedimentary rock.

[New word: Sedimentary rock: Rock that forms when sand and mud settle to the bottom of seas, lakes and swamps. They are compressed by more sediment and by water, and turn into rock.]

2.2 Radiometric and relative dating of fossils

How do we know the age of fossils? Figure 2.1 says the first fish lived 450 mya, and the second fish 355 mya. How do we know that they were that age?

Radiometric dating

Radiometric dating is a method of measuring the age of fossils that have formed in volcanic rock. The dead organisms were covered by a layer of volcanic ash, rather than sediments as in sedimentary rock. The ash hardened and became rock, and the dead organism is a fossil in volcanic rock.

Volcanic rock contains elements that are **radioactive**. They gradually decay to non-radioactive products at a known rate. For example,

- radioactive uranium decays to lead over billions of years;
- radioactive potassium decays to argon over millions of years;
- radioactive carbon$_{14}$ decays to non-radioactive carbon$_{12}$ over thousands of years.

Scientists use special equipment to measure the proportion of the radioactive element and its non-radioactive product in the rock. If the rock contains mostly the radioactive element, the fossil is young. If the rock contains very little of the radioactive element, the fossil is very old.

Radiometric dating is accurate, within a margin of error. Fossils found in volcanic rock can be dated more accurately than fossils found in sedimentary rock.

Relative dating

Relative dating uses the sequences of fossils in layers of sedimentary rock. Figure 2.1 shows that the deeper the layer of sedimentary rock in a sequence of rock, the older the fossil is.

Relative dating gives an accurate **sequence** of fossils, because the same sequence and combinations of fossils are found around the world. It does not tell us exactly how old a fossil is. Radiometric dating is more accurate than relative dating.

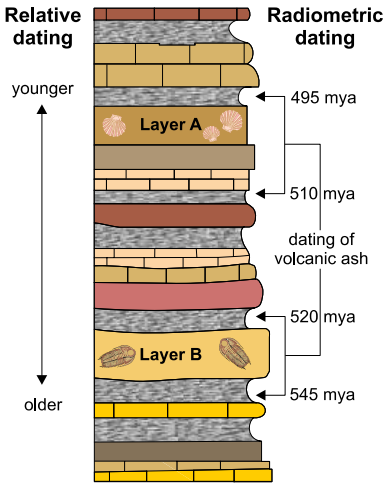


Figure 2.2: Comparison of relative dating and radioactive dating

[Source: Platinum Life Sciences Grade 10. Unpublished book.]

Figure 2.2 shows a rock sequence consisting of volcanic layers between layers of sedimentary rock. The volcanic layers are shown as grey bands. Layers of sedimentary rock lie between the layers of volcanic rock.

Layer A contains a number of fossilised shells. Layer B contains some fossilised animals with many legs.

Relative dating tells us that Layer B is older than layer A, because it is deeper in the rock sequence. Relative dating does not tell us exactly how old each layer of rock is.

Radiometric dating allows us to calculate the ages of the layers of volcanic rock in the sequence. Figure 2.2 shows that the volcanic layer below Layer B formed 545 mya, and the layer above Layer B formed 520 mya. We can estimate the age of the fossils in Layer B as between 545 and 520 million years.

Activity 2.1: Use Figure 2.2 to estimate the age of fossils in Layer A.

Expected outcome of activity: Learners will be able to interpret Figure 2.2

1. Use the information in Figure 2.2 to estimate the age of the fossils in Layer A. Show your reasoning. (5)
2. If you found fossils of the animals in Layer B in a different sedimentary rock sequence, how old would you estimate them to be? Give a reason for your answer. (2)

[New words: Radiometric dating: dating rock layers by measuring the relative amounts of radioactive elements and their decayed products in rock.

Relative dating: Organising rock layers and their fossils into a sequence according to the depth at which they are found.]

2.3 Patterns of succession in the fossil record

Sequences of fossils found in layers of rock give us a series of "snapshots" of the history of life. The timeline you constructed in Topic 1 tell the story of the evolution of life, based on fossils. Your timeline showed that the first fish evolved about 460 mya. Before that date, there were no fish. The oldest fossilised fish are 460 million years old.

Your timeline also showed that the first mammals evolved 230 mya. Before that date, there were no mammals on earth.

Fossils show a succession from the oldest to the present. If scientists find enough fossils of a particular group, they can see that the sequence goes from the most ancient, through a number of intermediate stages, to fossils that are similar to living species.

South Africa has an outstanding sequence of a vertebrate group called the **mammal-like reptiles**. The oldest mammal-like reptile is 308 million years old. It was very much like a reptile. The sequence becomes progressively more like mammals.

Thrinaxodon was a key species in the evolution of mammal-like reptiles. It lived between 250 and 200 mya.

[Caption: Figure 2.3 *Thrinaxodon* skull and whole skeleton

Source: Copied from MacRae: Life etched in Stone, with permission. These photographs appear in the unpublished book: Platinum Life Sciences Grade 10]

Study Figure 2.3 and notice the following mammal-like features of *Thrinaxodon*:

- Its teeth were differentiated into incisors, canines and molars. Reptiles have undifferentiated teeth.
- It had a bony palate forming the roof of the mouth. Reptiles do not have a bony palate, but mammals do.
- It had pits in the snout, showing that it may have had sensory whiskers, as mammals do.
- Fossils are sometimes found in a curled-up position, as you can see in Figure 2.3 Only mammals curl up to sleep, to keep warm. *Thrinaxodon* may have been warm-blooded, with fur.
- It walked with legs splayed out to the sides, like a crocodile. This is reptile-like.

Because *Thrinaxodon* had reptile-like and mammal-like features, it is intermediate between reptiles and mammals. Some people call it a "missing link".

The earliest mammals found in South Africa date from 190 mya. They have been found in rocks high up in the Drakensberg mountains. The mammal-like reptiles disappear from the fossil record at about the same time as the first mammals appear.

The sequence of mammal-like reptiles to mammals found in South Africa is strong evidence that mammals evolved from mammal-like reptiles, through a sequence of intermediates.

2.4 Similarities and differences between fossils and modern species.

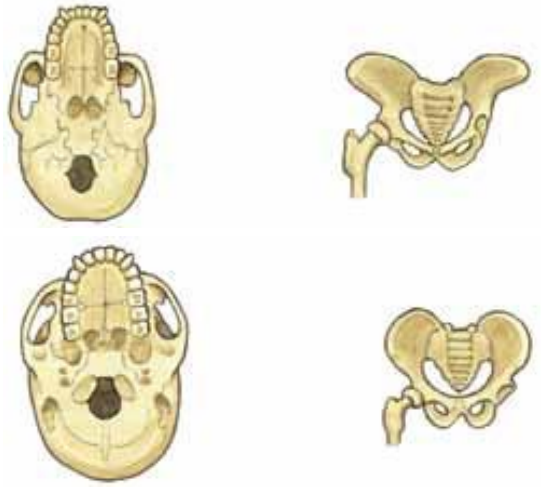
In section 2.3, we highlighted a number of similarities between *Thrinaxodon* and mammals. Here, we compare the skull and **pelvic girdle** of a **pre-human** (*Australopithecus africanus*) and a modern human.

[Caption: Figure 2.4: Skulls of a 2,4 million-year-old *Australopithecus africanus* and a 200 000-year-old human.
Source: Copied from MacRae: Life etched in Stone, with permission. These photographs appear in the unpublished book: Platinum Life Sciences Grade 10]

Figure 2.4 shows two fossilized skulls: on the left is a 2,4-million-year-old *Asutralopithecus africanus*, and on the right is a 200 000-year-old human skull. Both skulls have been found in southern Africa.

Look carefully at the two skulls. Both have forward-facing, large eyes. Both have a rounded braincase. However, there are some marked differences between the two skulls.

- *A.africanus* has a face that slopes forward towards the mouth. The human has a flat face.
- *A.africanus* has no forehead. The human has a forehead.
- *A.africanus* has a low brain-case. The human has a high braincase.
- *A.africanus* has thick bone above its eyes. The human does not have thick bone above its eyes.



[Caption: Figure 2.5 Skull and pelvis of A) *Australopithecus africanus* and B) a human. Add labels: foramen magnum, canines, upper part of pelvis, neck of femur, lower part of pelvis]

[Taken from Platinum Series Life Sciences Grade 12, p. 244. Pearson South Africa.]

Figure 2.5 shows the under-side of the skulls and the pelvis of *A.africanus* and the human. Notice that the teeth are very similar in both skulls. An important question is whether *A.africanus* walked on two legs, as modern humans do, or whether they walked on four legs. The position of the foramen magnum and the shape of the pelvis are very important features in answering the question.

- The **foramen magnum** of both *A.africanus* and humans is under the skull. This position of the foramen magnum is associated with walking upright on two legs. However, the foramen magnum of *A.africanus* is further back than that of humans.
- The **neck of the femur** in both *A.africanus* and humans is long and angled away from the pelvis. This shape and position of the femur is associated with walking upright.
- The pelvis of humans forms a shallow basin, which is associated with supporting weight of the body in an upright position. The pelvis of *A.africanus* is wide and flares outwards. It does not provide as much support as a human's pelvis.

Different species of *Australopithecus* existed from about 5 mya until about 200 000 years ago. Modern humans evolved about 200 000 years ago. Could *Australopithecus* be the ancestor of modern humans?

Scientists believe there are enough similarities to say that *Australopithecus* could be the ancestors of modern humans. They walked upright at least part of the time. Their teeth were very similar to modern human teeth. However, their brains were small, and their faces protruded forwards. Their pelvic bones were not as well adapted for walking on two legs as the human pelvis.

[New words: pelvic girdle: The bones that make up the pelvis of a vertebrate.

Australopithecus: One of many extinct species that show characteristics like apes and like humans.

Foramen magnum: The large hole in the skull through which the spinal cord passes.

Canines: pointed teeth that are also called "eye teeth".

Palate: the roof of the mouth.

Femur: the upper leg bone that joins the leg to the pelvis.]

Watch this video for a quick review of human evolution. It is called "Timeline of Human Evolution"

https://www.youtube.com/watch?v=i98cb-zj2vg

Main idea: The fossil record shows that life has changed over long periods of time. It is a strong source of evidence supporting evolution.

Unit 3: Comparative anatomy

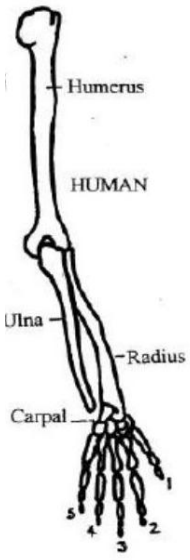
Learning outcomes

When you have completed this unit, you should be able to:

- Explain how comparative anatomy supports evolution with reference to modification of the vertebrate forelimb.

Comparative anatomy is the study of similarities and differences in structures present in organisms. Charles Darwin used comparative anatomy as evidence of evolution. He used the example of similarities in the forelimb of vertebrates. In humans, the forelimb is the arm.

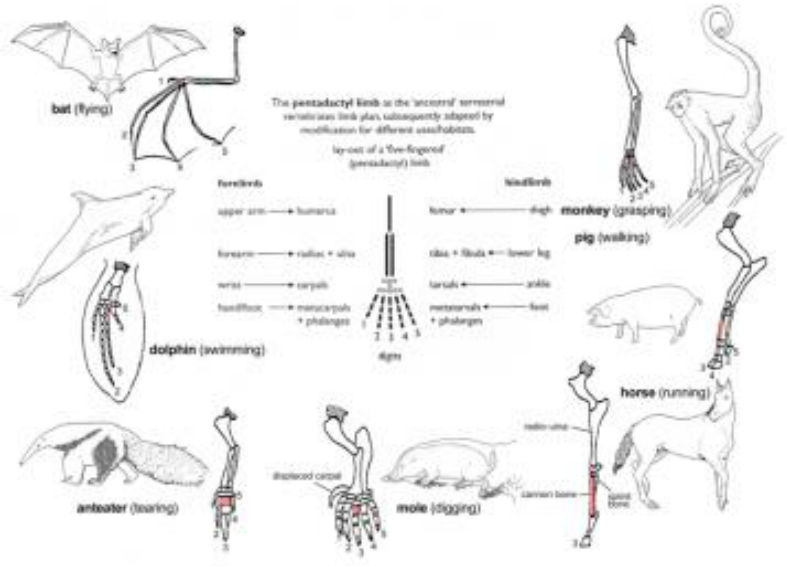
All vertebrates have the same basic set of bones. Human arm-bones are a good example.



[Caption: Figure 3.1 Bones of a human arm. Add labels for metacarpals and digits]

Identify these bones in Figure 3.1: humerus (your upper arm bone), radius, ulna (your lower arm bones), carpals (in your wrist), metacarpals (in your hand) and digits 1-5 (your fingers).

We can see the same bones in a bat, a dolphin, a horse and a mole. In each case, you can see how the bones are modified for the animal's lifestyle. For example, the bat flies, the mole digs, the horse runs fast, the dolphin swims.



[Note to editor: This is a good drawing, but resolution is too low. Omit anteater, pig and monkey, and the text in the centre. Retain the block diagram in the centre, with only the labels for the forelimb]

[Caption: Figure 3.2 Vertebrate forelimbs adapted for flying (bat), swimming (dolphin), fast running (horse)and digging (mole)]

https://ncse.com/files/images/800px-Evolution_pl.img_assist_custom.png

Activity 3.1: Write about the adaptations for each lifestyle.

Expected outcome of activity: Learners will be able to identify adaptations of the vertebrate forelimb.

1.Study Figure 3.2 carefully.

1.1 Compare each forelimb with the human forelimb. Write at least three sentences describing the adaptations of each forelimb for its lifestyle. (12)
1.2 Discuss your observations with your colleagues.
1.3 Compare your answers with the answers given in this workbook.

Why do groups of organisms have the same basic structure, but adaptations for different lifestyles? There are many examples, such as vertebrate forelimbs or Galapagos finches, which have adapted to different modes of feeding.

The scientific answer is that all members of a group that share similar basic structures are descended from a common ancestor. In Biology, a common ancestor is a species that gave rise to other species or groups of species. All vertebrates have the same basic plan

of their forelimbs, therefore they are descended from a common ancestor. This idea is called **descent with modification**.

Descent with modification assumes that all organisms of a particular group have evolved from a common ancestor. Comparative anatomy provides strong evidence of descent with modification.

Main idea: Comparative anatomy reveals similarities in basic body structures in related groups, but adaptation to particular lifestyles. Comparative anatomy supports descent with modification, which is another name for evolution.

[New words: Comparative anatomy: the study of similarities and differences in structures present in groups of organisms.

Common ancestor: the species that has given rise to a number of different species.

Descent with modification: The theory that all species arose from a succession of ancestors as they adapted to different lifestyles and environments.]

Unit 4: Biogeography

When you have completed this unit, you should be able to:

- Explain how biogeography supports evolution

Biogeography is the study of the distribution of species in different parts of the world. Alfred Wallace based his proposal of the theory of evolution by natural selection on biogeography. Charles Darwin was particularly fascinated with the large flightless birds that he saw in different continents. Flightless birds are birds that cannot fly. There are no large flightless birds in the northern hemisphere. In the southern hemisphere, Papua New Guinea, Australia, South America, and Africa have large flightless birds.

Before humans arrived, New Zealand had large flightless birds called moas. Madagascar had an enormous flightless bird called the elephant bird.

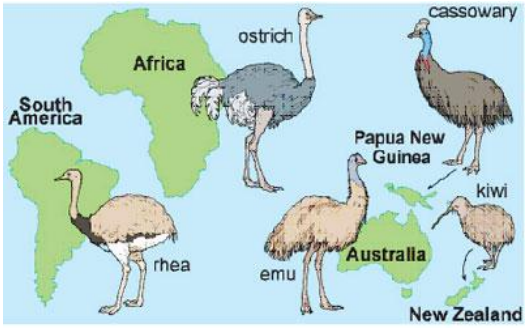


Figure 4.1: Large flightless birds of the southern hemisphere
https://naturalishistoria.files.wordpress.com/2013/02/ratites-birds-flightless-distribution.jpg

Activity 4.1: Match the flightless birds to the correct country.

Expected outcome of the activity: Learners will be able to identify which flightless bird is found in each continent.

1. Study Figure 4.1, which shows the large flightless birds of the southern hemisphere. Fill in the information missing in the table below.

Country	Australia	1.2	Africa	South America	1.5
Large flightless bird	1.1	kiwi	1.3	1.4	Cassowary

(5)

Why is there a different type of flightless bird in each continent or large island in the southern hemisphere? Scientists argue about the answer to this question. One possible answer is that the ancestor of the large flightless birds evolved about 56 million years ago on the supercontinent known as Gondwana. See Figure 4.2 for a map of Gondwana.

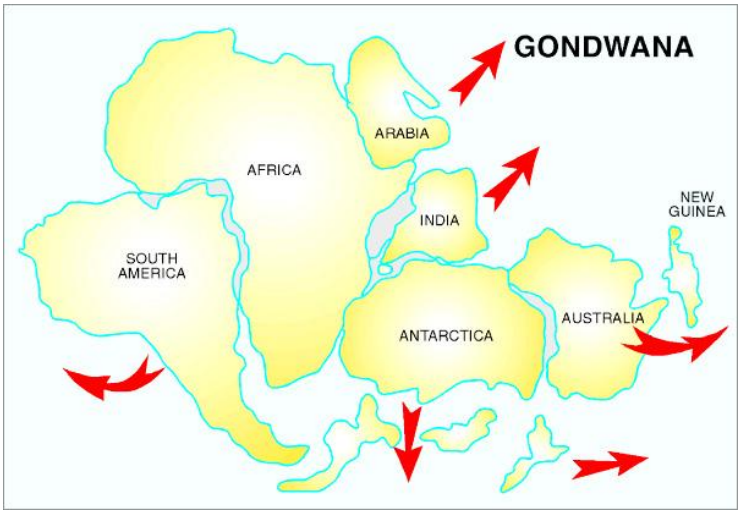


Figure 4.2: A map of Gondwana 175 million years ago. Red arrows show the direction of movement when Gondwana broke up.

http://kalistonia.weebly.com/uploads/3/9/5/6/39569789/2975090_orig.jpg

As Gondwana drifted apart (see Figure 4.2 for how this occurred), each continent and island took some of the ancestral large flightless birds with it. The birds were then geographically isolated from each other. Adaptation took place in each continent and island, resulting in the different species we see today.

Evolution explains the presence of different types of large flightless birds in different parts of the world. There are many other examples of related organisms found in

different parts of a continent or on a group of islands. Evolution explains the patterns of geographic distribution of species.

[New words: Biogeography**:** the study of the distribution of species in different parts of the world.

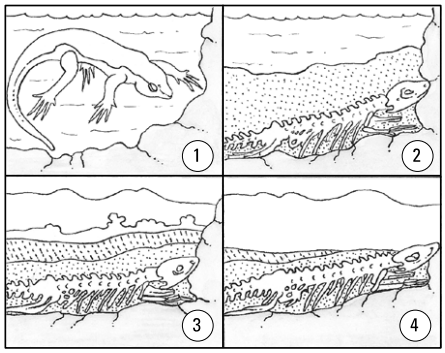
Main idea: Biogeography is the study of the distribution of species in different parts of the world. Evolution explains the patterns of geographic distribution of species.

Summary of key learning:

- Artificial selection illustrates that populations can change over time, due to selective breeding. Artificial selection demonstrates that natural selection is possible.
- The fossil record shows that life has changed over long periods of time. It is a strong source of evidence supporting evolution.
- Comparative anatomy reveals similarities in basic body structures in related groups, but adaptation to particular lifestyles. Comparative anatomy supports descent with modification, which is another name for evolution.
- Biogeography is the study of the distribution of species in different parts of the world. Evolution explains the patterns of geographic distribution of species.

Assessment: Subtopic 2

1. Give the correct biological term for each of the following descriptions.
   1.1 A type of dating that involves studying the layers of sedimentary rock.
   1.2 The oldest form of life.
   1.3 A mammal-like reptile that could be intermediate between reptiles and mammals.
   1.4 A super-continent that existed in the southern hemisphere 175 million years ago.
   1.5 The study of the distribution of species in different parts of the world.
   1.6 The study of similarities and differences in the physical structure of organisms.
   1.7 A type of dating that accurately dates volcanic rock. (7)
2. Fossils are the remains of dead organisms preserved in rock. The sketches below illustrate four steps in the process of fossil formation.



[From Focus Life Sciences Grade 10, p. 291. Published by Pearson South Africa]

2.1 Explain what is happening at each step 1 – 4. (8)

2.2 Name the type of rock in which this fossil is found. (1)

Topic 3: Genetics and Heredity

Introduction

Evolution by natural selection can only happen if variation is passed on from one generation to the next. The science of genetics shows that hereditary material passes from one generation to another. Genetics provides some Principles that explain patterns of inheritance. Gregor Mendel founded the science of genetics. His research helped scientists understand how evolution by natural selection happens at a genetic level.

The chemical nature of hereditary material was discovered in the mid-20th century. Deoxyribonucleic acid (DNA) carries hereditary information in the form of codes. DNA controls the structure and functioning of every organism. It passes from one generation to the next. It controls the manufacture of proteins that control the physical appearance and functioning of every organism.

Studying and manipulating the structure and functioning of DNA is cutting-edge research in Biology at present.

Sub-topic 1. Patterns of inheritance

Content:

Unit 1: Mendel and the science of genetics

Unit 2: Cell division

Unit 3: The nature of genes, alleles and their role in determining the phenotype.

Unit 4: Solving genetics problems

Unit 5: Variation

Activity 1.1: What do you already know about inheritance?

Expected outcome of activity: Learners will identify their prior knowledge of the topics.

1. In which ways do you look like your mother? Examples might be a gap between your two front teeth, a hairline that forms a point in the middle of your forehead, an extra finger or toe, or the same shape of your face.
2. In what ways do your children look like you?
3. How do children get to look something like their mother or their father?

Unit 1. Mendel and the science of genetics.

Learning outcomes:

When you have completed this unit, you should be able to:

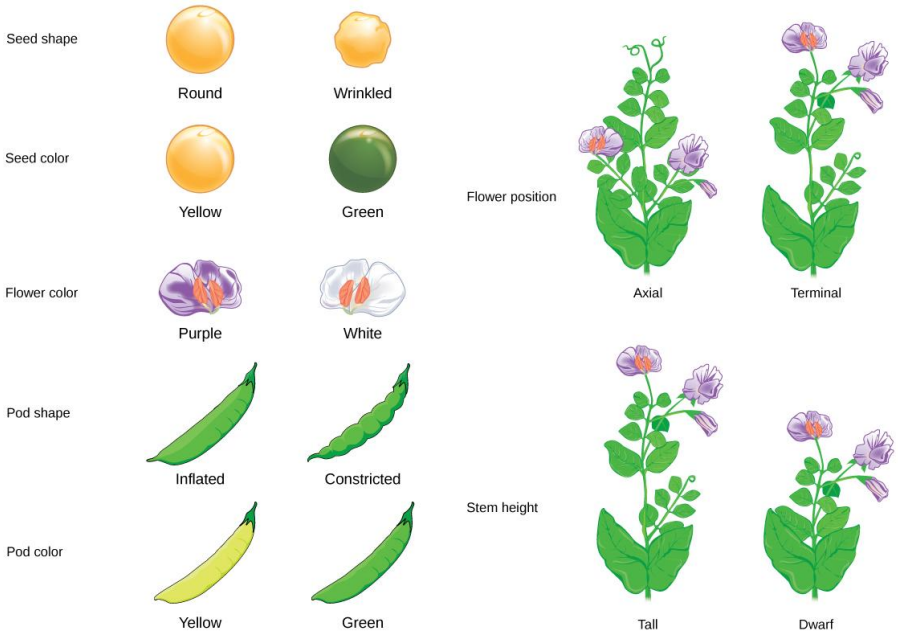
- Define inheritance and describe the importance of Mendel's work to understanding inheritance;

In everyday life, the word "inheritance" means money or belongings that you receive when a person has died. In biology, "**inheritance**" means the passing of characteristics from one generation to the next.

> For example, suppose your father has a gap between his two front teeth, and you have a similar gap. You have inherited the gap from your father.

Gregor Mendel (1822-1884) studied inheritance. He was a monk, who lived and studied in Austria. He studied natural sciences and mathematics and became interested in cross breeding plants. When he joined the monastery in 1853, he worked in the vegetable garden. His observations of the variations in the pea plants in the garden led him to perform many experiments in which he cross-bred plants.

Mendel studied seven different characteristics of pea plants, such as wrinkled or smooth seed coats, tall or dwarf plants, green or yellow seed coats, purple or white flowers. Mendel followed the scientific method strictly. He performed thousands of controlled experiments crossing plants with similar and different characteristics. He counted the thousands of seeds he gathered, and meticulously recorded what happened when they germinated.



[Caption: Figure 1.1: The seven characteristics that Mendel studied]

http://archive.cnx.org/resources/fa6f545cec588d620656d63cefaa1ad4c528df03/Figure_08_01_03.jpg.

Mendel discovered that physical features of the plants might disappear in one generation, and then re-appear in the next generation. For example. he cross-bred tall plants with dwarf plants, and found that all the seeds grew into tall plants. If he cross-bred those tall plants, the seeds grew into tall and dwarf plants in a ratio of 3 tall: 1 dwarf.

Mendel is regarded as the father of the science of **genetics**, which is the study of the mechanisms involved in inheritance and variation. However, the term genetics was first used in 1905, long after Mendel had died. Mendel realised that something passed from one generation to the next, but he did not know what it was.

As microscopes developed, it became clear that cells divide, and something happens in the nucleus when cells divide. We need to study cell division to understand what passes from one generation to the next.

[**New words**: Inheritance: the passing of characteristics from one generation to the next.

Variation: Differences in the characteristics of individuals.

Genetics: The study of the mechanisms involved in inheritance and variation

Hereditary material: a substance or structure that controls characteristics of an organism. It passes from one generation to the next]

Main idea: Inheritance means the passing of characteristics from one generation to the next. Gregor Mendel was the founder of the science of genetics. Genetics is the study of the mechanisms involved in inheritance and variation.

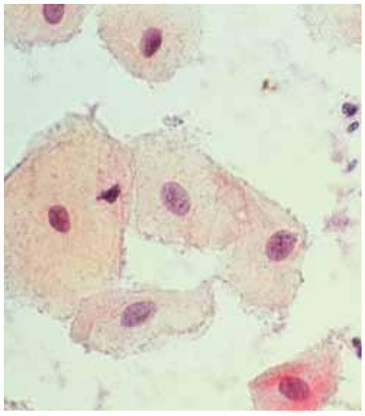
Unit 2: Cell division

[Note to editor: Unless otherwise indicated, the figures come from an unpublished book: Platinum Life Sciences Grade 10, commissioned by Pearson South Africa].

When you have finished this unit, you should be able to:

- Identify the following structures in a cell: nucleus, nuclear membrane, chromosomes, centromere, chromatin, homologous pairs.
- Describe the role of chromosomes in passing information accurately from one generation to the next;
- Identify, with the aid of diagrams, prophase, metaphase, anaphase and telophase of mitosis;
- Identify, with the aid of diagrams, prophase, metaphase, anaphase and telophase of meiosis I and meiosis II;
- Define the terms haploid and diploid, and explain the need for a reduction division prior to fertilisation.

2.1 Where is the hereditary material in a cell?



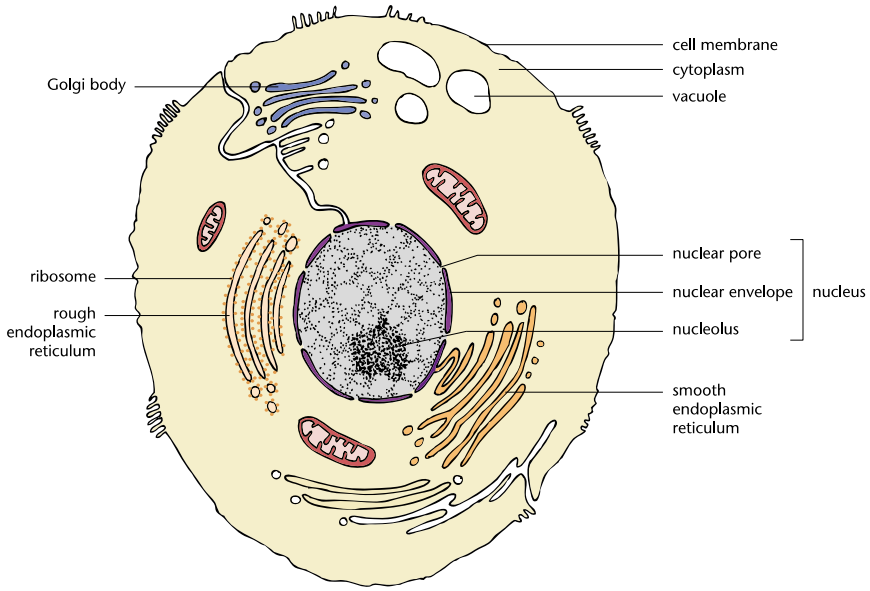
[Caption: Figure 2.1 Cells from the cheek of human. Labels: nucleus, cytoplasm]

We cannot see cells without a microscope. Figure 2.1 shows the structure of some animal cells, as seen with a microscope. The dark structure in each cell is the nucleus, which is surrounded by cytoplasm. The nucleus is an important structure because it carries the hereditary material of the organism.

Figure 2.2 shows more detail of the internal structure of an animal cell. Notice that the nucleus contains some material that is labelled **chromatin**. Chromatin is the name given to the hereditary material when the cell is not dividing.

Notice that the nucleus is separated from the cytoplasm by the **nuclear membrane**. The nuclear membrane has tiny holes in it, called nuclear pores. Nuclear pores allow chromatin to communicate with the cytoplasm.

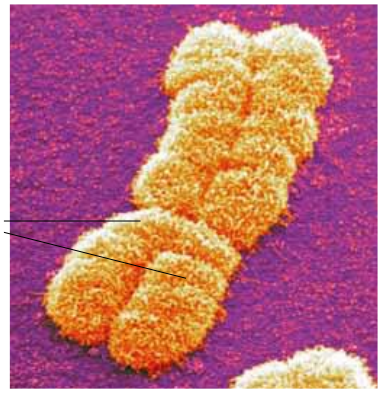
Chromatin is made up of long strands called **chromosomes**. Chromosomes carry the hereditary material from one generation to the next.



[Caption: Figure 2.2: Detailed structure of an animal cell. Label: ONLY nuclear pore, nuclear membrane, nucleolus and chromatin material]

Chromosomes

One of the first signs that a cell is about to divide is that the chromosomes become visible in the nucleus.



[Caption: Figure 2.3: Structure of a chromosome of a cell that is about to divide. Labels: Two chromatids, centromere]

Figure 2.3 shows what a chromosome looks like when it is seen with a very powerful microscope. It comes from a cell that is about to divide.

The chromosome consists of two identical **chromatids**, held together at the **centromere**. Normally, a chromosome has only one strand of hereditary material. Just before a cell divides, the chromosome makes a copy of itself. That is why the chromosome in Figure 2.3 consists of two chromatids.

Homologous pairs

At the time of fertilisation, a zygote receives a set of chromosomes from its mother, and a second set from its father. The two sets match each other in size and shape. You received 23 chromosomes from your mother and 23 chromosomes from your father. They form matched pairs. A matched pair of chromosomes is a called a **homologous pair** of chromosomes. Two chromosomes of a homologous pair control the same characteristics of the whole organism.

[New words: Nucleus: the structure in every cell that contains the hereditary material that controls all the activities of the cell.

Nuclear membrane: the membrane that separates the hereditary material from the cytoplasm.

Chromosomes: a strand of hereditary material in the nucleus of a cell.

Chromatid: After a chromosome has made a copy of itself, each identical strand is called a chromatid.

Centromere: the place that holds two chromatids together.

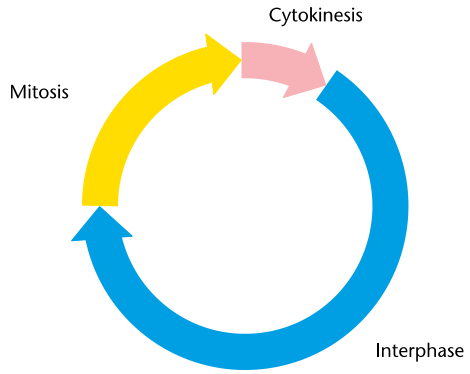
Chromatin: The strands of hereditary material in the nucleus when the cell is not dividing.

Homologous pairs: A matching pair of chromosomes, one inherited from the mother and one from the father.]

Main idea: Hereditary material is carried by the chromosomes, which are in the nucleus of every cell.

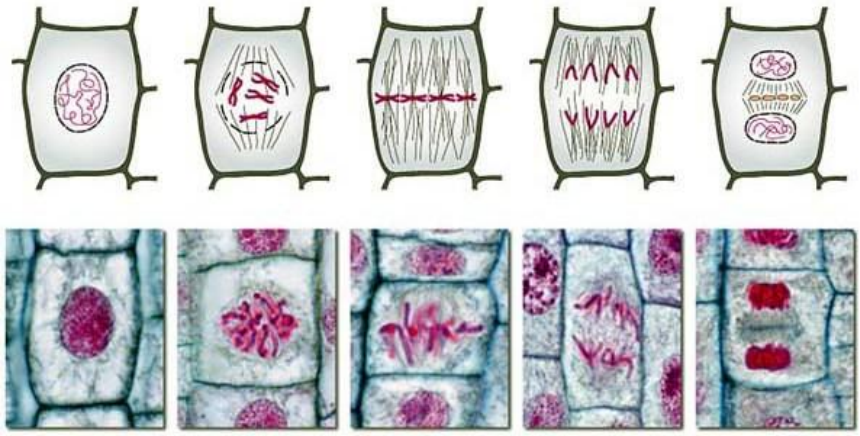
2.2 Mitosis (cell division)

Cells do not live forever. They go through a 'life cycle' called the cell cycle. Cells spend 90% of their life span growing and performing their normal metabolic functions. Some cells never divide. They die when they reach the end of their lifespan. Other cells divide to produce new cells.



[Caption: Figure 2.4: The cell cycle]

Cell division is called **mitosis**. You can see the stages of mitosis in Figure 2.5



[Diagram taken from www.clt.astate.edu/mhuss/mitosis1.jpg]

[Caption: Figure 2.5: Phases of mitosis in a plant cell. Labels from left to right: interphase, prophase, metaphase, anaphase, telophase. Place labels above the diagrams in the top row.]

Refer to the diagrams in Figure 2.5 as you read the description of the process of mitosis.

- **Interphase** occurs between cell divisions. The chromosomes are long strands that form the chromatin material in the nucleus. As a cell prepares to divide, each chromosome makes a copy of itself, as in Figure 2.3.
- **Prophase** is the start of mitosis. The chromosomes coil up, thicken and become visible as threads. The nuclear membrane disintegrates. Each chromosome consists of two identical chromatids. A structure called the **centriole** (plant cells) and centrosome (animal cells) separates into two parts. The parts move to opposite sides of the cell. The opposite sides are called the **poles**.
- **Metaphase** is the period when spindle fibres form between the centrioles. The chromosomes line up across the mid-line of the spindle. The mid-line is called the **equator**. The centromere of each chromosome attaches itself to the spindle.
- **Anaphase** happens quite quickly. The spindle fibres contract and pull the chromatids apart. The two chromatids of each chromosome move to opposite poles. The spindle fibres pull the chromatids away from each other.
- **Telophase** is the period when the chromatids move further apart and begin to uncoil. A nuclear membrane forms around each set of daughter chromosomes.
- **Cytokinesis** occurs after the chromatids have separated into two separate nuclei. The cytoplasm now divides to form two new daughter cells. In plant cells, a cell wall forms to separate the cytoplasm of the two cells. In animal cell, the cell membrane constricts in the middle, pinching the original cell into two cells.

At the end of mitosis, the two daughter cells have exactly the same number of chromosomes as the parent cell. The hereditary material is identical in the two daughter cells.

[New words: Mitosis: the process in which a nucleus divides into two daughter nuclei which have identical hereditary material to each other and to the parent cell.

Interphase: the phase of the cell cycle between cell divisions.

Prophase: The phase of mitosis when chromosomes coil up and attach themselves to the spindle.

Spindle: A set of threads that joins the two halves of the centriole.

Centriole: a structure in the cell that produces the spindle.

Poles: Opposite ends of the spindle.

Metaphase: The phase of mitosis when chromosomes line up across the equator of the spindle.

Equator: the mid-line of the spindle.

Anaphase: The phase of mitosis when sister chromatids separate and move to opposite poles of the cell.

Telophase: The phase of mitosis when the two daughter nuclei form.

Cytokinesis: The phase of the cell cycle when the cytoplasm divides]

Main idea: Mitosis is cell division. Mitosis produces two daughter cells that have exactly the same hereditary material as each other and as the parent cell.

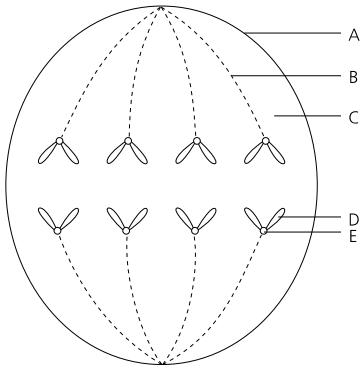
Watch the following Youtube video showing mitosis:

https://www.youtube.com/watch?v=AhgRhXl7w_g is a short animation showing mitosis.

Activity 2.1: Have you understood your reading?

Expected outcome of activity: Learners will demonstrate that they understand mitosis

1. Look at the diagram and answer the questions that follow.



1.1 Replace the labels A to E with the correct terms. Choose terms from the following list: cell membrane; centromere; chromatid; cytoplasm; gene; homologous pair; nuclear membrane; spindle fibres. (5)

1.2 Choose the correct answer for each of the questions that follow:

1.2.1 The phase of mitosis shown in the diagram is called
A anaphase
B telophase
C metaphase
D interphase

1.2.2 What is happening in the diagram?
A Homologous pairs are separating.
B The chromosomes are lining up across the midline of the spindle.
C Each chromosome is making an exact copy of itself.
D The chromatids of each chromosome are separating.

1.2.3 The result of the division shown in the diagram will be:

A Two daughter cells, one of which will die.
B Two daughter cells that have identical hereditary material.
C Two daughter cells, each having half the normal number of chromosomes.
D One cell in which each chromosome consists of two chromatids.

1.2.4 Before mitosis started, how many chromosomes were present in the cell shown in the diagram?
A Eight.
B Two
C Sixteen
D Four (8)

2.3 Meiosis (a special type of cell division)

Meiosis is a special type of cell division.

- It results in four daughter cells that each have half the normal number of chromosomes.
- The daughter cells do not carry identical hereditary material to each other or to the parents.
- Meiosis occurs much more rarely than mitosis.

In many organisms, meiosis occurs only when sex cells (gametes) are produced. Sex cells are sperm and eggs.

> For example, a normal human cell has 46 chromosomes. A sperm cell or an egg cell have half of that number, or 23 chromosomes. Sperm and eggs are produced by meiosis.

Figure 2.6 shows the process of meiosis. You can see that it is a much longer process than mitosis.

[Insert Figure 2.6 as supplied. From: www.phschool.com/science/biology_place/labbench/lab3/images/stages3.gif]

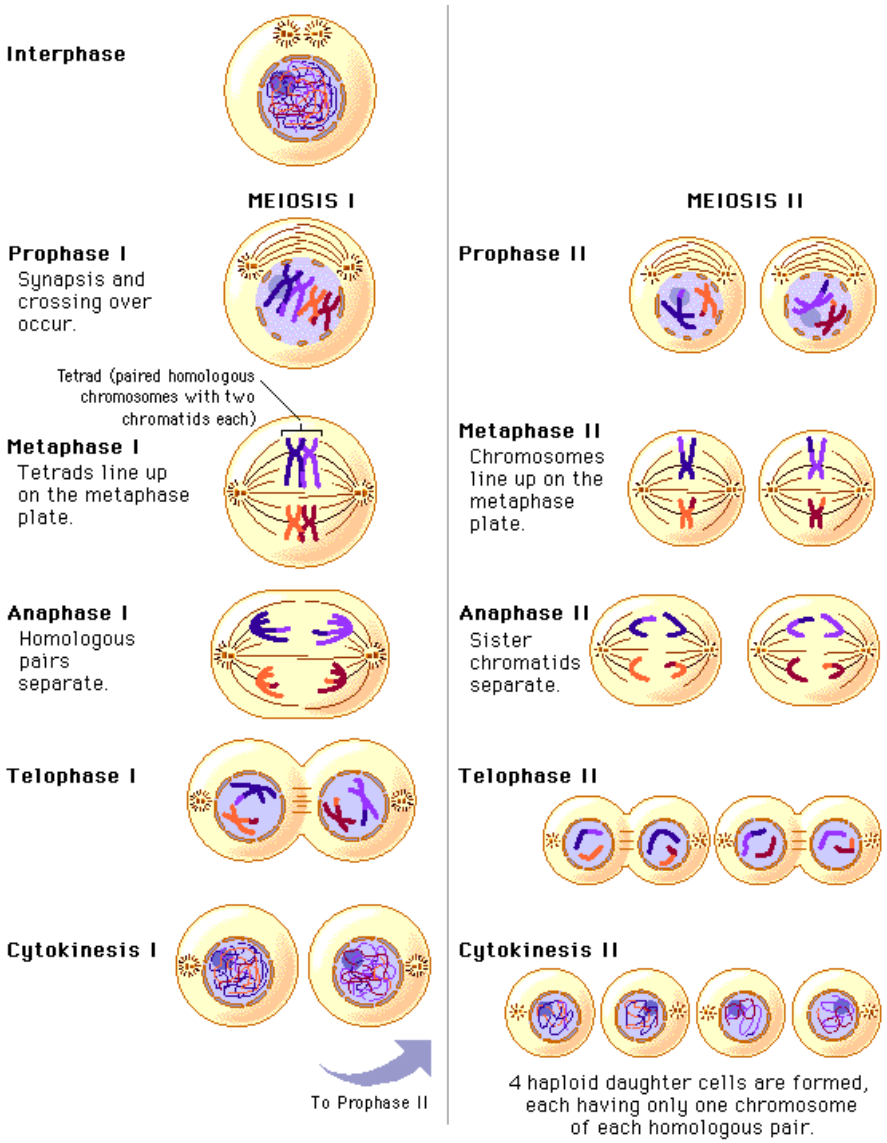


Figure 2.6 Stages of meiosis

Follow the diagrams in Figure 2.6 as you read the description of each phase of meiosis.

Interphase: Each chromosome makes an exact copy of itself. When the cell is ready to divide, each chromosome consists of two chromatids, just as for mitosis.

First meiotic division

Prophase I: The chromosomes coil up and become visible. The nuclear membrane disintegrates. The spindle begins to form. So far, the events are exactly the same as in mitosis. However, something special happens now in meiosis.

Homologous pairs move alongside each other. Remember that one chromosome of each homologous pair is inherited from the mother, and the other from the father. The homologous pairs lie close together. Now the homologous pairs exchange hereditary material. Pieces of each chromosome break off and swop with the other chromosome. The process is called "**crossing over**".

At the end of crossing over, each chromosome contains a mixture of hereditary material inherited from the mother and the father.

Metaphase I: The homologous pairs line up across the midline of the spindle. The midline is labelled the "metaphase plate" in the diagram. Each homologous pair has four chromatids, and is called a **tetrad**.

Anaphase I: The homologous pairs separate and move to opposite sides of the cell. Each chromosome still consists of two chromatids.

Telophase I: The two daughter cells divide. Each daughter cell contains only one member of each homologous pair. It has half the number of chromosomes that were present in the parent cell.

Cytokinesis I: The cytoplasm divides between the two daughter cells. This phase does not always happen; usually, the cells move straight into Meiosis II.

Second meiotic division

Prophase II: Spindle fibres form in each daughter cell from meiosis I. The chromosomes already consist of two chromatids.

Metaphase II: The chromosomes line up on the metaphase plate. Their centromeres are attached to the spindle fibres.

Anaphase II: The chromatids pull apart.

Telophase II: The chromatids unwind, the nuclear membrane re-forms, and the spindle disappears. The two cells begin to divide.

Cytokinesis II: The cytoplasm divides between each pair of new daughter cells. From the one parent cell, there are now four daughter cells. Each daughter cell has one chromosome of each homologous pair.

[New words: Meiosis: A nuclear division process that halves the chromosome number in a cell.

First meiotic division: A process in which homologous pairs of chromosome exchange genetic information and then separate into two nuclei.

Crossing over: Process in which homologous chromosomes exchange corresponding segments during meiosis.

Tetrad: A homologous pair of chromosomes, each consisting of two chromatids.]

Second meiotic division. Follows the first meiotic division. A process in which chromatids separate into two nuclei.]

2.4 Haploid and diploid

The daughter cells produced by meiosis have half the normal number of chromosomes. They are called **haploid**. The symbol for haploid is **n**.

The parent cell has two members of each homologous pair. It is called **diploid**. The symbol for diploid is **2n**.

Meiosis is a very important process for a number of reasons.

1. It halves the number of chromosomes before reproduction.

   For example, humans have a diploid number of 46. Each sperm and each egg is haploid, so they have 23 chromosomes as a result of meiosis. When a sperm and an egg meet at fertilisation, the chromosome number returns to 46.

2. It introduces genetic variation. Every cell produced by meiosis has its own combination of hereditary material. We say it is **unique**. The genetic variation comes from two sources:
   2.1 Crossing over means that hereditary material is exchanged between the chromosomes inherited from the mother and the father. Each chromosome ends up with a mixture of hereditary material from the two parents.
   2.2 Homologous pairs separate randomly during anaphase I. That means the daughter cells inherit a mixture of chromosomes inherited from the mother and the father. The correct scientific term for random separation of the chromosomes is **random segregation**.

Watch the following Youtube video to revise meiosis:

https://www.youtube.com/watch?v=D1_-mQS... is a short video showing meiosis.

[New words: Haploid: Cells that have one chromosome of each homologous pair.

Diploid: Cells that have two chromosomes of each homologous pair.

Random segregation: Separation of chromosomes at anaphase I so that each daughter nucleus receives a mixture of chromosomes inherited from the mother and the father.]

Main idea: Meiosis is a special type of cell division in which a diploid parent cell divides twice to produce four haploid cells. Each haploid cell has a unique set of hereditary material.

Unit 3: The nature of genes and alleles and their role in determining the phenotype.

Learning outcomes:

When you have finished this section, you should be able to:

- Define a gene as a unit of inheritance and distinguish clearly between the terms gene and allele;
- Explain the terms dominant, recessive, homozygous, heterozygous, genotype, phenotype, F_1 generation and F_2 generation.

3.1 Genes and alleles

The previous unit described chromosomes as carrying the hereditary material. Cell division explains how the hereditary material passes from one cell to the next. The chromosomes pass from one cell to the next in a carefully controlled way.

Mendel realised that the physical characteristics he studied were inherited independently of each other. He thought they were controlled by separate "factors". Later researchers introduced the name **genes**.

A gene is defined as a unit of inheritance. It is a section of a chromosome that is translated into a protein molecule. The protein causes the physical features to appear.

Mendel's work showed that a gene can cause different effects. For example, variations of the gene for flower colour in peas can produce purple flowers in some plants and white flowers in other plants. Variations of the same gene are called **alleles**. One allele of the gene for flower colour in pea plants produces purple flowers, while another allele of the same gene produces white flowers.

[New words: Gene: a unit of inheritance carried on the chromosomes.

Allele: Variations of a gene for a particular characteristic]

3.2 Getting to grips with genetic terms

Genetics uses a number of special terms. You need to become familiar with these terms.

Genotype and phenotype

The genes carry all the genetic information for an organism. The particular alleles an individual has are called its **genotype**. We cannot see which alleles are present in an individual's chromosomes. We can only see how the alleles are expressed through what the organism looks like, and how it functions. The characteristics expressed by the alleles are called the **phenotype**.

Homozygous and heterozygous

An individual inherits one set of chromosomes from its mother and a matching set from its father. A homologous pair of chromosomes carries genes controlling the same features, but the alleles may be different.

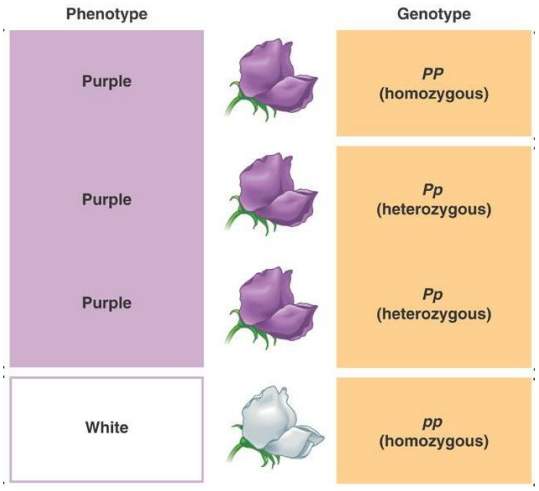
If the two alleles for a feature are the same, the individual is **homozygous**. If the two alleles are different, the individual is **heterozygous**. Homozygous means having two

identical alleles of a particular gene. Heterozygous means having two different alleles of a gene.

Dominant and recessive alleles

In some genes, one allele is always expressed in the phenotype, whether the individual is homozygous or heterozygous. This type of allele is called a **dominant** allele. The second allele is only expressed when the genotype is homozygous for that allele. This type of allele is called a **recessive** allele.

For example, pea plants have either purple or white flowers. If a pea plant has one allele for purple flowers, and one allele for white flowers, it will have purple flowers. The allele for purple flowers is dominant, and we give it a capital letter, *P*. A white-flowered pea plant has two alleles for white flowers. The allele for white flowers is recessive, and we give it a lower case *p*.



[Caption: Figure 3.1: In pea plants, purple flower colour is dominant to white flower colour.] http://cikgurozaini.blogspot.com/2010/06/genetic-1.html

Figure 3.1 shows the results of a cross between two pea plants. Three out of every four plants have purple flowers, and one out of four have white flowers. The white-flowered plant is homozygous recessive (***pp***). One-third of the purple-flowered plants are homozygous dominant (***PP***), and two-thirds are heterozygous (***Pp***).

Generations

The first cross in a series of cross-breeding experiments is called the **parent**, or **P** generation.

The offspring of a cross between two P individuals are called the **F_1 generation**.

The offspring of a cross between two F_1 individuals is called the **F_2 generation**.

> Think of it this way:
>
> Mendel chose a purple-flowered plant and a white-flowered plant for his first experiment. They are the P generation.
>
> He cross-bred the purple flowers with the white flowers. The seeds germinated and became the F_1 generation.
>
> Mendel cross-bred flowers of the F_1 generation. The seeds germinated and became the F_2 generation.

[New words: **Genotype**: The alleles that an individual carries for a particular characteristic.

Phenotype: The physical characteristic caused by an allele.

Homozygous: An individual that carries two identical alleles for a characteristic on a homologous pair of chromosomes.

Heterozygous: An individual that carries two different alleles for a characteristic on a homologous pair of chromosomes.

Dominant: An allele that is always expressed in the phenotype, even if the individual is heterozygous for that characteristic.

Recessive: An allele that is only expressed in the phenotype if the individual is homozygous for that characteristic

F_1 generation: the first generation of offspring produced by a parent (P) generation.

F_2 generation: the offspring of a cross between F_1 individuals.]

Main idea: A gene is the unit of inheritance in living organisms. Genetics uses a number of specialist terms, such as allele, genotype, phenotype, homozygous, heterozygous, dominant, recessive, F_1 and F_2 generations.

Activity 3.1: Practise using genetics terms.

Expected outcome of the activity: Learners will be able to use genetics terms correctly.

1. Choose the correct term from the list below to fill each blank. You may use each term more than once or not at all, and in the singular or the plural form.

Allele, chromosome, dominant, gene, genotype, heterozygous, homologous pair, homozygous, inheritance, phenotype, recessive.

Certain characteristics of adults pass to their offspring. This process is called ……1.1…… The nucleus of a dividing cell passes its ……1.2…….. to the daughter cells. The ……1.3…… carry coded information in sections of DNA called ……1.4……..

Every cell has two chromosomes of the same length and shape. One chromosome is inherited from the female parent and the other from the male parent. The pairs of chromosomes are called ……1.5…….. A matched pair of chromosomes carries ……1.6……. for the same characteristics, but the coded message may vary. Variations of a ……1.7……. are called ……1.8…… For example, purple seeds or yellow seeds on a maize cob are caused by different ……1.9……..

If the alleles for a particular characteristic are identical on two matching chromosomes, the individual is ……1.10…….. for that characteristic. If the alleles are different, the individual is ……1.11…… for that characteristic.

All the alleles carried by an individual are called its ……1.12…….. We cannot see the alleles. The alleles produce effects such as the appearance of an organism and the way it functions. This is called the ……1.13……..

Some alleles are expressed only when the individual has two copies of that allele. Such alleles are ……1.14…….. An allele that is expressed in ……1.15…….. or ……1.16…….. individuals is ……1.17…….. (17)

Unit 4 Solving genetics problems

Learning outcomes

When you have finished this unit, you will be able to:

- Solve genetics problems involving monohybrid crosses;
- Describe how sex is determined in humans – XX and XY chromosomes;

4.1 Monohybrid inheritance

Monohybrid inheritance is the inheritance of a characteristic that is controlled by a single pair of alleles that produce contrasting phenotypes. It is the simplest type of inheritance. Mendel chose seven characteristics of pea plants (shown in Figure 1.1) that follow monohybrid inheritance patterns.

> For example, the colour of the flowers of pea plants is controlled by a single pair of alleles. They follow monohybrid inheritance patterns.

We use letters to represent the alleles for each characteristic. For example, we have already used the letter ***P*** to represent the dominant allele for purple flower colour. The recessive allele is written as ***p***.

- A homozygous purple-flowered pea plant has the genotype ***PP***.
- A heterozygous pea plant has the genotype ***Pp***. It also has purple flowers.
- A white-flowered pea plant can only have one genotype: ***pp***.

Activity 4.1: Can you apply your reading?

Expected outcome: Learners will be able to apply the genotype notation to a new example.

1. Pea plants can produce green seeds or yellow seeds. Yellow colour is dominant over green colour. Use the letter ***Y*** to represent the dominant allele, and ***y*** to represent the recessive allele.

Write the correct genotype for each plant listed below:

1.1 Homozygous dominant for seed colour. (1)
1.2 Homozygous recessive for seed colour. (1)
1.3 Heterozygous for seed colour. (1)

Pure-breeding

Pure-breeding means that a characteristic stays the same in all the offspring, generation after generation. Mendel made sure that the plants he used in his experiments were all pure-breeding. For example, he made sure that the purple-flowered plants produced only purple-flowered plants for several generations. He made sure that the white-flowered plants produced only white-flowered plants for several generations.

Alleles separate during meiosis

Remember that each homologous pair of chromosomes carries two alleles for the same characteristic. During meiosis, all the homologous pairs separate. At the end of meiosis, each of the four cells has inherited only one of the two alleles.

Meiosis occurs in the male and female parts of a flower. The four haploid cells in the male parts become pollen grains. Each pollen grain contains one sperm. One haploid cell in the female parts becomes an egg cell.

In animals, including humans, meiosis takes place in the testes of a male and the ovary of a female. The four haploid cells produced in the testes develop into sperm. One of the four haploid cells produced in the ovary develops into an egg cell.

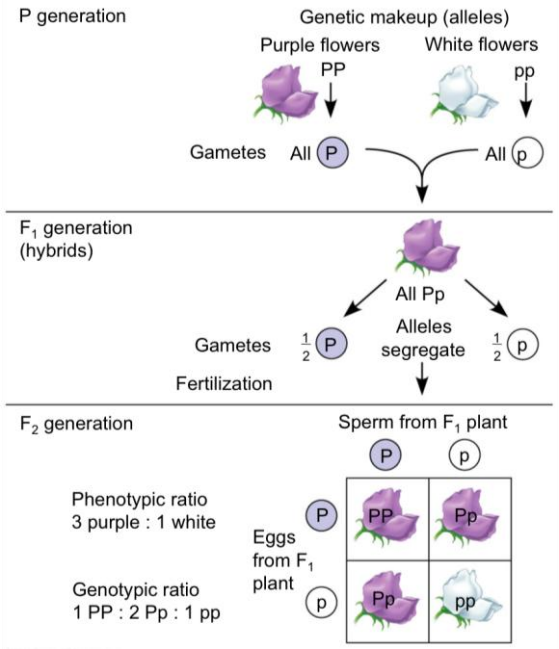
A pure-breeding purple-flowered pea plant has two identical alleles for flower colour. It is homozygous, with the genotype ***PP***. The alleles separate during meiosis. Every sperm and every egg has the genotype ***P***.

A pure-breeding white-flowered pea plant has two identical alleles for flower colour. It is homozygous, with the genotype ***pp***. The alleles separate during meiosis. Every sperm and every egg has the genotype ***p***.

Alleles join at fertilisation

When fertilisation takes place, one sperm joins with one egg. In pure-breeding purple-flowered pea plants, each sperm and each egg has the genotype **P**. When the sperm fertilises the egg, the new cell has the genotype **PP**. It will grow into a plant that produces purple flowers.

In pure-breeding white-flowered pea plants, each sperm and each egg has the genotype ***p***. When the sperm fertilises the egg, the new cell has the genotype ***pp***. It will grow into a plant that produces white flowers.



[Caption: Figure 4.1: Monohybrid cross between purple and white-flowered pea plants.]
https://classconnection.s3.amazonaws.com/567/flashcards/203567/png/law_of_segregation1316063912505.png

Figure 4.1 shows how meiosis separates the alleles into separate gametes. At fertilisation, any two gametes will join, returning the plant to a diploid genotype.

Results of a monohybrid cross.

Study Figure 4.1 as you read this description;

- Mendel chose pure-breeding purple-flowered and white-flowered plants to be the P generation. The purple flowered plants had the genotype ***PP*** and the white-flowered plants have the genotype ***pp***.

- Purple flowered plants produced gametes by meiosis. Each gamete from the purple-flowered plants had the genotype ***P***. Each gamete from white-flowered plants had the genotype ***p***.
- Mendel cross-pollinated the purple-flowered plants with the white-flowered plants. All the fertilised eggs in the F_1 generation had the genotype ***Pp***. They were heterozygous. All the plants in the F_1 generation had purple flowers.
- Half of the gametes in the F_1 generation had the genotype ***P***, and half had the phenotype ***p***.
- The F_2 generation had purple-flowered plants and white flowered plants in the ratio 3:1.

Punnett squares

A Punnett square is a diagram used to predict the outcomes of crossing different alleles for a characteristic.

Figure 4.2 is a Punnett square for the cross between two F_1 generation plants from Figure 4.1. The F_1 generation plants all have the genotype ***Pp***.

	Sperm	
Eggs ↓	***P***	***p***
P		
p		

[Caption: Figure 4.2: Punnett square for cross between F1 generation purple-flowered plants]

Notice the following points about drawing a Punnett square:

1. The alleles separate during meiosis. Each gamete can have either the ***P*** allele or the ***p*** allele. The sperm are written across the top row of the Punnett square, and the eggs in the first column of the square.

2. The remaining cells in the table show the combination of the two gametes in that row and column.

- The first cell is the combination of a ***P*** sperm and a ***P*** egg. The genotype of that plant would be ***PP***, and it will have purple flowers.

	P	***p***
P	***PP*** (purple flowers)	
p		

- The second cell is the combination of a ***p*** sperm and a ***P*** egg. The genotype of that plant will be ***Pp***, and it will have purple flowers.

	P	***p***
P	***PP*** (purple flowers)	***Pp*** (purple flowers)
p		

- The next cell is a combination of a ***P*** sperm and a ***p*** egg. The genotype of that plant is ***Pp***, and it will have purple flowers.

	P	***p***
P	***PP*** (purple flowers)	***Pp*** (purple flowers)
p	***Pp*** (purple flowers)	

- The final cell is a combination of a *p* sperm and a ***p*** egg. The genotype of that plant is ***pp***, and it will have white flowers.

	P	***p***
P	***PP*** (purple flowers)	***Pp*** (purple flowers)
p	***Pp*** (purple flowers)	***pp*** (white flowers)

2. In the F_2 generation, one genotype is homozygous dominant (***PP)***, and one combination is homozygous recessive (***pp)***. Two combinations are heterozygous (***Pp)***. Three of our every four plants in the F_2 generation have purple flowers, and one out of four have white flowers.

[**New words**: Pure-breeding: a characteristic stays the same in all the offspring, generation after generation.

Punnett square: A procedure for solving genetics problems.]

Main idea: We use a capital letter to represent the dominant allele, and the same letter in lower case for the recessive allele. Genetics problems can be solved using Punnett squares.

Activity 4.2: Can you solve a genetics problem using a Punnett square?

Expected outcome for the activity: Learners will be able to solve a genetics problem using a Punnett square.

1. Mendel noticed that some pea plants grew tall, and others were dwarf. He used the letter ***T*** to show the dominant allele for tall, and ***t*** for the recessive allele for short.
   1.1 Write the genotype for a) a pure-breeding tall plant; and b) a pure-breeding dwarf plant. (2)
   1.2 What are the possible genotypes of the gametes from a) the tall plants and b) the dwarf plants? (2)
   1.3 Mendel crossed a pure-breeding tall plant with a pure-breeding dwarf plant. What are the genotypes of the F_1 generation plants? (1)
   1.4 What are the phenotypes of the F_1 generation? (1)
   1.5 Mendel cross-bred two plants of the F_1 generation. Use a Punnett square to show the genotypes of the plants in the F_2 generation. (8)
   1.6 Mendel grew 240 plants of the F_2 generation. How may were a) tall and b) dwarf? (4)

4.2 Determination of sex

One pair of chromosomes is called the sex chromosomes. One chromosome is called the X chromosome, and the second, shorter sex chromosome is called the Y chromosome. The sex chromosomes determine what sex a person will be.

- If there are two **X** chromosomes, the person is female, with genotype **XX**.
- If there is one **X** and one **Y** chromosome, the person is male, with genotype **XY**.

At the time of meiosis, the sex chromosomes separate into different gametes. All of a woman's eggs will have one X chromosome. Half a man's sperm will have an X chromosome, and half will have a Y chromosome. The sperm that fertilises the egg determines the sex of the baby.

We can show in a Punnett square how sex is inherited.

	X	**Y**
X	**XX** (female)	**XY** (male)
X	**XX** (female)	**XY** (male)

The ratio of females: males is 1:1. Every time a baby is conceived, it has exactly 50% chance of being a girl or a boy.

Main idea: Sex is determined by the X and Y chromosomes. XX is a female, and XY is a male. The sperm that fertilises the egg determines the sex of the baby,

Activity 4.3: Discuss attitudes to the sex of a baby.

Expected outcome of the activity: Learners will be able to explain how sex is determined.

1. In some cultures, men would rather have boy babies than girl babies. They blame the woman if she only has girls. How would you explain to a man that sex is determined by the sperm? Discuss this in a group of students.
2. Draw up an educational poster that explains clearly how sex is determined.

Assessment subtopic 1

1. Choose the correct answers for each of the following questions.

   Questions 1.1 – 1.4 are based on inheritance of the colour of pea seeds. Pea plants produce yellow seeds or green seeds. Yellow colour is dominant over green colour. We use the letter ***Y*** to represent the dominant allele, and ***y*** to represent the recessive allele.

   1.1 A plant that is homozygous dominant for seed colour has the genotype ..
   A ***yy***

B ***Yy***
C ***Py***
D ***YY***

1.2 What is the phenotype of a plant that has the genotype ***Yy***?
A White flowers
B yellow-green seeds.
C Yellow seeds
D Green seeds

1.3 Mendel cross-bred plants of the F_1 generation. He germinated the seeds of the F_2 generation. He found that 360 F_2 plants produced yellow seeds. How many plants produced green seeds?
A 120
B 480
C 90
D 360

1.4 Which is the correct term for a plant that has the genotype ***yy***?
A Heterozygous.
B Homozygous recessive.
C Heterozygous recessive.
D Homozygous dominant.

1.5 The correct Punnett square to show how sex is inherited is:
A

	Y	**Y**
X	**XY**	**XY**
X	**XX**	**XY**

B

	X	**Y**
X	**XX**	**XY**
X	**XX**	**XY**

C

	X	**Y**
X	**XX**	**XY**
Y	**XY**	**YY**

D

	X	**X**
Y	**XY**	**XY**
Y	**XY**	**XY**

(10)

2. Pea plants can produce round or wrinkled seeds. Round (***R***) is dominant over wrinkled (***r***). Pure-breeding round-seeded plants were cross-bred with pure-breeding wrinkled-seeded plants.

2.1 Write the genotypes of the P generation. (2)

2.2 Round-seeded plants were cross-bred with wrinkled-seeded plants. Write a) the genotype, and b) the phenotype of the F_1 plants. (2)

2.3 F_1 plants were cross-bred. Draw a Punnett square to show the genotypes and phenotypes of the F_2 generation. (6)

Unit 5 Variation

Learning outcomes:

When you have finished this unit, you should be able to:

- Describe mutation as a change in the structure of a gene and nondisjunction as failure of homologous pairs to separate properly during meiosis;
- Illustrate the effects of gene mutations, such as in sickle cell anaemia, and chromosomal nondisjunction, such as in Downs' syndrome;
- Describe the role of random segregation of homologous pairs during meiosis, random fertilisation of sperm and egg, and mutations in producing genotypic and phenotypic variation;
- Differentiate between continuous and discontinuous variation, such as height of people of the same age (continuous variation) and human blood type (discontinuous variation);
- Explain that natural selection acts on variation in phenotypes, which are determined by genotypes;
- Explain how natural selection influences the survival of alleles in a population by differential survival of phenotypes that have a heritable, genetic basis;
- Define the terms gene pool, allele frequency and microevolution.

5.1 Origins of genetic variation

Variation refers to differences in the characteristics of individuals. Pea plants vary in a number of different characteristics. In Units 2 and 4, you learnt about the importance of meiosis and fertilisation in causing variation in a population.

- Meiosis introduces variation through crossing over;
- Meiosis introduces variation through random segregation of homologous pairs of chromosomes in anaphase I.
- During sexual reproduction, any sperm can fertilise any egg. The combination of alleles is unique to that individual.

No two individuals within a species are genetically identical. However, meiosis and fertilisation shuffle existing alleles within the population. They cannot produce new alleles.

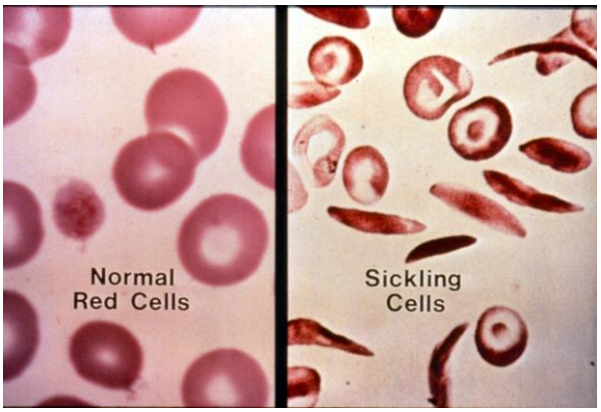
A **gene mutation** is a change in the structure of a gene. It produces a new allele. Most mutations are lethal, that is, the individual inheriting the mutated gene will not survive. Occasionally, a mutation is beneficial. Individuals that inherit the mutation have a better chance of surviving and reproducing than individuals without the mutation. The mutated allele increases in the population.

A **chromosome mutation** is loss or damage to a part or the whole of a chromosome. A chromosome mutation can also result from homologous pairs not separating properly during meiosis. This type of chromosome mutation is called **nondisjunction**.

The gametes resulting from nondisjunction have an abnormal number of chromosomes. Half have one extra chromosome, and half have one missing chromosome. The effect of nondisjunction ranges from no effect to lethal.

Effects of gene mutations

Sickle cell anaemia is an example of the effect of a gene mutation. The gene controls the formation of haemoglobin in red blood cells.



[Caption: Figure 5.1: Normal red blood cells and sickle cells.]

https://www.gemssforschools.org/sites/www.gemssforschools.org/files/default/sickle2.jpg

Figure 5.1 shows the shape of normal red blood cells, and cells that have the gene mutation for abnormal haemoglobin. The mutation makes the red blood cells sickle, and affects their ability to carry oxygen.

People who are homozygous for sickle cell anaemia do not get enough oxygen to their bodies. It usually causes stunted growth and early death.

People who are heterozygous for sickle cell anaemia have half normal red blood cells, and half sickle red blood cells. They are resistant to malaria, and live normal lives.

Sickle cell anaemia is common in parts of the world where malaria is common. People who are heterozygous have an advantage over people with normal alleles for haemoglobin.

Effects of chromosome nondisjunction

Down's syndrome is an example of chromosome nondisjunction. Chromosome 21 does not separate correctly during meiosis in the ovary. The egg cell produced has three copies of chromosome 21.

After fertilisation, the embryo has 47 chromosomes instead of the normal 46 chromosomes. Many Down's syndrome children have lethal heart defects. If they are given care and attention, people with Down's syndrome live productive lives.

A mother who is over 40 years old is at much higher risk of having a Down's syndrome baby than a younger mother.

[New words: Variation: differences in the characteristics of individuals in a population.

Gene mutation: a change in the structure of a gene.

Chromosome mutation: loss or damage to a part or the whole of a chromosome.

Nondisjunction: Homologous pairs of chromosomes that do not separate correctly during meiosis.]

Main idea: Gene mutations introduce new alleles into a population. Chromosomal nondisjunction results in individuals with one extra chromosome, or one missing chromosome.

5.2 Continuous and discontinuous variation

Some characteristics vary in an either/or fashion (pea plants are either tall or dwarf). This type of variation is called **discontinuous** variation. Other characteristics vary over a range of conditions (the heights of 25-year-old students can be any value between 1,2 m and 2,1m). Phenotypes that vary over a range show **continuous** variation.

Human blood types are an example of discontinuous variation. Do you know your blood type? There are four blood types: O, A, B or AB. The blood types are fixed categories. Human blood types are an example of discontinuous variation.

Human height is an example of continuous variation. Do you know how tall you are? Continuous variation is affected by genes and the environment. If both your parents are short people, there is a good chance you will also be short. However, children who are malnourished will not grow as tall as their genes allow them to. The amount of food they get to eat is an environmental factor that affects their adult height.

[Caption: Figure 5.2: Human height is an example of continuous variation]

http://cdn.yourarticlelibrary.com/wp-content/uploads/2013/12/b502.jpg

[New words: Discontinuous variation: characteristics that exist in two or more states, with no intermediates.

Continuous variation: characteristics that vary between a minimum and a maximum state]

Main idea: Variation in phenotypes may be discontinuous or continuous. Human height is an example of continuous variation. Human blood types is an example of discontinuous variation.

5.3 A modern explanation of natural selection

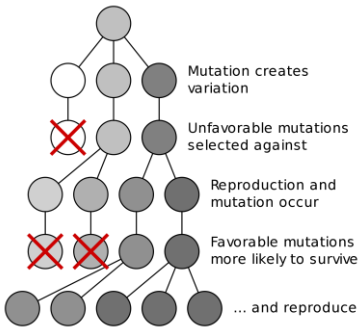
In Topic 2, we provided a description of natural selection, as it was proposed by Charles Darwin and Alfred Wallace. They said:

1. Organisms tend to produce more offspring than are needed to replace themselves when they die.
2. Individuals belonging to a species vary in characteristics such as their appearance, resistance to disease or their ability to survive drought. The variation is inherited, that is, they pass it on to their offspring.
3. The individuals in an overcrowded environment compete to survive.
4. Only the best-adapted individuals survive and reproduce. Individuals that are less well-adapted die before they reach reproductive age.
5. Over time, more and more individuals in the population have the most favourable adaptations.

Darwin and Wallace had no idea of the nature of the hereditary material. The theory of natural selection was falling out of favour among the scientific community. The discovery of genetics revived interest in natural selection, and showed that it was truly a possible mechanism for evolution. It had to be modified to accommodate the discoveries of genetics.

The modern theory of natural selection focuses on **populations** rather than individuals. It states that:

1. Populations tend to grow because rates of reproduction usually exceed rates of death.
2. As a population grows, resources such as food and living space become limited.
3. Individuals compete for the limited resources.
4. Individuals that belong to the same species share certain phenotypic characteristics.
5. Details of the phenotypic characteristics vary within a population.
6. Shared phenotypic characteristics are inherited through genes. Variations in the phenotype are caused by different alleles of the genes.
7. Certain phenotypes may increase the chance of an individual surviving and reproducing. Such phenotypes are called **adaptive traits**.
8. An allele associated with an adaptive trait tends to become more common in the population over time.



[Caption: Figure 5.3: Natural selection results in favourable alleles increasing in the population.]

https://upload.wikimedia.org/wikipedia/commons/thumb/f/f3/Mutation_and_selection_diagram.svg/2000px-Mutation_and_selection_diagram.svg.png

All the alleles that exist in a population are called its **gene pool**. The proportion of individuals that have a particular allele is called the **allele frequency** in the gene pool. If 50% of the individuals in a population have an adaptive trait, the allele frequency for that adaptive trait is 50%.

Microevolution is defined as the change in allele frequency in the gene pool of a population. Figure 5.3 illustrates how mutation introduces new alleles into the gene pool. Some mutations are eliminated, while others increase in frequency in the population. Natural selection gives rise to microevolution.

Main idea: Natural selection involves an increase in the frequency of alleles for adaptive traits in the gene pool of a population. Natural selection leads to microevolution.

[New words: population: a group of individuals of the same species living in a particular area and interbreeding.

Adaptive traits: Phenotypic characteristics that increase an individual's chance of surviving and reproducing.

Gene pool: All the alleles of all the genes in a population.

Allele frequency: The proportion of the population that have a particular allele.

Microevolution: The change in the frequency of an allele in a population.]

Assessment Subtopic 1

1. Match each term from the list below with its correct definition.

   Gene pool; Adaptive trait; Allele; Homologous pair; Mutation; Random segregation; Microevolution; Discontinuous variation

   1.1 All the alleles of all the genes in a population.
   1.2 A phenotypic character that increases an individual's chances of surviving and reproducing.
   1.3 The change in frequency of an allele in a population.
   1.4 A change in the structure of a gene.
   1.5 A characteristic that exists in two or more states, with no intermediates.
   1.6 Variations of a gene for a particular characteristic
   1.7 Two matching chromosomes, one inherited from the mother and one from the father
   1.8 Separation of chromosomes at anaphase I so that each daughter nucleus receives a mixture of chromosomes inherited from the mother and the father. (8)

2. Distinguish between the following pairs of terms:
   2.1 Mitosis and meiosis.
   2.2 Homozygous and heterozygous
   2.3 Dominant and recessive
   2.4 Genotype and phenotype
   2.5 Haploid and diploid (10)

Summary of key learning

- Inheritance means the passing of characteristics from one generation to the next. Gregor Mendel was the founder of the science of genetics. Genetics is the study of the mechanisms involved in inheritance and variation.
- Hereditary material is carried by the chromosomes, which are in the nucleus of every cell.
- Mitosis is cell division. Mitosis produces two daughter cells that have exactly the same hereditary material as each other and as the parent cell.
- Meiosis is a special type of cell division in which a diploid parent cell divides twice to produce four haploid cells. Each haploid cell has a unique set of hereditary material.
- A gene is the unit of inheritance in living organisms. Genetics uses a number of specialist terms, such as allele, genotype, phenotype, homozygous, heterozygous, dominant, recessive, F_1 and F_2 generations.
- We use a capital letter to represent the dominant allele, and the same letter in lower case for the recessive allele. Genetics problems can be solved using Punnett squares.
- Sex is determined by the X and Y chromosomes. XX is a female, and XY is a male. The sperm that fertilises the egg determines the sex of the baby,
- Variation in phenotypes may be discontinuous or continuous. Human height is an example of continuous variation. Human blood types is an example of discontinuous variation.
- Natural selection involves an increase in the frequency of alleles for adaptive traits in the gene pool of a population. Natural selection leads to microevolution.

Subtopic 2: DNA structure and function

Content:

Unit 1: The structure of DNA

Unit 2: Replication of DNA

Unit 3: The role of DNA in protein synthesis.

Unit 4: The effect of mutations on DNA structure and function.

Unit 1: The structure of DNA

Learning outcomes

When you have finished this unit, you should be able to:

- Explain the relationship between chromosomes, genes and DNA;

- Illustrate the structure of DNA as a double-helical structure, consisting of two parallel strands of nucleotides;
- Describe the components of a nucleotide;
- Describe the structure and location of messenger-RNA, transfer-RNA and ribosomal-RNA;
- Differentiate between the structure of DNA and RNA.

Activity1.1: What do you know about DNA?

1. Write down THREE things you know about DNA. If you have never heard of DNA, write "Nothing".
2. If you have never heard of DNA, watch the Youtube video called "What is a chromosome?"
   https://www.youtube.com/watch?v=xUrlreMaUrs

1.1 Chromosomes, genes and DNA

Subtopic 1 mentions chromosomes and genes frequently. Remember that

- A chromosome is a strand of hereditary material in the nucleus of a cell;
- A gene is a unit of hereditary information.

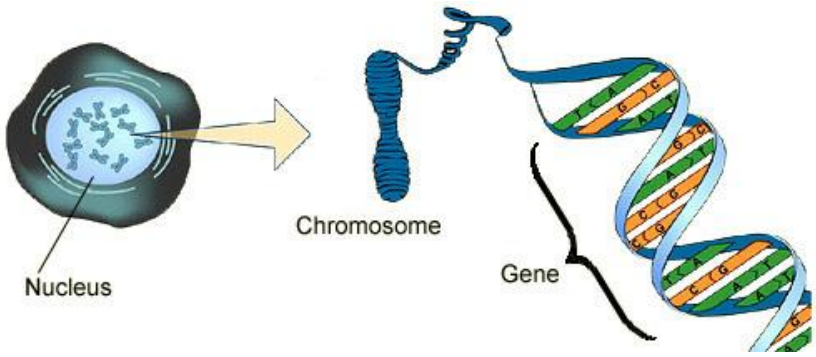


Figure 1.1: The nucleus contains chromosomes. A gene is a unit of a chromosome. The chromosomes consist of DNA.

http://www.bbc.co.uk/staticarchive/678f62dce35d0fc7ef2333d6d3bfbf53744374ff.jpg

Figure 1.1 illustrates the relationship between chromosomes, genes and DNA. It shows that chromosomes consist of long strands of a twisted molecule called DNA (deoxyribonucleic acid). It depicts a gene as a section of DNA. Figure 1.1 does not show that in a chromosome, the DNA is coiled around protein molecules called **histones**.

DNA is the hereditary material that passes from one cell to its daughter cells and from one organism to its offspring. It carries the blueprint for the structure and functioning of every cell and every organism.

[New words: DNA (deoxyribonucleic acid): the hereditary material carried by chromosomes.

Histone: A protein that is a component of a chromosome.]

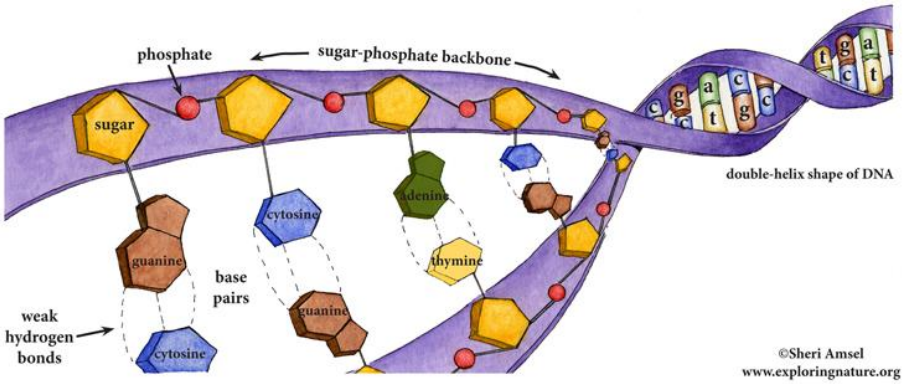
Main idea: Chromosomes consist of DNA wound around proteins called histones. Genes are sections of DNA that control phenotypic characteristics.

1.2 The structure of DNA

DNA is a very large molecule consisting of two strands that are twisted together. This type of structure is called a **double helix**.

Figure 1.2 shows more detail of the structure of DNA. Each strand consists of a backbone of alternating sugar and **phosphate** molecules. The sugar in DNA is called **deoxyribose**. It is bonded to a phosphate molecule. Together, the sugar and phosphate molecules form the two strands of DNA.

Each sugar molecule has a nitrogen-containing base attached to it. They are called **nitrogenous** bases. Find the names in Figure 1.2: **guanine**, **cytosine**, **adenine** and **thymine**. The nitrogenous bases are known by the first letters of their names: G (guanine), C (cytosine), A (adenine), T (thymine).



[Caption: Figure 1.2 Structure of DNA]

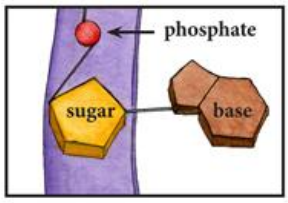
http://www.exploringnature.org/graphics/genome_art/DNA_structure72.jpg

Notice in Figure 1.2 that the base pairs hold the two strands of the sugar-phosphate backbones together. Weak **hydrogen bonds** hold the bases together. Guanine always bonds with cytosine, and adenine always bonds with thymine.

Imagine that DNA is like a tall ladder. The side-bars of the ladder are the sugar-phosphate backbones of DNA. The base-pairs are like the rungs (steps) of the ladder. The whole ladder is twisted to form the double helix.

Nucleotides

Each unit of a DNA molecule is called a **nucleotide**. It consists of a deoxyribose sugar attached to a phosphate molecule and a nitrogenous base. You can see the structure of a nucleotide in Figure 1.3.



Caption: Figure 1.3: Structure of a nucleotide

http://www.exploringnature.org/graphics/genome_art/DNA_structure72.jpg

Main idea: DNA consists of two strands wound together in a double helix. It has a sugar-phosphate backbone with nitrogenous bases linking the two strands.

[New words: Nucleotide: A unit of a nucleic acid that consist of a sugar molecule, a phosphate molecule and a nitrogenous base.

Double helix: a structure that results when two strands are twisted together to make a double spiral.

Nitrogenous base: a molecule that contains nitrogen.

Phosphate: a molecule consisting of phosphorus bonded to oxygen.

Deoxyribose: The type of sugar found in DNA.

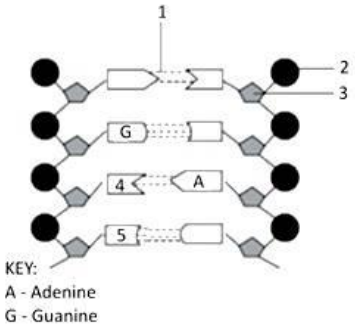
Guanine, cytosine, adenine and thymine: the names of the four nitrogenous bases found in DNA.

Hydrogen bonds: A type of weak chemical bond that forms between two molecules]

Activity 1.2 Have you understood your reading?

Expected outcome of activity: Learners will demonstrate understanding of the structure of DNA

1. The diagram shown below represents part of a molecule.



1.1 Identify the molecule. (1)
1.2 Label the parts numbered 1 – 5. (5)
1.3 Which numbers show the sugar-phosphate backbone? (2)
1.4 Complete the sentence: This molecule is normally twisted to form a ……. (1)

1.3 The structure of RNA

DNA never leaves the nucleus of the cell. A second nucleic acid molecule, called ribonucleic acid (RNA) carries the plans from DNA to the cytoplasm.

RNA differs from DNA in some important ways:

Table 1: Differences between DNA and RNA

	DNA	RNA
Number of strands	Two, twisted into a double helix	Single strand, untwisted.
Type of sugar	Deoxyribose	Ribose
Nitrogenous bases present	Adenine, cytosine, guanine, thymine	Adenine, cytosine, guanine, uracil
Where it is found	Only in the nucleus	In the nucleus and the cytoplasm
Types of each molecule	One type only	Messenger(m)-RNA, ribosomal(r)-RNA, transfer (t)-RNA

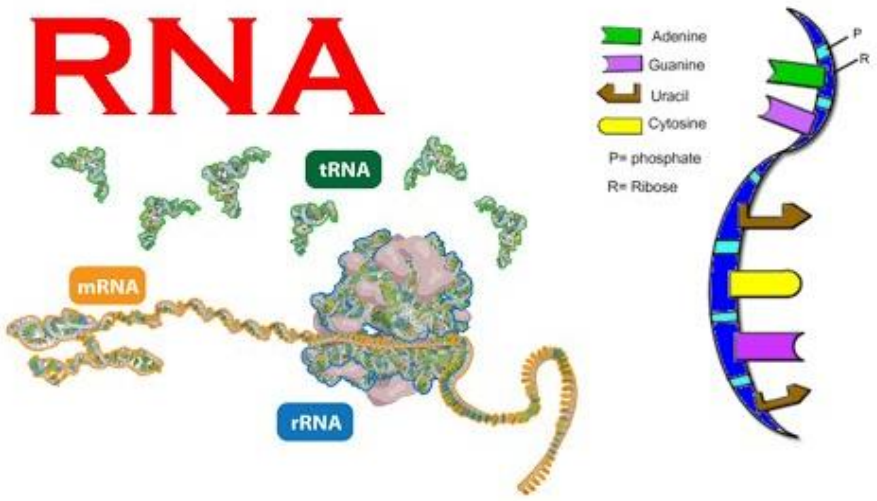


Figure 1.4 The structure of RNA.

https://i.ytimg.com/vi/FHq7kzjB9u0/hqdefault.jpg

Figure 1.4 shows the structure and types of RNA. RNA has a sugar-phosphate backbone with nitrogenous bases attached to the sugars. It is a single-stranded molecule.

Figure 1.4 shows that there are three types of RNA in a cell.

- Messenger –RNA (**mRNA**) is a single strand of RNA. It is assembled in the nucleus and then moves into the cytoplasm. mRNA translates the DNA into an instruction for making a protein.
- Ribosomal RNA (**rRNA**) is packed into small organelles called ribosomes in the cytoplasm. The ribosomes play a role in making proteins.
- Transfer-RNA (**tRNA**) is short lengths of RNA that float in the cytoplasm. They play a role in making proteins.

Main idea: RNA is a single-stranded nucleic acid. Three types of RNA are found in the nucleus and cytoplasm of the cell.

Unit 2: Replication of DNA.

Learning outcomes

When you have finished this unit, you should be able to:

- Describe the process of DNA replication, and relate it to mitosis and meiosis;
- Explain the importance of exact replication of DNA for transmission of genetic material to daughter cells and to the next generation.

2.1 Why is exact replication of DNA important?

DNA is the hereditary material that passes from one cell to its daughter cells and from one organism to its offspring. It carries the instructions for the physical characteristics and the functioning of every cell and every whole organism. It is referred to as the blueprint (or plan) for the appearance and functioning of every cell and every organism.

It is vitally important that each daughter cell and each offspring receive a complete and accurate blueprint for their development and functioning. It is like photocopying a house plan so that the builder knows exactly how to build the house. How does this happen inside a nucleus?

Do you remember that before mitosis or meiosis begins, each chromosome makes an exact copy of itself? Since a chromosome consists of DNA, this means that each DNA strand makes an exact copy of itself. The process is called **DNA replication**.

2.2 The process of DNA replication

Refer to Figure 2.1 as you read the steps of DNA replication.

1. An enzyme causes the DNA helix to unwind. It starts at one end of a DNA strand and works its way to the opposite end.
2. A second enzyme breaks the weak hydrogen bonds that hold the base pairs together. The double strand of DNA unzips, exposing the bases.
3. Free nucleotides in the nucleus pair up with the exposed bases. A always pairs with T, and G always pairs with C. This is **complementary** base pairing. New hydrogen bonds form between the new base pairs. Enzymes make this step happen quickly and accurately.
4. The two original strands (called the "old strand" in Figure 2.1) are also called the **parent strands**. The two new strands are called the **daughter strands**. Each daughter strand is **complementary** to its parent strand.
5. Each new double strand of DNA coils into a double helix again. The new DNA strands each consist of a parent strand and a daughter strand.

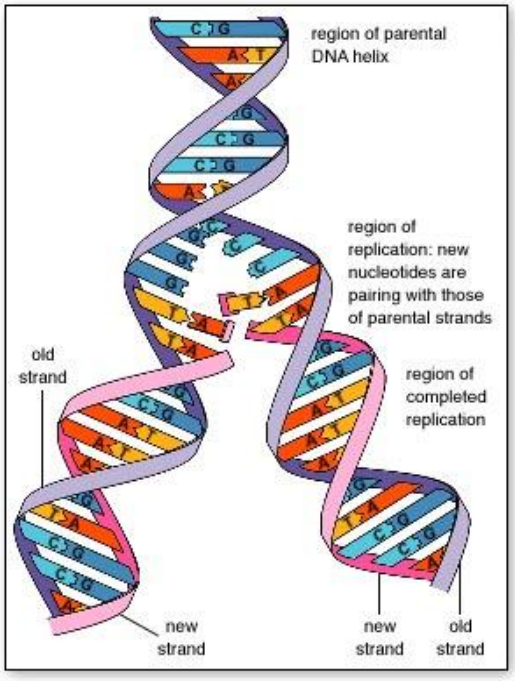


Figure 2.1: The process of DNA replication

http://www.mhhe.com/biosci/esp/2001_saladin/folder_structure/le/m7/s1/assets/images/lem7s1_1.jpg

Main idea: DNA replication is the production of an exact copy of a DNA molecule. Since DNA carries all the instructions for the appearance and functioning of a cell and an organism, exact DNA replication is very important.

[New words: DNA replication: The process whereby a DNA molecule makes an exact copy of itself.

Parent strand: the strand of DNA from the original DNA molecule.

Complementary: Matching.

Daughter strand: the new strand that is complementary to the parent strand.]

Activity 2.1 Do you understand the process of DNA replication?

Expected outcome of activity: Learners will demonstrate that they understand DNA replication.

1. Refer to Figure 2.1 to answer the questions that follow.
   1.1 In the region of replication, the new nucleotide T is moving in to pair with A on the parent strand. Which nucleotide will pair with nucleotide C on the right-hand parent strand? (1)

1.2 Which nucleotide will pair with G on the left-hand parent strand? (1)
1.3 What causes the double helix to unwind? (1)
1.4 The table below shows the sequence of bases in the region of completed replication. Two pairs of bases have been filled in.
1.4.1 Complete the base-pairs between.

Left-hand strand	A-T									C-G
Right-hand strand	A-T									C-G

(8)

1.4.2 What do you notice about the sequence of bases in the two strands? (1)

Unit 3: The role of DNA in protein synthesis

Learning outcomes

When you have finished this unit, you should be able to

- Explain that DNA carries the genetic code, which is transcribed into sequences of amino acids to form proteins that are responsible for phenotypic characteristics;
- Explain the transcription of a gene into m-RNA;
- Explain the translation of m-RNA into a polypeptide chain;
- Explain the concept of the triplet code, and use the genetic code.

2.1 How do genes control phenotypic characteristics?

Subtopic 1 of this Topic focused on patterns of inheritance. We saw how different alleles produce variation in the characteristics of organisms, for example, some pea plants produce purple flowers and some produce white flowers. This effect is due to differences in the gene for flower colour.

We now look deeper into how genes actually cause phenotypic characteristics. Genes are segments of DNA in the chromosomes. DNA is the hereditary material, but it never leaves the nucleus. How does it control characteristics like the colour of flowers?

DNA carries the instructions for how to make chains of **amino acids** called **polypeptide chains**. However, there is an intermediate step between DNA and a protein molecule. Study Figure 3.1 to see the relationship between DNA, RNA and protein synthesis.

1. DNA is first **transcribed** (re-written) into an mRNA molecule.
2. The mRNA molecule moves from the nucleus into the cytoplasm. It joins up with one or more ribosomes.
3. The mRNA molecule is **translated** into a polypeptide chain.

The polypeptide chains are further processed to become **protein** molecules. The physical characteristics of the cell are produced by protein molecules. One protein produces purple flowers, while a slightly different protein produces white flowers. The

type of protein made is controlled by the mRNA, which has transcribed the instructions from a section of DNA, the gene.

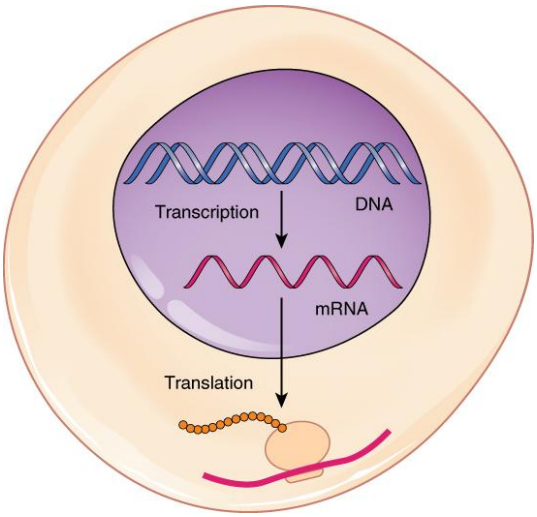


Figure 3.1: Summary of protein synthesis in a cell [Add labels for mRNA, ribosome and polypeptide chain.]

http://oerpub.github.io/epubjs-demo-book/resources/0328_Transcription-translation_Summary.jpg

[New words: Amino acid: the smallest unit of a protein molecule.

Polypeptide chain: a sequence of amino acids joined together to form a chain.

Protein: an organic molecule that plays an important role in building structures and speeding up reactions in a cell.

Transcribe (transcription): process in which a section of DNA is re-written into RNA.

Translate (translation: process in which a sequence of amino acids is assembled into a polypeptide chain following the sequence of codes in a mRNA molecule]

3.2 Transcription of a gene into mRNA

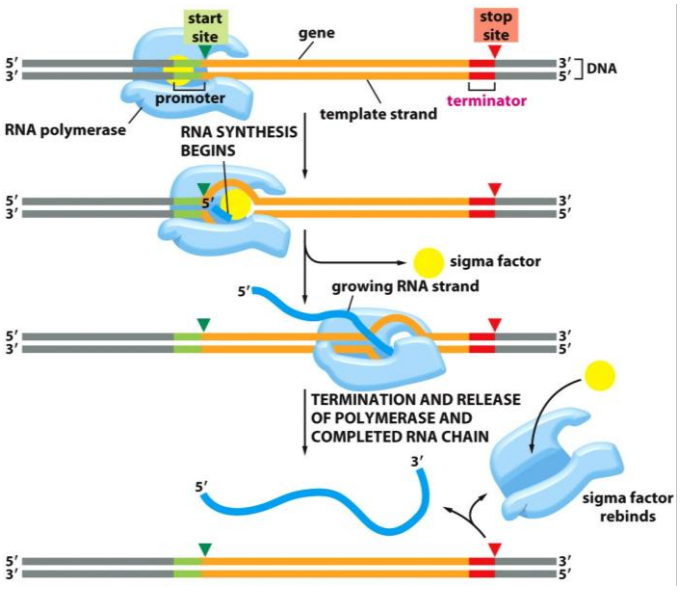


Figure 3.2 Transcription of a gene into mRNA.

http://oregonstate.edu/instruction/bi314/fall11/figure_07_09.jpg

Most of the genes in a nucleus are inactive most of the time. When a gene becomes active, it is transcribed into mRNA. Follow the process in Figure 3.2.

1. A gene becomes active when an enzyme called **RNA polymerase** and **regulatory proteins** attach themselves to a site called the **promoter**. The promoter is on the chromosome near the gene that will be transcribed. The promoter positions RNA polymerase close to the gene, Find the promoter and the RNA polymerase molecule in Figure 3.2.
2. The polymerase starts moving along the DNA, over the gene region. Find the gene in Figure 3.2. As the polymerase moves along the gene, it unwinds the double helix of the gene. It breaks the weak hydrogen bonds between base pairs to separate the double helix.
3. The polymerase adds RNA nucleotides to match the exposed bases on one strand of DNA. It matches G with C, and U with A. Remember that RNA has the base uracil instead of DNA's thymine (T). See this step in more detail in Figure 3.3.

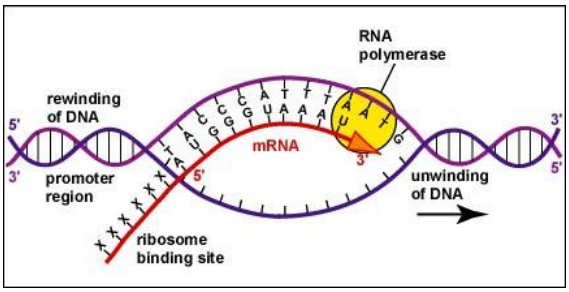


Figure 3.3 A strand of RNA grows.
http://www.tokresource.org/tok_classes/biobiobio/biomenu/transcription_translation/10000000000001B1000000D9E9F2CFD4.jpg

4. As polymerase moves along the gene, the RNA strand grows. It is **complementary** to the DNA strand.
5. The end of the gene is marked with a STOP code. It is labelled "terminator" in Figure 3.2. RNA polymerase and the new RNA strand leave the gene.

Main idea: When a gene become active, it is transcribed from DNA into a complementary strand of RNA.

[New words: RNA polymerase: An enzyme that facilitates transcription.

Regulatory proteins: Protein molecules that activate a gene.

Promoter: A section of DNA to which RNA polymerase binds to start transcription.]

3.3 Translation of mRNA into a polypeptide chain

The strand of mRNA leaves the nucleus and moves into the cytoplasm. mRNA's function is to carry the DNA's protein-building instructions to the ribosomes and tRNA where the instructions are translated.

The triplet code

Now you need to understand the nature of the instructions for assembling a polypeptide chain. Remember that DNA has four different bases: A, T, G and C. RNA has A, U, G and C. A **codon** is a sequence of three bases in either the DNA or the RNA. Examples of DNA codons are:

AAA; ATC; GCG; ATG

The nature of the instructions for assembling a polypeptide chain is the **triplet code**.

Quick activity: Write down four more codons for DNA.

When mRNA is transcribed from DNA, it is complementary to the DNA codons. Table 3.1 shows a few DNA codons and the complementary RNA codons.

Table 3.1: DNA codons and their complementary RNA codons							
DNA codons	AAA	ATC	GCG	ATG	CCC	TAG	CTG
Complementary mRNA codons	UUU	UAG	CGC	UAC	GGG	AUC	GAC

Because there are four bases, and each code consists of three bases, there are 64 possible triplet codes. But what do triplets code for?

Proteins are large molecules that are made up of units called **amino acids**. There are 20 amino acids. Examples are glutamine, valine, adenine and proline. The amino acids must be assembled in a particular order to make a **polypeptide chain**. The chain is then folded and modified to make the protein.

The codons in DNA tell the cell which amino acids must be selected, and in which order they must be assembled to make the polypeptide chain. The DNA instructions are transcribed exactly into a sequence of codons in mRNA. mRNA is therefore also a list of codes for the amino acid sequence in a polypeptide.

Translation

When the mRNA enters the cytoplasm, a ribosome clamps onto one end of the mRNA. The ribosome has two **active sites** where translation takes place.

tRNA now enters the picture. tRNA has two active sites: one is a triplet code, and the other is a site where an amino acid is attached. The triplet codes on tRNA are complementary to the mRNA codons. They are called **anticodons**.

Quick activity: Figure 3.4 shows three tRNA molecules. Find the anticodons on each tRNA, and find the amino acid attached to the tRNA.

The anticodon on each tRNA molecule determines which amino acid is attached. Table 3.2 shows some tRNA anticodons and the amino acids they code for.

Table 3.2 tRNA anticodon and their amino acids					
tRNA anticodon	AAA	GGG	UGU	CCG	CUU
Amino acid	phenylalanine	proline	threonine	glycine	glutamine

Figure 3.4 shows how the mRNA, ribosome and tRNA interact to produce a polypeptide chain. The mRNA slides through the ribosome until it reaches the start code. This is usually AUG in mRNA. It signals to the ribosome that translation starts at this point.

In Figure 3.4, the mRNA is sliding through the ribosome from left to right. As the first mRNA codon moves into the active site on the ribosome, a matching tRNA moves into place. Its anticodon is complementary to the mRNA codon.

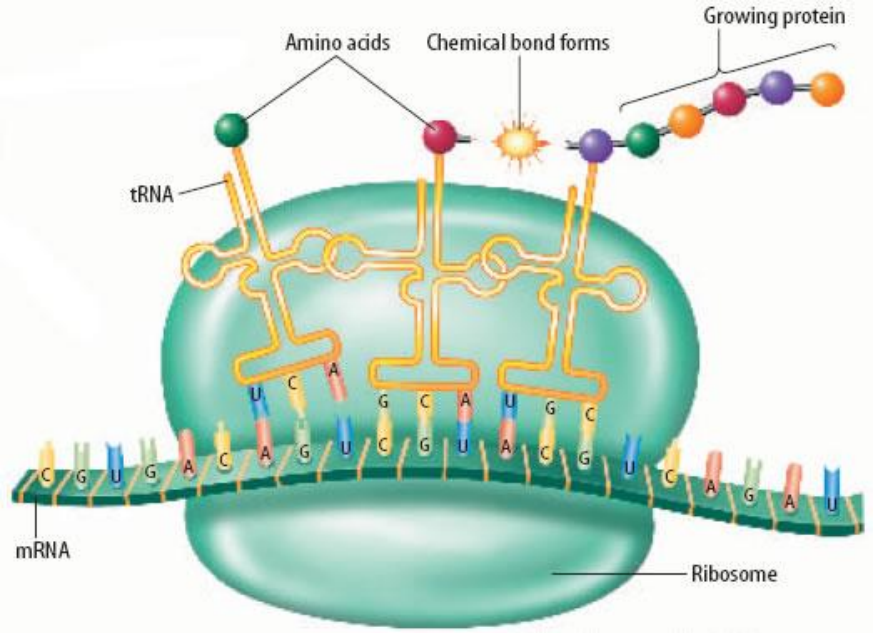


Figure 3.4 mRNA is translated into a polypeptide chain.

http://www.proteinsynthesis.org/wp-content/uploads/2015/09/what-is-the-second-step-of-protein-synthesis.jpg

Figure 3.4 shows that the codon in the active site is ACG. The anticodon on the tRNA in that site is UGC. It is the correct match for the codon. The tRNA locks into place, and its amino acid has joined the growing polypeptide chain. The tRNA then leaves the ribosome.

The second active site has the codon CGU. The correct anticodon is GCA. That tRNA is about to give up its amino acid to join the polypeptide chain.

A tRNA is entering the ribosome from the left. The codon is AGU. The anticodon is UCA, which is correct. The amino acid will be next to join the polypeptide chain.

Three codons mark the point at which translation must stop. These are UAA, UAG and UGA. They are called the **stop codons**. When the ribosome reaches a stop codon, it leaves the mRNA. The polypeptide chain leaves the ribosome, and moves to other cell organelles for further processing until it is a functional protein molecule.

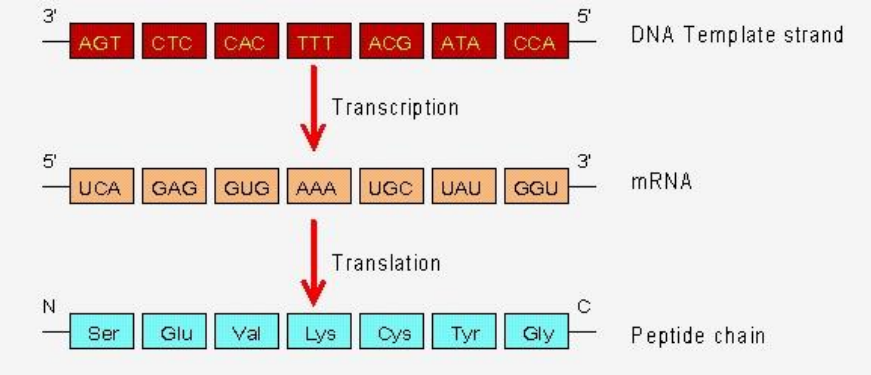


Figure 3.5: Summary of protein synthesis

https://blog.udemy.com/wp-content/uploads/2014/06/dna1.jpg

Figure 3.5 summarizes the processes of transcription and translation. Study the diagram, and see that the mRNA codons are complementary to the DNA codons. Notice that each mRNA codon translates into an amino acid.

Watch the YouTube video called "From DNA to protein" for a summary of protein synthesis. https://www.youtube.com/watch?v=gG7uCskUOrA

Activity 3.1: Can you apply what you have learnt?.

Expected outcome of activity: learners will be able to construct an amino-acid sequence given an mRNA sequence.

Table 3.3: Amino acids and their mRNA codons.

Amino acid	Alanine	Arginine	Asparagine	Aspartic acid	Cysteine	Glutamic acid	Glutamine
mRNA codons	GCU, GCC, GCA, GCG	AGA, AGG	AAU, AAC	GAU, GAC	UGU, UGC	GAA, GAG	CAA, CAG
Amino acid	Glycine	Histidine	Isoleucine	Leucine	Lysine	Methionine/ START	Phenylalanine
mRNA codons	GGU, GGC, GGA, GGG	CAU, CAC	AUU, AUC, AUA	CUU, CUC, CUA, CUG, UUA, UUG	AAA, AAG	AUG	UUU, UUC
Amino acid	Proline	Serine	Threonine	Tryptophan	Tyrosine	Valine	STOP
mRNA codons	CCU, CCC, CCA, CCG	UCU, UCC, UCA, UCG	ACU, ACC, ACA, ACG	UGG	UAU, UAC	GUU, GUC, GUA, GUG	UAA, UAG, UGA

1. Study Table 3.3 and answer the questions that follow.
   1.1 How many codons code for each of the following amino acids?
      a. Proline
      b. Isoleucine
      c. Tyrosine
      d. Tryptophan (4)
   1.2 The tRNA anticodon is complementary to the mRNA codon. For example, the anticodon for the codon CGU is GCA. Write the anticodons for each of the following codons:
      a. ACU
      b. AUG
      c. CCG
      d. UUU (4)
   1.3 A sequence of four codons is: AUG CAU CCG. The sequence of anticodons that will bind to each codon are: UAC GUA GGC. The amino-acid sequence coded by the codons is methionine – histidine – proline.

      Translate each of the following codon sequences into:

      a) the sequence of anticodons that will bind to the codons;

      b) the amino acid sequence coded by the codons.

      1.3.1 UGG AAC GCC GCU
      1.3.2 AAG GGA UUU UAG
      1.3.3 ACG UCC UCG GUA (12)

Main idea: mRNA is translated into a polypeptide chain, with the assistance of ribosomes and tRNA. The code that carries the instructions for assembling the polypeptide consists of sequences of 3 bases, called the triplet code.

[New words: Codon**:** a sequence of three bases in either the DNA or the RNA, which codes for an amino acid.

Triplet code**:** the nature of the instructions for assembling a polypeptide chain.

Amino acid: a unit of a protein.

Polypeptide chain: a sequence of amino acids that eventually forms part of a protein.

Anticodon: a sequence of three bases that is complementary to an RNA codon.]

Unit 4: The effect of mutations on DNA structure and function

Learning outcomes

When you have finished this unit, you should be able to:

- Explain the effects of mutations on the triplet code;

- Apply the processes of mutation in DNA to genetic mutations and phenotypic variation, and thereby to natural selection.

4.1 Small-scale mutations

We discussed genetic mutations in Subtopic 3.1. In this section, we explore how genetic mutations occur in DNA. Now that you understand the nature of the genetic code, you can understand the effect of a change in a single base-pair. It can change the amino acid that is coded in the polypeptide chain.

Most mutations occur during DNA replication. Even though the nucleus has mechanisms to check and delete any errors in replication. Some slip through undetected. These are small-scale mutations, involving a single base pair in a gene. They are called **point mutations.**

Point mutations can be divided into two categories: substitutions and insertions or deletions. We discuss each separately.

Substitutions

A substitution occurs when a base-pair is replaced with a different base-pair. For example, if a base-pair A-T is replaced C-G, a substitution has occurred.

Some substitutions have no effect on the encoded protein. Others code for a different amino acid, which can alter the way a protein functions.

Sickle cell anaemia is the result of a substitution of just one base-pair in the gene for making the protein haemoglobin. Haemoglobin is a very large protein consisting of hundreds of amino acids. The two genes containing the codes for haemoglobin are very long. Table 4.1 shows the substitution that is responsible for sickle-cell haemoglobin.

Table 4.1 Effect of a single base substitution on haemoglobin

	Normal haemogolobin	Sickle-cell haemoglobin
DNA	------CTC-------	-------CAC------
mRNA	------GAG------	-------GUG-----

Table 3.3 shows that the mRNA codon GAG codes for the amino acid *glutamic acid*, while GUG codes for the amino acid *valine*. Sickle-cell haemoglobin causes abnormal red blood cells. The substitution of just one base-pair in the DNA has a significant effect on the life of the individual.

Insertions and deletions

Insertions are the addition of a base pair in a gene. Deletions are the loss of a base pair in a gene. These mutations have a much greater effect on the resulting protein than most substitutions.

Consider Table 4.2

Table 4.2 Normal DNA sequence, its transcription and translation

Normal DNA sequence	T A C T T C A A A C C G A T T
DNA divided into triplet codes	TAC TTC AAA CCG ATT
Complementary mRNA	AUG AAG UUU GGC UAA
Amino acid sequence	Methionine – Lysine – Phenylalanine – Glycine – stop

If an extra base is **inserted** in the DNA code, Table 4.2 changes.

Table 4.3 Effect of an insertion (shown in red) in a DNA sequence.	
DNA sequence with insertion	T A C A T T C A A A C C G A T T
DNA divided into triplet codes	TAC ATT CAA ACC GAT T
Complementary mRNA	AUG UAA GUU UGG CUA A
Amino acid sequence	Methionine – stop

The insertion changes all the triplet groupings following the insertion. The result is a completely different sequence of amino acids. The protein will almost certainly be non-functional.

If one or more bases are **deleted** from the DNA code, the results are similar to insertions of one or two bases, as you can see in Table 4.3. Table 4.4 shows what happens if a whole triplet of three codes is deleted.

Table 4.4 Effect of a deletion in a DNA sequence.	
DNA sequence with deletion of one triplet	T A C A A A C C G A T T
DNA divided into triplet codes	TAC AAA CCG ATT
Complementary mRNA	AUG UUU GGC UAA
Amino acid sequence	Methionine – Phenylalanine – Glycine - stop

If a whole triplet code is deleted, one amino acid (lysine) is missing from the polypeptide. This may have no effect on the protein, or it could make the protein function differently, or it could make the protein completely dysfunctional.

Insertions and deletions of one or two base pairs have a serious effect on the resultant protein. Insertions or deletions of three base pairs alter one amino acid: one extra if it is an insertion, or one less if it is a deletion. The effect could be lethal, detrimental, or it could be beneficial.

Activity 4.1: Substitutions, deletions and insertions

You will need to refer to Table 3.3 when you answer this question.

1. A normal DNA sequence reads:

   TACTTGTCCGATATC

   1.1 Work out a) the mRNA sequence that is complementary to this DNA sequence and b) the amino-acid sequence that would result. (4)

   1.2 A mutation inserts an extra A to change the sequence as follows:
   TACTTGTCCGAATATC
   Work out a) the mRNA sequence and b) the amino acid sequence that would result. (4)

   1.3 A different mutation substitutes one C for a G as follows:
   TACTTGTCGGATATC
   Work out a) the mRNA sequence and b) the amino acid sequence that would result. (4)

   1.4 A deletion removes two bases as follows:
   TACTTGTCCGATATC
   Work out a) the mRNA sequence and b) the amino acid sequence that would result. (4)

Main idea: Substitutions, insertions and deletions are types of gene mutations that occur during DNA replication. They alter the proteins that are produced by the gene.

[New words: Point mutations: mutations involving only one triplet code.

Substitution: the replacement of one base pair in a gene with another.

Insertion: the addition of one or more base pairs to a gene.

Deletion: the removal of one or more base pairs from a gene.]

Summary of key learning

- Chromosomes consist of DNA wound around proteins called histones. Genes are sections of DNA that control phenotypic characteristics.
- DNA consists of two strands wound together in a double helix. It has a sugar-phosphate backbone with nitrogenous bases linking the two strands.
- RNA is a single-stranded nucleic acid. Three types of RNA are found in the nucleus and cytoplasm of the cell.
- DNA replication is the production of an exact copy of a DNA molecule. Since DNA carries all the instructions for the appearance and functioning of a cell and an organism, exact DNA replication is very important.
- When a gene become active, it is transcribed from DNA into a complementary strand of RNA.
- mRNA is translated into a polypeptide chain, with the assistance of ribosomes and tRNA. The code that carries the instructions for assembling the polypeptide consists of sequences of 3 bases, called the triplet code.
- Substitutions, insertions and deletions are types of gene mutations that occur during DNA replication. They alter the proteins that are produced by the gene.

4.2: Pulling together Subtopics 1 and 2

We can relate Subtopic 1 with subtopic 2 in this way:

Table 4.5: Applying mutations in DNA to genetic mutations and phenotypic variation, and thereby to natural selection.	
Genes control the physical characteristics and functioning of cells and whole organisms. The genotype controls the phenotype.	Genes consist of long sections of DNA. Genes act by the DNA being transcribed into RNA, which is translated into a polypeptide chains. The polypeptides become proteins that control the phenotype.
Different forms of genes, called alleles, are responsible for phenotypic variation in a population.	Alleles are actually variations of the DNA codes for a protein. Slight differences in the DNA code produce phenotypic variations.
Variation arises from re-shuffling the existing gene pool during meiosis and fertilisation. New alleles are introduced into a population through genetic mutations, which are changes in the genetic information carried by the genes.	Most mutations arise during DNA replication. They involve substitutions, insertions or deletions. They change the sequence of bases in the DNA. The mutant DNA changes one or more amino acids in a protein. Some mutations are harmful, some are neutral, and some are beneficial.
Natural selection results in an increase in favourable alleles in a population.	Favourable alleles result from DNA mutations that produce improved proteins. Substitutions are more likely to produce favourable alleles than insertions or deletions.

We reach the conclusion that the observations made by geneticists such as Gregor Mendel can be explained by the structure and functioning of DNA. DNA controls all aspects of the phenotype. It does so by being transcribed into mRNA, which is translated into chains of amino acids making polypeptide chains. Polypeptides mature into proteins, which are responsible for producing the phenotype of the cell or organism.

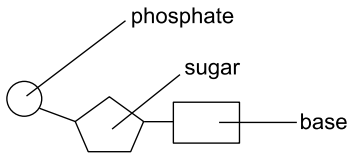
Mutations to the DNA result in new alleles, which may be favourable. The favourable mutations increase in the population, resulting in evolution and increased biodiversity.

Biodiversity and adaptation to environmental conditions result from gene mutation, natural selection and speciation. Evolution ultimately depends on mutations in the DNA.

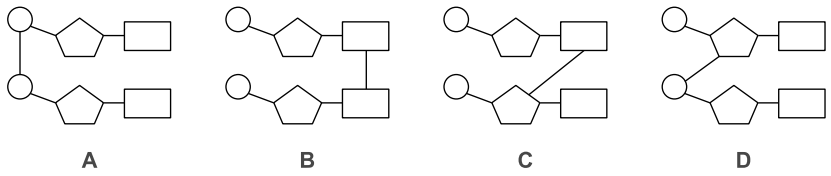
Assessment: Subtopic 2

1. Choose the correct answer for each of the following questions.

1.1 The structure of one nucleotide is shown below



Which of the following diagrams shows two nucleotides joined together correctly?



1.2 DNA is NOT present in a …
A nucleus.
B gene.
C membrane.
D chromosome.

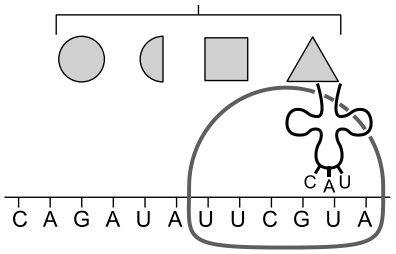
1.3 Which nucleic acids are involved in the transcription phase of protein synthesis?
A DNA and rRNA.
B DNA, mRNA and tRNA.
C DNA only.
D DNA and mRNA.

1.4 What is the name of the type of gene mutation where one incorrect nucleotide replaces the correct nucleotide?
A Inversion
B Deletion
C Substitution
D Insertion

1.5 During DNA replication, the base T is complementary to the base A. During transcription, which RNA base is complementary to A?
A uracil
B thymine
C guanine
D cytosine

1.6 The two strands of DNA are held together by ....
A weak hydrogen bonds.
B the double helix.
C nitrogen bases.
D the sugar-phosphate strand.

1.7 Identify the process taking place in the following diagram ...



A DNA replication
B Translation
C Transcription
D Mutation

1.8 Which of the following is/are correct for the structure of DNA?

i) It contains equal amounts of adenine and thymine.
ii) It contains equal amounts of guanine and cytosine.
iii) The sequence UCCGCAG is complementary to the sequence AGGCGTC.
iv) It contains the sugar ribose.
v) It is made up of building blocks called nucleotides.

A i), ii) and v)

B i), ii) iii) and iv)

C i), ii) iv) and v)

D i), ii), iii) and v) (16)

2. The following table lists some amino acids and their codons on a mRNA strand.

Amino acid	Tyrosine	Alanine	Phenylalanine	Leucine	Arginine	Glycine	Arginine
mRNA codon	UAU	GCG	UUU	UUA	CGU	GGG	AGG

Part of a DNA strand has the base sequence: **AATCGCAAATCCCGCATA**

2.1 Name the process by which the DNA is copied into mRNA. (1)

2.2 List the base sequence of the mRNA made from this strand of DNA. (2)

2.3 The mRNA strand is read from left to right. List the amino acid sequence it codes for. (6)

2.4 A single base deletion occurs in the DNA, changing the strand to **AATCGCAAACCCGCATA.**

What effect does this deletion have on the polypeptide produced? (4)

2.5 A tRNA carries the anticodon CCC. Name the amino acid attached to this tRNA. (1)

GLOSSARY OF TERMS

Adaptation: Any special feature of an organism that helps it to survive in its environment**.**

Adaptive traits: Phenotypic characteristics that increase an individual's chance of surviving and reproducing.

Allele frequency: The proportion of the population that have a particular allele.

Allele: Variations of a gene for a particular characteristic

Allopatric speciation: Speciation that results from a population being separated into two or more separate populations by a physical barrier.

Amino acid: A unit of a protein.

Anaphase: The phase of mitosis when sister chromatids separate and move to opposite poles of the cell.

Ancestral species: A species that produces descendant species.

Annual: A plant that lives for only one season.

Antibiotic: A drug that treats bacterial infections.

Anticodon: A sequence of three bases that is complementary to an RNA codon.

Autotrophic: An organism that is able to manufacture its own food.

Biodiversity: The number of different species in an area.

Biogeography: The study of the distribution of species in different parts of the world.

Biome: A region of the biosphere that has a particular type of plant life, controlled by the climate of the region

Biosphere: All parts of the Earth where life can exist.

Canines: Pointed teeth that are also called "eye teeth".

Centriole: A structure in the cell that produces the spindle.

Centromere: The place that holds two chromatids together.

Chitin: A substance that strengthens the cell walls.

Chromatid: After a chromosome has made a copy of itself, each identical strand is called a chromatid.

Chromatin: The strands of hereditary material in the nucleus when the cell is not dividing.

Chromosome mutation: Loss or damage to a part or the whole of a chromosome.

Chromosomes: A strand of hereditary material in the nucleus of a cell.

Classification: Sorting objects into groups according to features they share.

Codon: A sequence of three bases in either the DNA or the RNA, which codes for an amino acid.

Common ancestor: The species that has given rise to a number of different species.

Comparative anatomy: The study of similarities and differences in structures present in groups of organisms.

Complementary: Matching.

Conservation concern: Species that must be conserved.

F_1 generation: the first generation of offspring produced by a parent (P) generation.

Continuous variation: Characteristics that vary between a minimum and a maximum state.

Crossing over: Process in which homologous chromosomes exchange corresponding segments during meiosis.

Cytokinesis: The phase of the cell cycle when the cytoplasm divides.

Daughter strand: The new strand of DNA that is complementary to the parent strand.

Deletion: The removal of one or more base pairs from a gene.

Deoxyribose: The type of sugar found in DNA.

Descent with modification: The theory that all species arose from a succession of ancestors as they adapted to different lifestyles and environments.

Diploid: Cells that have two chromosomes of each homologous pair.

Discontinuous variation: Characteristics that exist in two or more states, with no intermediates.

DNA (deoxyribonucleic acid): The hereditary material carried by chromosomes.

DNA replication: The process whereby a DNA molecule makes an exact copy of itself.

Dominant: An allele that is always expressed in the phenotype, even if the individual is heterozygous for that characteristic.

Double helix: A structure that results when two strands are twisted together to make a double spiral.

Endemic: Species that occur naturally in a particular area and nowhere else on earth.

Equator: The mid-line of the spindle.

Eukaryotic: Cells that have a nuclear membrane around the chromosomes, membranes and organelles.

Evolution: A change in the line of descent.

Exotic: Species that have been introduced to an area from another part of the world

Extinct: A species that no longer exists alive.

F_2 generation: The offspring of a cross between F_1 individuals.

Femur: The upper leg bone that joins the leg to the pelvis.

First meiotic division: A process in which homologous pairs of chromosome exchange genetic information and then separate into two nuclei.

First-line antibiotics: Antibiotics that are prescribed when a person is first diagnosed with TB.

Foramen magnum: The large hole in the skull through which the spinal cord passes.

Fossil: The preserved remains of an organism, or preserved traces of organisms that lived a long time ago.

Gene mutation: A change in the structure of a gene.

Gene pool: All the alleles of all the genes in a population.

Gene: A unit of inheritance carried on the chromosomes.

Genetics: The study of the mechanisms involved in inheritance and variation.

Genotype: The alleles that an individual carries for a particular characteristic.

Geographic isolation: Separation of two or more populations by a physical barrier.

Guanine, cytosine, adenine and thymine: The names of the four nitrogenous bases found in DNA.

Haploid: Cells that have one chromosome of each homologous pair.

Hereditary material: A substance or structure that controls characteristics of an organism. It passes from one generation to the next.

Heterotrophic: An organism which consumes food for nutrition.

Heterozygous: An individual that carries two different alleles for a characteristic on a homologous pair of chromosomes.

Histone: A protein that is a component of a chromosome.

Homologous pairs: A matching pair of chromosomes, one inherited from the mother and one from the father.

Homozygous: An individual that carries two identical alleles for a characteristic on a homologous pair of chromosomes.

Hotspot: A region with a high level of biodiversity, particularly endemic species.

Hydrogen bonds: A type of weak chemical bond that forms between two molecules.

Hyphae: The threads that make up the body of a fungus.

Indigenous: Species that occur naturally in a particular area.

Inheritance: The passing of characteristics from one generation to the next.

Insertion: The addition of one or more base pairs to a gene.

Interphase: The phase of the cell cycle between cell divisions.

Meiosis: A nuclear division process that halves the chromosome number in a cell.

Metaphase: The phase of mitosis when chromosomes line up across the equator of the spindle.

Microevolution: The change in the frequency of an allele in a population.

Mitosis: The process in which a nucleus divides into two daughter nuclei which have identical hereditary material to each other and to the parent cell.

Monera: The kingdom to which bacteria belong.

Multicellular: An organism that consists of many cells.

Natural selection: The differential survival and reproduction of individuals of a population based on differences in heritable characteristics.

Nitrogenous base: A molecule that contains nitrogen.

Nondisjunction: Homologous pairs of chromosomes that do not separate correctly during meiosis.

Nuclear membrane: The membrane that separates the hereditary material from the cytoplasm.

Nucleotide: A unit of a nucleic acid that consist of a sugar molecule, a phosphate molecule and a nitrogenous base.

Nucleus: The structure in every cell that contains the hereditary material that controls all the activities of the cell.

Organelles: Structures in a cell that perform a particular function. Examples are the nucleus, chloroplasts and mitochondria.

Palate: The roof of the mouth.

Parasite: An organism that lives in or on another organism and feeds on another organism.

Parent strand: The strand of DNA from the original DNA molecule.

Pelvic girdle: The bones that make up the pelvis of a vertebrate.

Phenotype: The physical characteristic caused by an allele.

Phosphate: A molecule consisting of phosphorus bonded to oxygen.

Point mutations: Mutations involving only one triplet code.

Poles: Opposite ends of the spindle.

Polypeptide chain: A sequence of amino acids that eventually forms part of a protein.

Population: A group of individuals of the same species living in a particular area and interbreeding.

Pre-human: One of many species that show characteristics that are like humans.

Prokaryotic: Cells that have no membrane surrounding the chromosome.

Promoter: A section of DNA to which RNA polymerase binds to start transcription.

Prophase: The phase of mitosis when chromosomes coil up and attach themselves to the spindle.

Protein: An organic molecule that plays an important role in building structures and speeding up reactions in a cell.

Punnett square: A procedure for solving genetics problems.

Pure-breeding: A characteristic stays the same in all the offspring, generation after generation.

Radiometric dating: Dating rock layers by measuring the relative amounts of radioactive elements and their decayed products in rock.

Random segregation: Separation of chromosomes at anaphase I so that each daughter nucleus receives a mixture of chromosomes inherited from the mother and the father.

Recessive: An allele that is only expressed in the phenotype if the individual is homozygous for that characteristic

Regulatory proteins: Protein molecules that activate a gene.

Relative dating: Organising rock layers and their fossils into a sequence according to the depth at which they are found.

Reproductive isolation: Populations that cannot breed successfully together.

RNA polymerase: An enzyme that facilitates transcription.

Saprotrophic: An organism that feeds on living or dead organic matter.

Second meiotic division. Follows the first meiotic division. A process in which chromatids separate into two nuclei.

Sedimentary rock: Rock that forms when sand and mud settle to the bottom of seas, lakes and swamps. They are compressed by more sediment and by water, and turn into rock

Selective advantage: Characteristic of an organism that enables it to survive and reproduce better than other organisms in the population.

Similarity: Aspects of two objects that are alike.

Speciation: The evolutionary process in which new species arise.

Species: A group of organisms that share many characteristics, and can breed successfully.

Spindle: A set of threads that joins the two halves of the centriole.

Substitution: the replacement of one base pair in a gene with another.

Telophase: The phase of mitosis when the two daughter nuclei form.

Tetrad: A homologous pair of chromosomes, each consisting of two chromatids.

Threatened: Species that face a high risk of extinction.

Tissue: A group of cells that perform a particular function, e.g. muscle tissue

Transcribe (transcription): Process in which a section of DNA is re-written into RNA.

Translate (translation): Process in which a sequence of amino acids is assembled into a polypeptide chain following the sequence of codes in a mRNA molecule.

Triplet code: The nature of the instructions for assembling a polypeptide chain.

Variation: Differences in the characteristics of individuals.

Viable: Organisms that survive and are able to reproduce.

Answers to activities and assessments

Topic 1: Biodiversity

Subtopic 1: Biodiversity and the biomes of South Africa

Activity 1.1 This is an open-ended activity to enable you to identify your prior knowledge about the topic.

Unit 1: Definitions of the biosphere and biomes

No activities

Unit 2: Factors defining biomes

Activity 2.1: Find the biomes on a map of South Africa

1.1 Follow the instructions.
1.2 Use the map to find the biome that you live in.
1.3 Nama Karoo, Savanna, and Grassland (3)
1.4 Fynbos and Succulent Karoo (2)

Activity 2.2: Have you understood your reading?

1.1 Answer is given.
1.2 Fynbos, savanna, grassland.
1.3 Grassland, Albany thicket, Nama Karoo.
1.4 Forest, grassland.
1.5 Savanna
1.6 Succulent Karoo
1.7 Indian Ocean Coastal Belt, Savanna, Grassland, Nama Karoo.
1.8 Grassland
1.9 Albany Thicket, Desert, Succulent Karoo.
1.10 Albany Thicket
1.11 Desert (10

Activity 2.3: Have you understood your reading?

1.2, 1.5, 1.6, 1.7, 1.9 (5)

Unit 3: Exploring the biomes of South Africa

Assignment 1: Carry out research on one biome of South Africa

Rubric for marking the assignment:

Aspect of the report	Meets all the requirements	Meets some requirements	Meets a few requirements	Present, but does not meet the requirements	Absent
Title	2	1	0	0	0
Map showing the location	3	2	1	0	0

of the biome					
Description of climate	5	4	3	1	0
Graphs of temperature and rainfall	5	4	2	1	0
Description of soils	4	3	2	1	0
Description of altitude	3	2	1	0	0
Description of vegetation	5	4	2	1	0
Description of animals	4	3	2	1	0
Threats to the biome	4	3	2	0	0
Conservation efforts	4	3	2	1	0
Uses own words; no copying from sources	3	2	1	0	0
References given	2	1	0	0	0
Illustrations are appropriate	3	2	1	0	0
Neat presentation	3	2	1	0	0
TOTAL	50				

Activity 3.1: Have you understood your reading?

1.1 Threatened
1.2 Extinct
1.3 Least concern
1.4 Threatened
1.5 Least concern
1.6 Threatened
1.7 Extinct
1.8 Least concern (8)

Assessment: Subtopic 1

1.1 Biosphere

1.2 Biome
1.3 Adaptation
1.4 Threatened
1.5 Extinct
1.6 Least Concern
1.7 Sustainable (7)

2.

Column A	Column B
2.1 Fynbos	B Winter rainfall area, with great diversity of plants.
2.2 Forest	H Small patches of large trees in areas with fertile soils.
2.3 Desert	G Sandy area that receives very little rainfall.
2.4 Albany Thicket	F Area with rainfall all year round and thick bush.
2.5 Savanna	A Characteristic vegetation is grassland with scattered trees.
2.6 Nama Karoo	I Semi-desert biome with small shrubs and grasses
2.7 Succulent Karoo	D Winter rainfall area along the west coast of South Africa.
2.8 Grassland	C Area with summer rainfall; mostly at high altitude.
2.9 Indian Ocean Coastal Belt	E Summer rainfall area along the east coast of South Africa.

(9)

3.

3.1 There are no pepperbark trees left growing in the wild. (2)

3.2 Plants growing in the fynbos biome have special characteristics that enable them to survive in those climatic conditions.
(2)

3.3 The white rhinoceros is at risk of becoming extinct. (2)

Subtopic 2: Principles of classification

Unit 1: The extent of biodiversity

Activity 1.2

1.

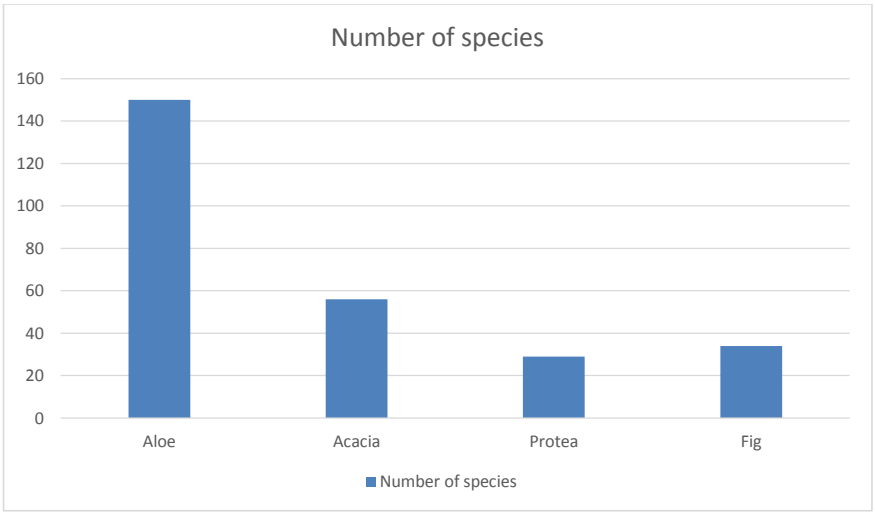
1.1 Birds (1)

1.2 Amphibians (1)

1.3 The number of species (1)

1.4 An animal that has an internal skeleton with a backbone. (2)

2.



Mark allocation:

Title (2)

y-axis correct (2)

Bars correctly plotted (4)

Neatness (2)

Total (10)

Unit 2: Taxonomic levels

Activity 2.1

1. This is an open-ended question. ONE possible answer would be:
   A underwear and socks
   B shirts and jerseys,
   C skirts and jeans,
   D pyjamas

   Group A is similar because it is small items that Maite wears frequently.
   Group B is similar because it is clothes that cover the top of her body.
   Group C is similar because it is clothes that cover the bottom half of her body.
   Group D is items she wears at night.

2. Underwear consists of pants and bras. Pants cover the bottom of her body. Bras cover her breasts.

Activity 2.2

1.
1.1 Answer is given.
1.2 Hyaenidae (1)
1.3 Viverridae, Felidae and Canidae (3)
1.4 Mammalia (1)
1.5 Mammalia, Pisces. Reptilia, Amphibia, Aves (5)
1.6 Animalia (1)
1.7 Phylum: Chordata
Class: Mammalia
Order: Carnivora
Family: Hyaenidae
Genus: *Proteles*
Species: *Proteles cristatus* (6)

Activity 2.3

Common name	Scientific name
Giraffe	*Giraffa camelopardis*
African elephant	Loxodonta africana
Southern African Python	*Python natalensis*
Natal cycad	*Encephalartos natalensis*
Ostrich	*Struthio camelus*

(4)

Unit 3: Characteristics of the five kingdoms.

Activity 3.1: Have you understood your reading?

1. Mushroom: Kingdom Fungi; Frog: Kingdom Animalia; Seaweed: Kingdom Protista; Bacteria: Kingdom Monera; Daisy: Kingdom Plantae.

2.2 Protista, Fungi, Plantae, Animalia (4)
2.3 Plantae (1)
2.4 Monera (1)
2.5 Protista (1)
2.6 Monera (1)
2.7 Fungi (1)
2.8 Animalia (1)
2.9 Fungi, Monera (2)

Assessment Subtopic 2

1.

1.1 Answer is given

1.2 Genus

1.3 Class
1.4 Family
1.5 Kingdom
1.6 Order (5)

2.
2.1 B
2.2 D
2.3 D
2.4 A
2.5 C (10)

3.
3.1 Indigenous means belonging to a particular geographic area. Endemic means occurring in a particular geographic area and nowhere else on earth.
3.2 Prokaryote means a cell that has no nuclear membrane, and no organelles. Eukaryote means a cell that has a nuclear membrane and organelles.
3.3 Extinct means there are no more of that species left in an area or in the world. Threatened means there are a few individuals, but the species may become extinct if not protected.
3.4 Monera are prokaryotic, unicellular organisms. Protista are eukaryotic, unicellular or simple multicellular organisms. (8)

Subtopic 3: The History of Life
Unit 1: Life has an extremely long history
Assignment 3.1: Make a timeline

Assessment criteria:

1. The timeline must be constructed to the correct scale. If toilet paper is not used, the line must show markings at equal intervals. (5)
2. All events listed in Table 3.1 must be shown in the correct places on the timeline. (10)
3. Labels must be neatly written. (3)
4. Students must show how far back the first prokaryotes and eukaryotes appeared. (2)

TOTAL (20)

Topic 2: Evolution
Subtopic 1: the theory of evolution by natural selection
Activity 1.1

This is an open-ended activity for you to identify your prior knowledge about the topic.

Unit 2. Development of the theory of evolution by natural selection.

Activity 1.2: Have you understood your reading?

1. 1.1; 1.4; 1.9; 1.7; 1.3; 1.5; 1.10; 1.8; 1.2; 1.6
   (10)

Unit 2 The theory of evolution by natural selection

No activities

Unit 3: Natural selection in action: antibiotic resistance.

Activity 3.1: Interpret a poster about drug-resistant TB

1.

1.1 *Mycobacterium tuberculosis* (1)

1.2 Spreads through the air and is breathed into the lungs. (2)

1.3 2 million people per year. (1)

1.4 First-line drugs are the first antibiotics prescribed when a person is diagnosed with TB. (2)

1.5 It does not respond to the two most powerful first-line drugs. (2)

1.6 Tugela Ferry, South Africa. (1)

1.7 Incorrect prescription, unreliable supply of drugs, poor quality drugs, patient not taking the drugs correctly. (4)

1.8 A mutation introduces a new allele that makes the bacteria resistant to first-line drugs. (2)

Unit 4: Mechanisms of speciation and reproductive isolation

Activity 4.1: Interpret a diagram showing speciation in Darwin's finches.

1.1 Ancestral seed-eating ground finch (1)

1.2 Four species (1)

1.3 *Camarhynchus crassirostris* (1)

1.4 *Camarhynchus; Geospiza; Pinaroloxias; Certhidae* (4)

1.5 They eat mainly insects. (1)

1.6 Large ground finch (*Geospiza magnirostris*). It has a large, heavy bill that can crack hard seeds. (2)

Activity 4.2: Have you understood your reading?

1.

1.1 Behavioural isolation.

1.2 Hybrid sterility

1.3 Ecological isolation.

1.4 Gamete incompatibility

1.5 Behavioural isolation

1.6 Temporal isolation. (6)

Assessment subtopic 1

1.

Column A	Column B
1.1 A pond dries up during a drought to make two smaller ponds.	C Geographical isolation
1.2 One frog species breeds in March, while a related frog species breeds in May.	H Temporal isolation
1.3 Tortoises with long necks survive and breed on an island with tall shrubs growing on it.	A Natural selection
1.4 Pollen from a lily lands on the stigma of a daisy.	G Gamete incompatibility
1.5 The offspring of a zebra and a donkey cannot reproduce.	B Hybrid sterility
1.6 Pigs are crossbred to produce more meat.	D Artificial selection
1.7 The courtship dance of the rock pigeon is different from that of an olive pigeon.	E Behavioural isolation
	F Ecological isolation

(7)

2.

2.1 TRUE

2.2 FALSE Darwin proposed that natural selection is the way evolution takes place.

2.3 FALSE Each generation produces more offspring than are needed to replace itself.

2.4 FALSE Charles Darwin developed the idea of evolution after a 5-year voyage on the ship HMS Beagle.

2.5 TRUE (5)

3.

3.1 B is best adapted to the environment. (1)

3.2 B lives longer and produces more offspring than any other variety.
(2)

3.3 Varieties A and C will die out, because they do not survive and reproduce well in the environment. Varieties B and D have a selective advantage because they are not so visible to the owls. They will increase in proportion in the population. Variety B will increase faster than Variety D.
(7)

Subtopic 2: Evidence supporting evolution

Activity 1.1

This is an open-ended activity for you to identify your prior knowledge about the topic.

Unit 1: Artificial selection.

No activities

Unit 2: Fossil record

Activity 2.1

1. Between 510 and 495 mya. There is a layer of volcanic rock dated at 510mya below the layer of fossils. There is another layer of volcanic rock dated at 495 mya above the fossils. The fossils are between those two ages.
(5)
2. Estimated age would be between 545 and 520 mya. The same fossils occurred at the same time in earth's history. They are the same age. (2)

Unit 3: Comparative anatomy

Activity 3.1 Write about the adaptations for each lifestyle

1.

1.1 The bat has much thinner bones than the human. It has very long metacarpals and digits. It has four fingers forming the wing, and a small thumb.

The dolphin has short, thick humerus, radius and ulna. There are many small bones forming the carpals, metacarpals and digits. Digits 2 and 3 are very long, forming the flipper. The other three digits are shorter.

The horse has a short humerus, and long radius and ulna. There are fewer metacarpals than the human, and only one digit. The horse stands on the tip of the nail.

The mole has short, thick humerus, radius and ulna. The carpals and digits are large, and one carpal forms an extra digit. There are five digits, which are thick and strong.

(12)

Unit 4: Biogeography

Activity 4.1: Match the flightless birds to the correct country.

1.

1.1 emu; 1.2 New Zealand; 1.3 ostrich; 1.4 rhea; 1.5 Papua New Guinea. (5)

Assessment subtopic 2

1.

1.1 Relative dating.

1.2 Bacteria

1.3 *Thrinaxodon*

1.4 Gondwana

1.5 Biogeography

1.6 Comparative anatomy

1.7 Radiometric dating. (7)

2.

2.1 At 1, a reptile-like animal is swimming in the sea. At 2, it has died and fallen to the bottom of the ocean. It is covered with sediment. Soft parts have decayed, leaving the skeleton. At 3, more layers of sediment have been deposited on top of the fossil layer. Minerals have replaced the bone, and the skeleton is now rock. At 4, the fossil layer has been eroded and the tip of the fossil is exposed. (8)

2.2 Sedimentary rock (1)

Topic 3 Genetics and Heredity

Sub-topic 2. Patterns of inheritance

Activity 1.1

This is an open-ended activity for you to identify your prior knowledge about the topic.

Unit 2. Mendel and the science of genetics.

No activity

Unit 2: Cell division

Activity 2.1 Have you understood your reading?

1.

1.1 A cell membrane; B spindle fibres; C cytoplasm; D chromatid; E centromere. (5)

1.2

1.2.1 A

1.2.2 D

1.2.3 B

1.2.4 D (8)

Unit 3: The nature of genes and alleles and their role in determining the phenotype.

Activity 3.1: Practise using genetics terms.

1.1 Inheritance; 1.2 chromosomes; 1.3 chromosomes; 1.4 genes; 1.5 homologous pairs; 1.6 genes/alleles; 1.7 gene; 1.8 alleles; 1.9 alleles; 1.10 homozygous; 1.11 heterozygous; 1.12 genotype; 1.13 phenotype; 1.14 recessive; 1.15 homozygous; 1.16 heterozygous; 1.17 dominant. (Note: 1.15 and 1.16 can be reversed) (17)

Unit 4 Solving genetics problems

Activity 4.1: Can you apply your reading?

1.1 ***YY***
1.2 ***Yy***
1.3 ***Yy*** (3)

Activity 4.2: Can you solve a genetics problem using a Punnett square?

1.

1.1 a) ***TT*** b) ***tt*** (2)

1.2 a) All ***T*** b) All ***t*** (2)

1.3 All ***Tt*** (1)

1.4 All tall plants (1)

1.5

	T	***t***
T	***TT*** (tall)	***Tt*** (tall)
t	***Tt*** (tall)	***tt*** (dwarf)

(8)

1.6 a) ¾ of 240 will be tall = 180 tall

b) ¼ of 240 will be dwarf = 60 dwarf. (4)

Activity 4.3: Discuss attitudes to the sex of a baby.

1. This is an open-ended activity for discussion.
2. The poster should explain clearly how sex is determined.

Assessment subtopic 1

1. 1.1 D
   1.2 C
   1.3 A
   1.4 B
   1.5 A (10)
2. 2.1 ***RR*** and ***rr*** (2)
   2.2 a) ***Rr*** b) round seeds. (2)
   2.3

	R	***r***
R	***RR*** (round)	***Rr*** (round)
r	***Rr*** (round)	***rr*** (wrinkled)

(6)

Unit 5 Variation

No activity

Assessment Subtopic 1

1. 1.1 Gene pool; 1.2 Adaptive trait; 1.3 Microevolution; 1.4 Mutation; 1.5 Discontinuous variation; 1.6 Alleles; 1.7 Homologous pair; 1.8 Random segregation (8)
2. 2.1 Mitosis is a type of cell division that results in two daughter cells that are genetically identical to each other. Meiosis is a type of cell division that results in four daughter cells which are genetically different from each other.
   2.2 Homozygous is two identical alleles on a homologous pair. Heterozygous is two different alleles on a homologous pair.
   2.3 Dominant refers to a characteristic that is expressed whether the individual is homozygous or heterozygous. Recessive refers to a characteristic that is expressed only if the individual is homozygous for that characteristic.
   2.4 Genotype is the combination of alleles that an individual has. Phenotype is how the genotype is expressed in physical characteristics or functioning of an organism.
   2.5 Haploid refers to a cell that has only one member of each homologous pair. Diploid refers to a cell that has two members of each homologous pair.
   (10)

Subtopic 2: DNA structure and function

Unit 1: The structure of DNA

Activity 1.1

This is an open-ended activity for you to identify your prior knowledge about the topic.

Activity 1.2 Have you understood your reading?

1.1 DNA (1)

1.2 1 – hydrogen bonds; 2 – phosphate molecules; 3 – deoxyribose sugar; 4 – T (thymine); 5- C (cytosine)
(5)

1.3 2 and 3 (2)

1.4 double helix (1)

Unit 2: Replication of DNA.

Activity 2.1 Do you understand the process of DNA replication?

1. 1.1 G (1)
   1.2 C (1)
   1.3 Enzymes (1)
   1.4

Left-hand strand	A-T	C-G	C-G	T-A	C-G	A-T	A-T	A-T	C-G	C-G
Right-hand strand	A-T	C-G	C-G	T-A	C-G	A-T	A-T	A-T	C-G	C-G

(8)

1.5 They are identical (1)

Unit 3: The role of DNA in protein synthesis

Activity 3.1: Can you apply what you have learnt?

1.

1.1 a) 4; b). 3; c) 2; d) 1 (4)

1.2 a) UGA; b) UAC; c) GGC; d) AAA (4)

1.3 1.3.1 a) ACC UUG CGG CGA b) tryptophan – asparagine-alanine-alanine

1.3.2 a) UUC CCU AAA AUC b) lysine-glycine-phenylalanine-stop

1.3.3 a) UGC AGG AGC CAU b) threonine-serine-serine-valine (12)

Unit 4: The effect of mutations on DNA structure and function

Activity 4.1: Substitutions, deletions and insertions

1. 1.1 a) AUG AAC AGG CUA UAG b) methionine-asparagine-arginine-leucine-stop (4)
   1.2 a) AUG AAC AGG CUU AUA AG b) methionine-asparagine-arginine-leucine-isoleucine- (4)
   1.3 a) AUG AAC AGC CUA UAG b) methionine-asparagine-serine-leucine-stop (4)
   1.4 a) AUG AAG GCU AUA G b) methionine-lysine-alanine-isoleucine (4)

Assessment Subtopic 2

1. 1.1 D

1.2 C
1.3 D
1.4 C
1.5 A
1.6 A
1.7 B
1.8 A (16)

2. 2.1 Transcription (1)
2.2 UUA GCG UUU AGG GCG UAU (2)
2.3 leucine-alanine-phenylalanine-arginine-alanine-tyrosine (6)
2.4 UUA GCG UUU GGG CGU AU leucine-alanine-phenylalanine-glycine-arginine
The polypeptide is changed significantly. (4)
2.5 glycine (1)

EXEMPLAR(S)

Writing an essay

The essay is worth 20 marks in your exam paper. Below are some tips on how to write a good essay.

Tip 1: Do what you're asked to do

Read the topic of the essay question. Think about exactly what the examiner wants you to say in the essay. Underline the key words that tell you what you must do in the essay. Some key words that often appear in essay questions are these:

Key words	**What you must do**
State	Give the facts.
List	Make a list.
Describe	Give a detailed account.
Explain	Give a detailed account, but also give reasons.
Compare	Set two structures or processes in contrast to each other; identify the similarities and differences.
Discuss	Look at an issue from several different angles; consider the pros and cons of a solution to a problem.

Here is an example of an essay topic:

Explain how natural selection has given rise to antibiotic-resistant bacteria.
(20)

The key verb is *explain*. Your essay must give a detailed account, with reasons.

Tip 2: Identify the subject of the essay

Read the question and underline the subject matter on which it is based. This is highlighted in green in the essay question above. Read the first part: *how natural selection …* This tells you that the essay is about natural selection. But the subject continues: …*has given rise to antibiotic-resistant bacteria*. The examiners want you to show that you can explain how natural selection has caused bacteria to become resistant to antibiotics.

Tip 3: Plan your answer

You must show that you understand the question, and that you have selected suitable facts and ideas to answer the question.

Draw up a simple plan to guide your writing, as follows:

1. How will you start the essay? It should have an introductory paragraph.
2. What will you include in the main body of the essay? This is where you address the topic.
3. How will you end the essay? It should have a concluding paragraph.

Here is a plan for the essay topic: '*Explain how natural selection has given rise to antibiotic-resistant bacteria.'*

Introduction: Define "natural selection", "bacteria" and "antibiotics"; outline the structure of essay.
Paragraph 1: Describe the process of natural selection.
Paragraph 2: Describe how antibiotics assist the body to kill bacteria.
Paragraph 3: Describe how natural selection applies to antibiotic resistance.
Conclusion: Summarise the main points emerging from the essay.

Tip 4: Write the essay
• The introduction is usually just one paragraph. It is meant to indicate to the reader what they can expect to find in the essay. Keep it brief.
• The main body of the essay is where you expand on the topic. Keep related ideas together in each paragraph. Your plan will help you to do this. Try to explain the ideas in a simple and straightforward way.
• Each paragraph should have a leading idea that you state in the first sentence. The rest of the paragraph expands on that idea. The final sentence often links with the next paragraph.
• The conclusion rounds off the essay. It should summarise what you have said in the essay, and end with a concluding comment that relates to the title of the essay.

Tip 5: Write concise sentences
• Write in proper sentences that have a subject, verb and object. Examiners will not give good marks for poor writing, even if all the facts are present.
• Each sentence should convey a single point. Avoid long, complicated sentences.
• Use scientific terminology whenever it is appropriate.

Here is an example of an essay about the topic on natural selection and bacteria.

1. Natural selection has given rise to antibiotic-resistant bacteria
[In shoulder, with arrow connecting to the title text]
This is the title of the essay. It is rephrased from the original question.
[End shoulder text]

2. Natural selection is a process in which individuals with favourable adaptations increase in the population. Favourable adaptations are characteristics that help an individual to survive and reproduce. Favourable adaptations often arise due to a genetic mutation. The mutation introduces a new allele into the gene pool. The frequency of the favourable allele will increase in the population. This essay will explain how natural selection gives rise to antibiotic resistance in bacteria.

[In shoulder, with arrow pointing to paragraph 2:

This paragraph defines natural selection and describes the process. It ends with a statement about the purpose of the essay]
End shoulder text]

3. Antibiotics are medicines that help the body fight bacterial infections. They kill the bacteria that are causing a disease. A sick person must take the antibiotics regularly and complete the whole course. The antibiotics must act quickly and kill all the bacteria in the body.

[In shoulder, with arrow pointing to paragraph 3:
This paragraph describes what antibiotics are, and how they are used to treat patients
End shoulder text]

4. Some bacteria develop a mutation that makes them resistant to antibiotics. The antibiotics no longer kill the bacteria. The resistant bacteria have an allele that makes them resistant to antibiotics. This is a favourable adaptation for the bacteria. Bacteria with the mutated allele survive and reproduce faster than bacteria without the mutation. The frequency of the favourable mutated allele increases in the population. Natural selection causes the population to change to an antibiotic-resistant population.

[in shoulder, with arrow pointing to paragraph 4:
This paragraph describes antibiotic resistance in terms of natural selection.
End shoulder text]

5. In conclusion, antibiotic resistance is a favourable adaptation in bacteria. It increases in a population of bacteria because of natural selection.

[Shoulder text]
The words 'in conclusion' tell the examiner that this is the last paragraph that summarises the main points from the essay. This paragraph shows the examiner that you have been able to synthesize your thoughts and draw a valid conclusion.
[End shoulder text]

Essay topics for practice:

1. Compare and contrast the Succulent Karoo biome and the Savanna biome of South Africa.
2. Describe how proteins are synthesised in a cell.
3. Explain why fossils such as *Thrinaxodon* and *Australopithecus* support evolution.

NASCA Natural Sciences Artwork list

Component 2: Biology

Topic 1: Biodiversity

Subtopic 1: Biodiversity and the Biomes of South Africa

Unit 2: Factors defining biomes	Source	Permission required?
Figure 2.1: Graphs showing rainfall and temperature in Durban and Cape Town.	www.worldweatheronline.com	
Figure 2.2: The major terrestrial biomes of South Africa	http://redlist.sanbi.org/imgs/stats/biomes.png	
Figure 2.3 Fynbos	from plantzafrica.com	
Figure 2.4 Yellow vygies flowering in the succulent	Own photograph	No
Figure 2.5 Botterboom plants	own photo	No

are adapted to the climate of the Succulent Karoo		
Figure 2.6: The desert biome	http://wp.roadstoroam.co.za/wp-content/uploads/2014/03/Richtersveld-National-Park-Springbokvlakte-viewpoint.jpg	
Figure 2.7: Nama Karoo vegetation	plantzafrica.com	
Figure 2.8: Grassland biome.	Own photograph.	No
Figure 2.9: The savanna biome.	https://room42.wikispaces.com/file/view/savanna_geography.jpg/33724861/savanna_geography.jpg	
Figure 2.10: Albany thicket vegetation	Pza.sanbi.org	
Figure 2.11: Indian Ocean Coastal Belt vegetati	own photograph	No

on		
Figure 2.12: Forest in the Hogsback	plantzafrica.com	
Activity 2.3 Halfmens plant	https://www.plantzafrica.com/plantnop/plimagesnop/pachynam.jpg	
Unit 3: Exploring the biomes of South Africa		
Figure 3.1 Cycads are not being used sustainably in South Africa.	https://www.sanbi.org/sites/default/files/images/encephfridguil2.jpg	

Subtopic 2: Principles of classification

Unit 1: The extent of biodiversity	Source	Permission required?
Figure 3.2 Giraffe are a species because they look alike,	http://thebiomes.yolasite.com/resources/subequatorial-climate-tanzania.jpg.opt993x595o0,0s993x595.jpg	

and can breed together.		
Figure 3.3 Bugweed is an exotic species in South Africa.	http://www.weedbusters.org.nz/resizer/w=800&h=700&zc=3~/uploads/images/Gallery/_weeds/solanum-mauritianum/DSCF0801.JPG	
1.1 Displaying biodiversity Bar graph	own drawing.	No
Unit 2: Taxonomic levels		
Figure 2.1: Sort Maite's clothes.	Image from an unpublished book, Platinum Life Sciences Grade 10. Pearson South Africa. Drawn from my concept.	
Figure 2.2: Classification of four species of hyaena using the main classification groups	Adapted from an image in: Mills, G. & Hex, L. 1997. The Complete Book of Southern African Mammals. Cape Town, Struik Publishers. ISBN: 0947430555 Permission was given verbally by the artist to scan and use the individual images from the diagram.	
Unit 3: Characteristics of the five kingdoms		
Figure	Image from an unpublished book, Platinum Life Sciences Grade 10.	

3.1 Examples of Whitaker's five kingdoms.	My concept.	
Figure 3.2 Structure of a Monera.	Image from an unpublished book, Platinum Life Sciences Grade 10.	
Figure 3.3: Three different types of single-celled Protista.	Image from an unpublished book, Platinum Life Sciences Grade 10. My concept	
Figure 3.4: Bracket fungus growing on a dead log, a mushroom, and mould growing on an orange.	Image from an unpublished book, Platinum Life Sciences Grade 10. My concept	
Figure 3.5: Worms, snails, elephants, beetles and crabs belong to the Kingdom Animalia.	Image from an unpublished book, Platinum Life Sciences Grade 10. My concept.	

Figure 3.6: Plant cells are eukaryotic.	Image from an unpublished book, Platinum Life Sciences Grade 10.	
Figure 3.7 A variety of plants growing on the banks of a stream.	Image from an unpublished book, Platinum Life Sciences Grade 10.	
Activity 3.1 Question 1.	Images from an unpublished book, Platinum Life Sciences Grade 10.	

Subtopic 3: The history of Life

Unit 1: Life has an extremely long history		
Figure 1.1: A Fossilized leaves; B Fossilized dinosaur skull. Both fossils were found in South Africa	Images from an unpublished book, Platinum Life Sciences Grade 10, scanned with permission from the author MacRae, C. 1999. Life Etched in Stone: Fossils of South Africa. Johannesburg, Geological Society of South Africa. ISBN 0-620-23390-3	

Topic 2 Evolution

Subtopic 1: The theory of evolution by natural selection

Unit 1: Development of the theory of evolution by natural selection		
Figure 1.1 Charles Darwin as a youn	Image is from Getty images, but it is widely available.	Probably

g man.		
Figure 1.2: The voyage of HMS Beagle.	http://www.mhhe.com/biosci/esp/2001_gbio/folder_structure/ev/m1/s3/assets/images/evm1s3_1.jpg	
Figure 1.3: Extinct glyptodont and living armadillo.	https://upload.wikimedia.org/wikipedia/en/b/bc/Glyptodon-Armadillo.jpg	
Figure 1.4: Vertebrate forelimbs are made up of the same set of bones.	https://online.science.psu.edu/sites/default/files/biol011/Fig-8-5-Vertebrate-Limbs.gif	
Figure 1.5 Alfred Wallace (1823 - 1913)	http://dl0.creation.com/articles/p046/c04670/Alfred-Wallace.jpg	
Unit 2: The theory of evolution by natural selection		

Figure 2.1 A summary of natural selection	https://classconnection.s3.amazonaws.com/878/flashcards/663878/png/screen_shot_2011-09-06_at_5.26.59_pm1315301241192.png	
Unit 3: Natural selection in action: antibiotic resistance		
Figure 3.1: Development of antibiotic resistance in a population of bacteria	https://y12hb.files.wordpress.com/2013/03/antibiotic-resistance.png	
Figure 3.2: TB poster	https://www.sott.net/image/s4/91554/full/Drug_resistant_TB.jpg	
Unit 4: Mechanisms of speciation and reproductive isolation		
Figure 4.1 Allopatric speciation	http://larryfrolich.com/Evolution/ch5c.jpg	
Figure 4.2: Speciation in Darwin's finches	http://images.slideplayer.com/10/2752683/slides/slide_10.jpg	
Figure 4.3: Adaptive radiation in Darwin's finches.	http://media-1.web.britannica.com/eb-media//11/54911-050-0E225E16.jpg	

Subtopic 2: Evidence supporting evolution

Unit 1: Artificial selection		
Figure 1.1 Artificial selection and vegetables	http://65.media.tumblr.com/103e5c3e6dd283721f37b6885f4fc013/tumblr_moxn48L0k21r8ebyno1_400.png	
Figure 1.2 Artificial selection and cattle. A. The original	http://joshuabloom.co.uk/assets/img/blog/Veganism/cow%20vs%20cow.png	

Auroch cow. B. A modern dairy cow.		
<u>Unit 2: Fossil record</u>		
Figure 2.1 How fossils form in sedimentary rock.	From: Platinum Life Sciences Grade 10. Unpublished by Pearson South Africa.	
Figure 2.2 Comparison of relative dating and radioactive dating.	Source: Platinum Life Sciences Grade 10. Unpublished book.	
Figure 2.3 *Thrinaxodon* skull and whole skeleton	Source: Copied from MacRae: Life etched in Stone, with permission. These photographs appear in the unpublished book: Platinum Life Sciences Grade 10	
Figure 2.4 Skulls of a 2,4 million-year-old *Australopithecus africanus* and a 200 000 year-old human.	Source: Copied from MacRae: Life etched in Stone, with permission. These photographs appear in the unpublished book: Platinum Life Sciences Grade 10	
Figure 2.5 Skull and pelvis of A) *Australopithecus africanus*	Taken from Focus Life Sciences Grade 12, p. 244. Pearson South Africa. ISBN 978-0-636-14104-9	

and B) a human. Add labels: foramen magnum, canines, upper part of pelvis, neck of femur, lower part of pelvis.		
Unit 3: Comparative anatomy		
Figure 3.1 Bones of a human arm. Add labels for metacarpals and digits.	THIS IMAGE NEEDS TO BE RE-DRAWN.	No
Figure 3.2 Vertebrate forelimbs adapted for flying (bat), swimming (dolphin), fast running (horse) and digging (mole).	THIS IMAGE NEEDS TO BE RE-DRAWN. https://ncse.com/files/images/800px-Evolution_pl.img_assist_custom.png	
Unit 4: Biogeography		
Figure 4.1 Large flightless birds of the southern hemisphere	https://naturalishistoria.files.wordpress.com/2013/02/ratites-birds-flightless-distribution.jpg	
Figure 4.2 A map of	http://kalistonia.weebly.com/uploads/3/9/5/6/39569789/2975090_orig.jpg	

Gondwana 175 million years ago. Red arrows show the direction of movement when Gondwana broke up.		
Assessment Subtopic 2		
Question 2:	Illustration comes from Focus Life Sciences Grade 10, p. 291, published by Pearson South Africa. ISBN ??	

Topic 3: Genetics and Heredity

Subtopic 1: Patterns of inheritance

Unit 1: Mendel and the science of genetics		
Figure 1.1: The seven characteristics that Mendel studied.	http://archive.cnx.org/resources/fa6f545cec588d620656d63cefaa1ad4c528df03/Figure_08_01_03.jpg.	
Unit 2: Cell division		
Figure 2.1 Cells from the cheek of a human. Labels: nucleus, cytoplasm	From Platinum Life Sciences Grade 10 unpublished book. Pearson South Africa, Cape Town	
Figure 2.2 Detailed structure of an	From Platinum Life Sciences Grade 10 unpublished book. Pearson, South Africa, Cape Town.	

animal cell. Label ONLY nuclear pore, nuclear membrane, nucleolus and chromatin material.		
Figure 2.3 Structure of a chromosome of a cell that is about to divide. Labels: two chromatids, centromere.	From Platinum Life Sciences Grade 10 unpublished book. Pearson, South Africa, Cape Town.	
Figure 2.4 The cell cycle	From Platinum Life Sciences Grade 10 unpublished book. Pearson, South Africa, Cape Town	
Figure 2.5 Phases of mitosis in a plant cell. [Labels from left to right:	www.clt.astate.edu/mhuss/mitosis1.jpg	

interphase, prophase, metaphase, anaphase, telophase. Place labels above the diagrams in the top row.]		
Activity 2.1		
Question 1	my own diagram.	N
Figure 2.6: Stages of meiosis	www.phschool.com/science/biology_place/labbench/lab3/images/stages3.gif	
Unit 3: The nature of genes and alleles and their role in determining the phenotype.		
Figure 3.1: In pea plants, purple flower colour is dominant to white flower colour	http://cikgurozaini.blogspot.com/2010/06/genetic-1.html	
Unit 4: Solving genetics problems		
Figure 4.1: Monohybrid	https://classconnection.s3.amazonaws.com/567/flashcards/203567/png/law_of_segregation1316063912505.png	

cross between purple and white-flowered pea plants.		
Figure 4.2 Punnett square for cross between F1 generation purple-flowered plants.	My own diagram.	N
Unit 5: Variation		
Figure 5.1: Normal red blood cells and sickle cells.	https://www.gemssforschools.org/sites/www.gemssforschools.org/files/default/sickle2.jpg	
Figure 5.2: Human height is an example of continuous variation	http://cdn.yourarticlelibrary.com/wp-content/uploads/2013/12/b502.jpg	
Figure 5.3: Natural	https://upload.wikimedia.org/wikipedia/commons/thumb/f/f3/Mutation_and_selection_diagram.svg/2000px-Mutation_and_selection_diagram.svg.png	

selection results in favourable alleles increasing in the population		

Subtopic 2: DNA structure and function

Unit 1: The structure of DNA		
Figure 1.1: The nucleus contains chromosomes. A gene is a unit of a chromosome. The chromosomes consist of DNA.	http://www.bbc.co.uk/staticarchive/678f62dce35d0fc7ef2333d6d3bfbf53744374ff.jpg	
Figure 1.2 Structure of DNA	http://www.exploringnature.org/graphics/genome_art/DNA_structure72.jpg	
Figure 1.3: Structure of a nucleotide	http://www.exploringnature.org/graphics/genome_art/DNA_structure72.jpg	
Activity 1.2		
Questio	Own diagram	

n 1		
Figure 1.4: The structure of RNA.	https://i.ytimg.com/vi/FHq7kzjB9u0/hqdefault.jpg	
Unit 2: Replication of DNA		
Figure 2.1: The process of DNA replication	http://www.mhhe.com/biosci/esp/2001_saladin/folder_structure/le/m7/s1/assets/images/lem7s1_1.jpg	
Unit 3: The role of DNA in protein synthesis		
Figure 3.1: Summary of protein synthesis in a cell [Add labels for mRNA, ribosome and polypeptide chain.]	http://oerpub.github.io/epubjs-demo-book/resources/0328_Transcription-translation_Summary.jpg	
Figure 3.2 Transcription of a gene into mRNA.	http://oregonstate.edu/instruction/bi314/fall11/figure_07_09.jpg	
Figure 3.3 A strand	http://www.tokresource.org/tok_classes/biobiobio/biomenu/transcription_translation/100000000000001B1000000D9E9F2CFD4.jpg	

of RNA grows.		
Figure 3.4 mRNA is translated into a polypeptide chain.	http://www.proteinsynthesis.org/wp-content/uploads/2015/09/what-is-the-second-step-of-protein-synthesis.jpg	
Figure 3.5: Summary of protein synthesis	https://blog.udemy.com/wp-content/uploads/2014/06/dna1.jpg	
Assessment Subtopic 2		
Question 1.1	Own diagrams	N
Question 1.7	Own diagrams	