

Life Sciences

Part 2

CLASS TEXT & STUDY GUIDE

Liesl Sterrenberg, Helena Fouché & Grace Elliott

GRADE
12
CAPS

3-in-1



THE
ANSWER
SERIES *Your Key to Exam Success*



Grade 12 **Life Sciences** 3-in-1 Part 2 CAPS

CLASS TEXT & STUDY GUIDE

This book is PART 2 of a SET of 2 Life Sciences study guides comprehensively covering the Grade 12 CAPS curriculum.

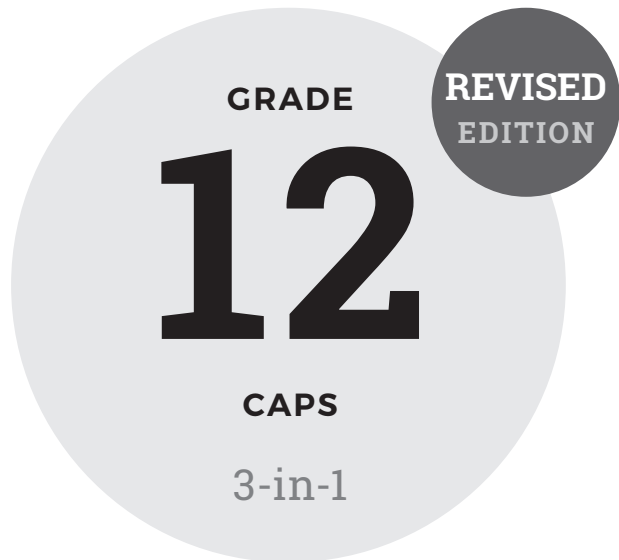
It contains the 2 Knowledge Areas examined in Paper 2 (National final exam):

- Life at the Molecular, Cellular and Tissue level
- Diversity, Change and Continuity

Key Features:

- Comprehensive, accessible notes per module
- Carefully selected, graded questions and answers per module
- 'Rapid-fire' questions for key concepts and terms
- Clear, explanatory diagrams
- Up-to-date, relevant material

As you work methodically through this study guide, you will become increasingly prepared to achieve excellent results in your exams.



Life Sciences

Part 2

Liesl Sterrenberg, Helena Fouché, Grace Elliott & Mariechen Vermeulen

Also available

**GRADE 12
LIFE SCIENCES
PART 1**

Life Processes in Plants and Animals



THIS CLASS TEXT & STUDY GUIDE INCLUDES

1

Notes

- Life at the Molecular, Cellular and Tissue level
- Diversity, Change and Continuity

2

Questions & Rapid Fire Questions

3

Detailed Memos (separately)

**ALL
the content
for
PAPER II**

**eBook
available** 

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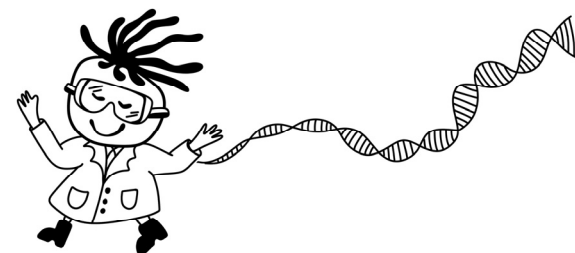
WHAT IS LIFE SCIENCES?

Life Sciences is the scientific study of living things from molecular level to their interaction with one another and the environment.

- ▶ Living systems exhibit levels of organisation from molecules to biomes.
- ▶ Life on Earth is dynamic, with homeostasis maintaining balance at every level of organisation.
- ▶ Life is characterised by changes over time.

AIMS IN LIFE SCIENCES

- Specific Aim 1:** Knowing Life Sciences
(concepts, processes, phenomena, mechanisms, principles, theories, laws, models, etc.)
- Specific Aim 2:** Investigating phenomena in Life Sciences
- Specific Aim 3:** Appreciating and Understanding the History, Importance and Applications of Life Sciences in Society



Uses of DNA profiling

DNA profiling is used to:

- ▶ identify **potential crime suspects** in forensic investigations
- ▶ identify **dead bodies**
- ▶ identify **relatives**
- ▶ prove **paternity** (determining the biological father) or **maternity** (determining the biological mother)
- ▶ determine the probability and/or causes of **genetic defects**
- ▶ trace **missing persons**
- ▶ identify **matching tissues** for **organ transplants**

Working with DNA profiles

1 Paternity testing

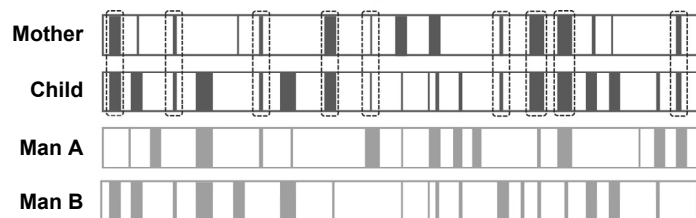
Compare the DNA profiles of a mother, her child and two potential fathers (Man A and Man B).



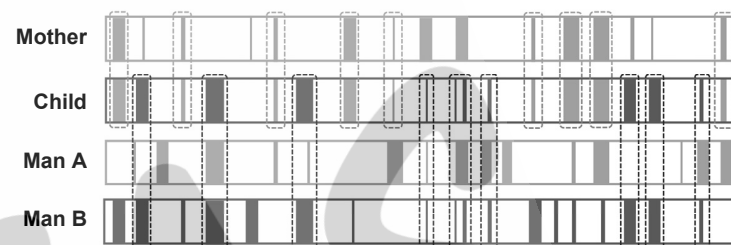
- ▶ Start on the left-hand side of the child's DNA profile and **compare** the **thickness** and **position** of the **bands** with the mother's DNA profile. Identify and mark all the bands that match.

NOTE

Use a ruler to guide you as you move down the DNA profile of the child.



- ▶ Compare the **thickness** and **position** of the **remaining bands** on the child's DNA profile to the DNA profiles of the two potential fathers.
- ▶ If **all** the **remaining DNA bands** in the child's profile **match** a **possible father's DNA bands** – then he is the **biological father**, i.e. **Man B**.
- ▶ If all the remaining DNA bands in the child's profile do not match a possible father's DNA bands – then he is not the biological father, i.e. **Man A**.



NOTE



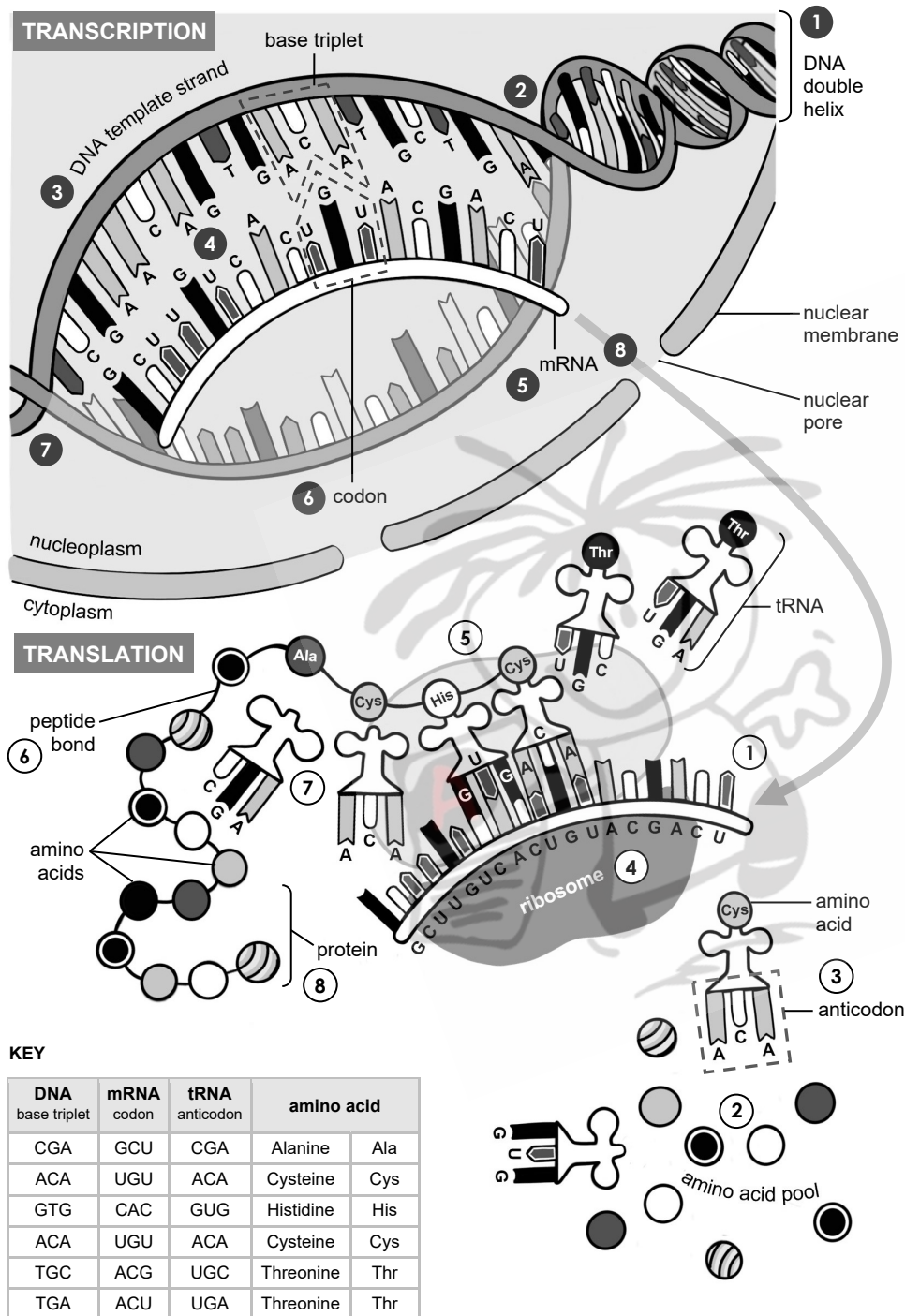
Some of the bands on the child's DNA profile match Man A's DNA profile as well. This is because all humans share certain gene sequences. However, Man B shares **all** the remaining bands of the child's DNA profile which proves he is the biological father.

2 Identifying potential crime suspects

Compare the DNA profile of a hair sample found at a crime scene with the DNA profiles of two potential suspects (**A** and **B**) for the crime.



- ▶ The hair sample found at the crime scene could belong to the person who committed the crime.
- ▶ A suspect may be placed at the crime scene if there is an **exact match** between two DNA profiles, i.e. all the bands on the DNA profile from the hair sample must match the banded pattern on the suspect's DNA profile.



TRANSCRIPTION (DNA into mRNA)

- **DNA** occurs in the nucleoplasm and **never leaves the nucleus**.



REMEMBER

DNA is too large to pass through the nuclear pores.

- **Protein synthesis** occurs in the cytoplasm (outside the nucleus) in the **ribosomes**.
- The **code** for the synthesis of a particular protein must be **transferred from DNA to mRNA** which is able to leave the nucleus.
- This process where mRNA copies the code for a particular protein from DNA is known as **transcription**.

NOTE

Transcription means 'to rewrite' or 'carry over'.



- The specific **gene** on a DNA strand, that codes for a particular protein, serves as a **template** for building mRNA.

Process of transcription

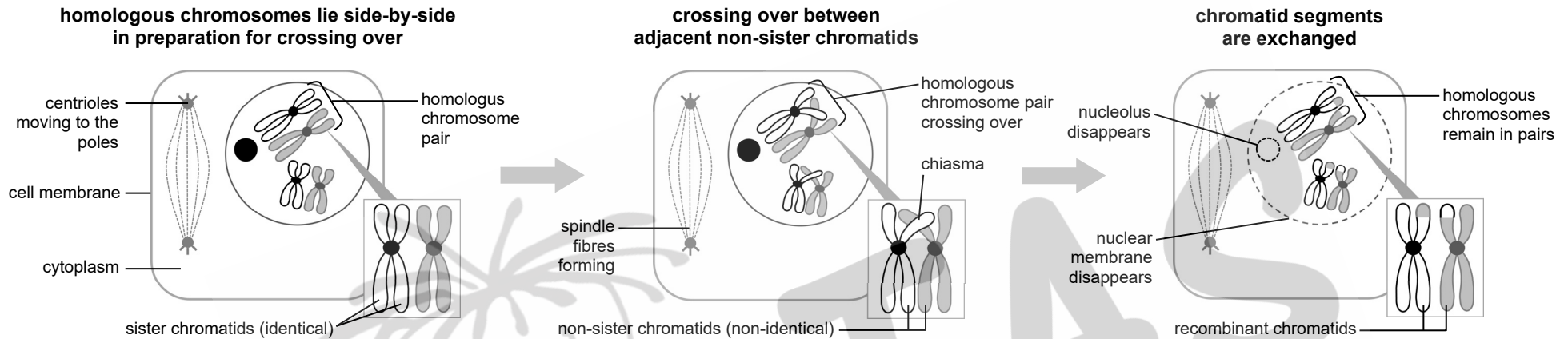
- 1 The **DNA double helix unwinds** and **unzips** in the region where the gene is located.
- 2 The **weak hydrogen bonds** between the DNA strands **break**, forming two separate strands.
- 3 **One DNA strand acts as a template**.
- 4 Free-floating **RNA nucleotides** in the nucleoplasm find their matching bases and join together to **form a complementary mRNA strand** on the DNA template.
- 5 A single mRNA strand is formed with groups of three RNA nitrogenous bases matching each DNA base triplet.

ENRICHMENT

The enzyme RNA polymerase controls the transfer of the code from DNA to RNA.

MEIOSIS I (first meiotic division)

PROPHASE I



- ▶ The **chromatin network condenses**, the threads become shorter and thicker and visible as **chromosomes**.
- ▶ **Homologous chromosomes arrange themselves in pairs** so that the two chromosomes of each pair lie side-by-side to form a **bivalent** during crossing over.
- ▶ Each homologous chromosome is visible as two chromatids joined by a centromere. These identical chromatids of a single chromosome are known as **sister chromatids**.
- ▶ **Crossing over** occurs between homologous chromosomes.
 - ▶ Homologous chromosomes lie side-by-side.
 - ▶ Their **non-sister chromatids overlap** and touch at points called **chiasmata** (singular: **chiasma**).
 - ▶ **Chromatid segments** break off and are **exchanged** at the **chiasmata**.
 - ▶ In this way, **genetic material** is **exchanged** between homologous chromosomes to form **recombinant chromatids**.
- ▶ Crossing over introduces **genetic variation** by **shuffling** or **recombination of genetic material** between maternal and paternal chromosomes.
- ▶ The **nucleolus** and **nuclear membrane disappear**.
- ▶ In animal cells, the centrosome splits and pairs of **centrioles move to opposite poles** of the cell.
- ▶ **Spindle fibres develop** between the centrioles to form the spindle.

*A **bivalent** refers to a pair of homologous chromosomes lying side-by-side during crossing over in Prophase I. After crossing over has been completed, the homologous chromosomes are no longer called a bivalent.*

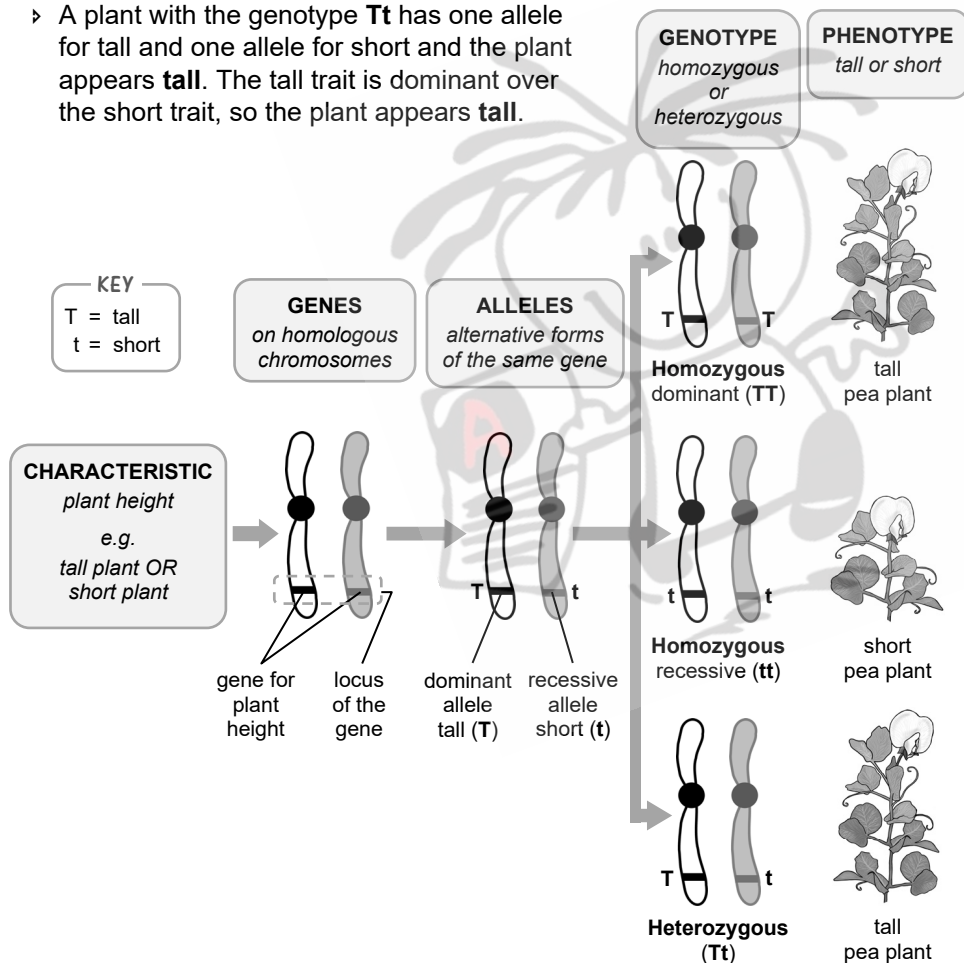


NOTE

*After crossing over, the two chromatids of a chromosome are **not known as sister chromatids**, as their genes have changed, and they are **not identical** anymore. They are referred to as **recombinant chromatids**.*

Phenotype

- ▶ The **physical appearance (visible characteristics)** of an organism is known as its **phenotype**, e.g. tall or short pea plants. The observable characteristics in the phenotype are determined by the genotype as well as the environment.
- ▶ A **dominant allele** will **always** be **expressed** (visible) in the phenotype even if it is paired with a recessive allele.
- ▶ A **recessive allele** will **only** be **expressed** in the phenotype when it is paired with another recessive allele, i.e. the genotype is **homozygous recessive**.
 - ▶ A plant with the genotype **TT** has two alleles for tall and appears **tall**.
 - ▶ A plant with the genotype **tt** has two alleles for short and appears **short**.
 - ▶ A plant with the genotype **Tt** has one allele for tall and one allele for short and the plant appears **tall**. The tall trait is dominant over the short trait, so the plant appears **tall**.



NOTE

An organism can be homozygous with respect to some characteristics and heterozygous with respect to others, e.g. a pea plant can be homozygous with respect to plant height (TT) and heterozygous with respect to flower colour (Pp) (P = purple and p = white).



Phenotype: Tall with purple flowers

Genotype: TTPp



MEIOSIS AND THE SEPARATION OF ALLELES

- ▶ During Meiosis, homologous chromosome pairs (with pairs of alleles) separate from each other.
- ▶ Thus each **gamete** produced by Meiosis **receives only one allele** of a gene.
- ▶ The **pair of alleles** for **one characteristic** on homologous chromosomes, **separate** during **Meiosis**, so that **each gamete** contains **only one allele** for that **characteristic**.
- ▶ This phenomenon is known as **Mendel's Law of Segregation**.



segregation: to separate

TERMS

MENDEL'S LAW OF SEGREGATION

An organism possesses two 'factors' (alleles) which separate or segregate during Meiosis, so that each gamete contains only one of these 'factors' (alleles).



- Somatic cells:**
- ▶ homologous chromosomes occur in pairs
 - ▶ 2 alleles for every gene
 - ▶ diploid
- Gametes:**
- ▶ no homologous chromosome pairs
 - ▶ only one allele for every gene
 - ▶ haploid

DIHYBRID CROSS

WORKED EXAMPLE up to F₁ GENERATION

QUESTION

Mendel crossed **two true-breeding plants**. One that is **homozygous** for both **dominant traits (yellow, smooth seeds)** and the other that is **homozygous** for both **recessive traits (green, wrinkled seeds)**. All the F₁ plants produced yellow, smooth seeds. Draw a genetic diagram to illustrate this cross.

ANSWER

STEP 1 & 2 - Determine the phenotypes and genotypes of the parents

- ▶ The phenotypes of both parents can be determined from the question:
 - ▶ parent plant 1 = yellow, smooth seeds
 - ▶ parent plant 2 = green, wrinkled seeds

REMEMBER

The genes for the characteristics seed colour and seed texture are carried on different homologous chromosome pairs.



NOTE

All the F₁ offspring had yellow, smooth seeds. Therefore yellow is dominant over green and smooth is dominant over wrinkled.

- ▶ Symbols of characteristics:

- ▶ seed colour: **G = yellow**
g = green
- ▶ seed texture: **R = smooth**
r = wrinkled

- ▶ Two symbols/letters are used to represent the two alleles of each characteristic:

- ▶ homozygous yellow = **GG** homozygous smooth = **RR**
- ▶ homozygous green = **gg** homozygous wrinkled = **rr**

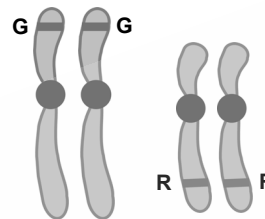


REMEMBER

There are two alleles for every characteristic.

- ▶ The genotype of both characteristics must be provided as a dihybrid cross refers to the inheritance of **two characteristics**.

- ▶ The genotypes of the two characteristics are always written next to each other, e.g. the genotype of true-breeding plants with yellow, smooth seeds is **GGRR**.



Genotype: GGRR

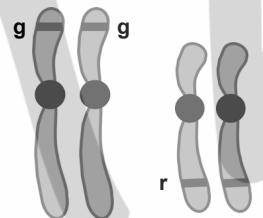
Phenotype: yellow, smooth seeds



NOTE

Always write the same letters first in the genotype, e.g. the G's followed by the R's and keep the same sequence to avoid confusion.

- ▶ The genotype of true-breeding plants with green, wrinkled seeds, is thus **ggrr**.



Genotype: ggrr

Phenotype: green, wrinkled seeds

- ▶ Use the information in the question that both parents are homozygous for both characteristics to complete Steps 1 and 2.

STEP 1

P₁ Phenotype yellow, smooth seeds × green, wrinkled seeds

STEP 2

Genotype GGRR × ggrr

STEP 3 - Determine the gametes

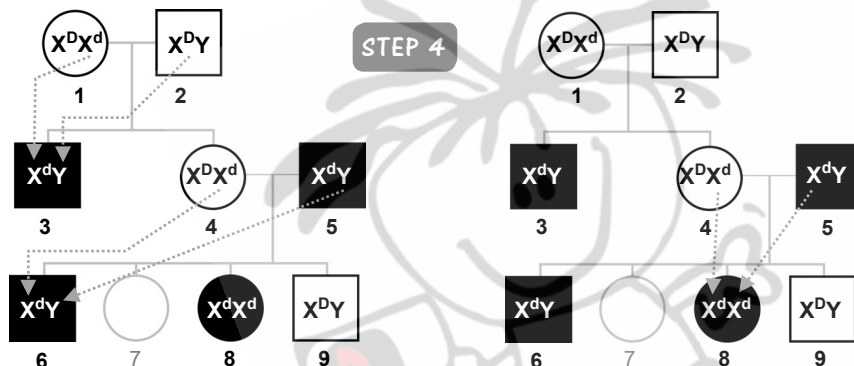
- ▶ The two alleles of each gene separate during Meiosis (**Mendel's Law of Segregation**).
- ▶ Thus gametes will have only one gene (allele) for each characteristic.
- ▶ As there are two sets of alleles, there will be two different symbols/letters for each gamete.

NOTE

The normal dominant allele (X^D) will mask the abnormal recessive allele (X^d) and the mothers appear phenotypically unaffected.



- Colour blind daughter 8 inherits one X chromosome from her father 5 (X^d) and the other from her mother 4 (X^d).
- Therefore, colour blind daughter 8 has a colour blind father 5 (X^dY) and a mother 4 who is heterozygous (X^DX^d) and a carrier for colour blindness.



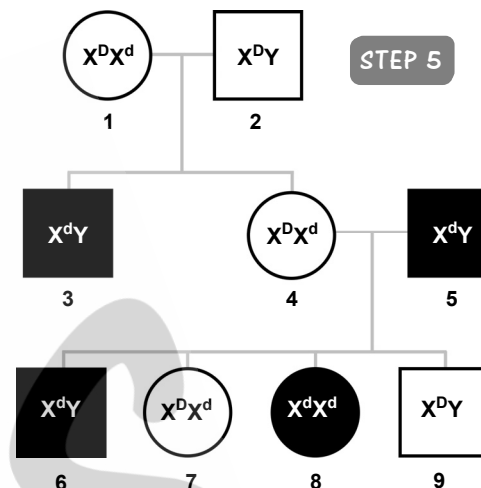
Colour blind sons will always have mothers who are carriers / colour blind

Colour blind daughters will always have colour blind fathers and mothers who are carriers / colour blind

STEP 5 - Identify the remaining unaffected females

- Individual 7 is a phenotypically unaffected female. She can either be a carrier (X^DX^d) or homozygous normal (X^DX^D).
- Use a Punnett square cross between parents 4 and 5 to determine the possible genotypes of individual 7.
 - an unaffected female must have at least one normal allele (X^D)
 - the only possible genotype in the Punnett square is X^DX^d – a carrier female

Parent 5	Parent 4	
	gametes	X^D X^d
	X^d	X^DX^d X^dX^d
	Y	X^DY X^dY



Final pedigree diagram with all the genotypes

PEDIGREE DIAGRAM TIPS

X-linked recessive disorders

- males** are affected more frequently than females
- X-linked recessive disorders may skip generations
- affected sons** often have **unaffected mothers** that are carriers as they inherit their only X chromosome with the abnormal recessive allele (X^d) from their mother
- affected daughters** always have
 - affected fathers** who pass on their only X chromosome with the abnormal recessive allele to their daughters
 - affected mothers or carrier mothers** who pass on an X chromosome with the abnormal recessive allele to their daughters

REMEMBER

Affected fathers can never pass on X-linked genes to their sons as fathers only pass on their Y chromosome to their sons.



REMEMBER

- ▶ A **gene** is a segment of a DNA strand that provides the code for the synthesis of a particular protein.
- ▶ Different genes code for different proteins.
- ▶ Importance of proteins:
 - ▶ enzymes
 - ▶ hormones
 - ▶ reserve fuel
 - ▶ building material
 - ▶ immune responses

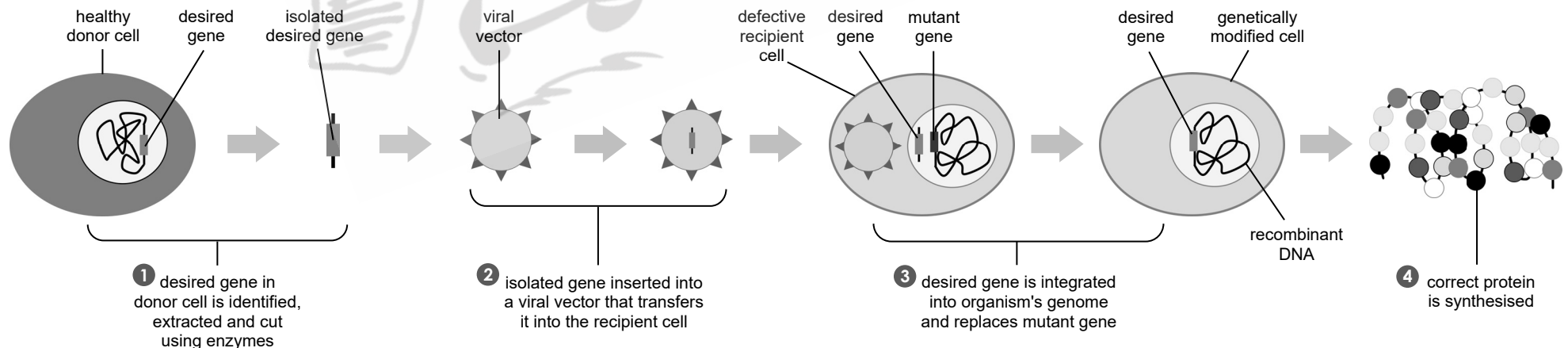


- ▶ Genetic engineering can replace faulty (mutant) or missing genes that cause disorders or diseases in organisms.
- ▶ The new inserted gene ensures that the correct protein is synthesised.
- ▶ The process of genetic engineering follows 4 basic steps:
 - 1 The desired/normal gene is identified in a healthy donor cell, extracted and cut from the DNA using enzymes.
 - 2 The isolated gene is inserted into a **vector** (attenuated virus or bacterium) that transfers it into the recipient cell.



vector: an organism that transfers something, e.g. an isolated gene is transferred by a vector to a defective cell

attenuated: to be made less effective, e.g. a virus that is made less virulent/harmful but still useful



Basic steps in Genetic Engineering

- 3 The desired gene becomes integrated in the organism's **genome** and replaces the mutant/missing gene.
- 4 The correct protein is synthesised and the desired characteristic is expressed in the phenotype.

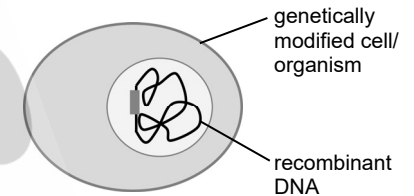
genome:
the complete set of genes in a particular cell/organism



- ▶ Genetic engineering results in the formation of a new DNA sequence in the recipient cell. The new DNA formed is known as **recombinant DNA**.

NOTE

The word '**recombinant**' refers to the new combination of DNA in the recipient cell/organism that received the new gene.



- ▶ The organism that possesses the recombinant DNA is the **genetically modified** or **transgenic organism** that can now synthesise the protein coded by the new gene(s).



GM: genetically modified
GMO: genetically modified organism

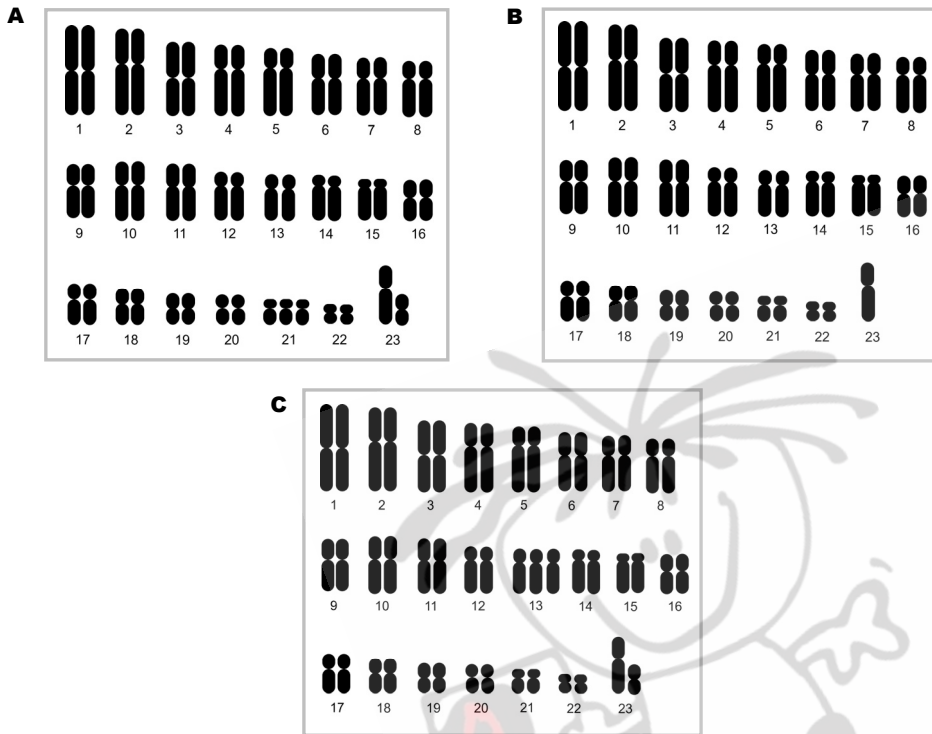
NOTE

The integration of genes (for therapeutic purposes) in cells with faulty or missing genes is known as **gene therapy**.



QUESTION 14

The following karyotypes **A**, **B** and **C** show the chromosomes in the somatic cells of three individuals with different genetic abnormalities.

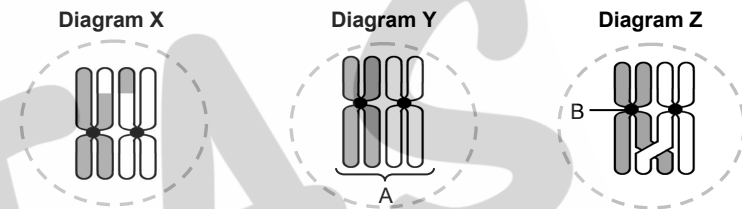


- 14.1 What type of genetic mutation causes all three of these abnormalities?
- 14.2 How many cells will carry the Y chromosome at the end of Meiosis in karyotype **A**?
- 14.3 How many autosomes are found in:
 - 14.3.1 karyotype **B**
 - 14.3.2 karyotype **C**
- 14.4 State the origin of each of the chromosomes in a homologous chromosome pair during the formation of the zygote.
- 14.5 List any THREE characteristics that the chromosomes in a homologous pair have in common.
- 14.6 Explain which karyotype(s) (**A**, **B** or **C**):
 - 14.6.1 belong(s) to a male
 - 14.6.2 belong(s) to a female that is most likely infertile
 - 14.6.3 show(s) an autosomal abnormality
 - 14.6.4 show(s) a gonosomal abnormality

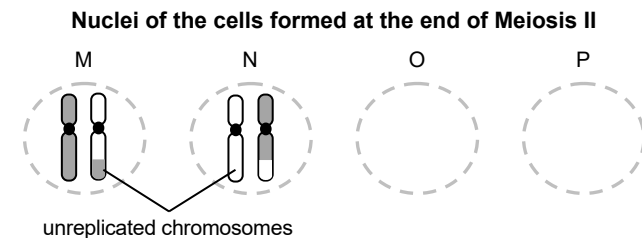
- 14.7 Name the process that occurs during Meiosis and leads to the development of all these genetic abnormalities.
- 14.8 Identify the chromosome position of the abnormality in karyotype **C**.
- 14.9 Name the genetic abnormality shown in karyotype **A** and discuss the events that caused it.
- 14.10 Explain why a mutation in a somatic cell would not affect the offspring.

QUESTION 15

The diagrams below show chromosome pair 21 in the nucleus of a cell from the female ovary. The chromosomes are involved in a process that occurs in a phase of Meiosis.



- 15.1 Give labels for **A** and **B**.
- 15.2 Rearrange the letters **X**, **Y** and **Z** to show the correct sequence in which the events take place in this phase.
- 15.3 Explain why the chromosomes in diagrams **X** and **Y** differ in appearance.
- 15.4 The diagram below shows the nuclei of the four cells that resulted from Meiosis involving the chromosomes in diagram **X** above.



- 15.4.1 Explain why nuclei **O** and **P** do NOT have chromosomes.
- 15.4.2 Name and explain the disorder that will result if diagram **M** represents an egg cell that fuses with a normal sperm cell.

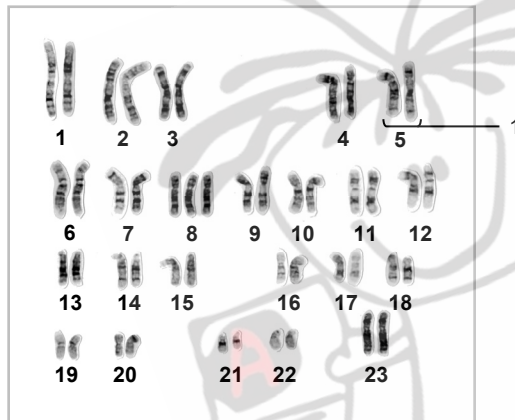
QUESTION 31

The events that occur during cell division are controlled by many different genes. One of these genes, called *MAD1L1*, produces a protein, called *MAD1*, that ensures the correct alignment of chromosomes on the equator of the cell. It plays a role in suppressing the development of tumours due to non-disjunction.

Scientists recently discovered a patient **X** who had developed 12 different types of tumours before the age of 36. Five of these tumours were malignant. Despite this, the patient had responded well to all the different types of cancer treatment.

In an attempt to locate the cause, the scientists analysed thousands of patient **X**'s blood cells and discovered that around 30 – 40% of them had an abnormal number of chromosomes.

The image below shows the chromosome composition of one of patient **X**'s blood cells.



After sequencing the DNA of patient **X**'s blood cells, scientists discovered that the patient suffered from *Mosaic Variegated Aneuploidy (MVA)*. This very rare genetic disorder occurs when a person carries the autosomal mutation in both copies of the *MAD1L1* gene. However, patient **X**'s parents are both unaffected by *MVA*.

31.1 Identify:

31.1.1 the type of diagram represented by the image above

31.1.2 label 1

31.2 What is the gender of the patient? Give a visible reason for your answer.

31.3 Calculate the percentage of malignant tumours that the patient developed. Show ALL calculations.

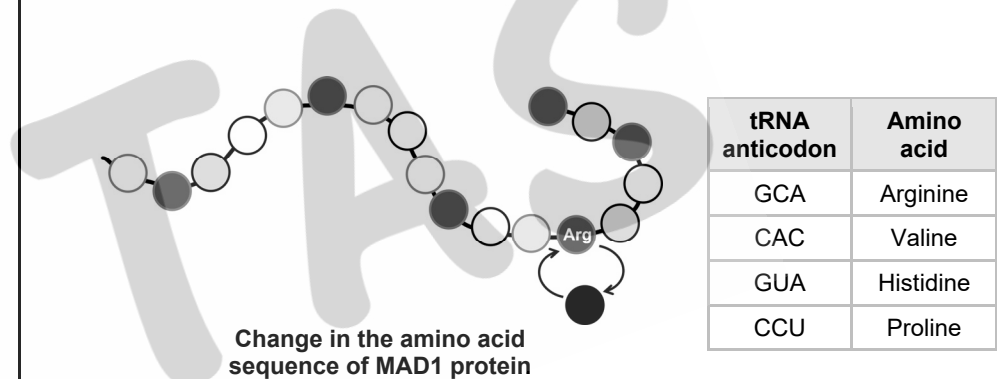
31.4 Describe the chromosomal abnormality visible in the image.

31.5 Is the development of *MVA* linked to a person's gender?

31.6 Is the allele that causes *MVA* dominant or recessive?

31.7 Draw a genetic cross between patient **X**'s parents to support your answer in QUESTION 31.6. Use the letter **D** to represent the dominant allele and **d** for the recessive allele.

31.8 The mutation in the *MAD1L1* gene occurs when a single Cytosine nitrogenous base is replaced with a Thymine nitrogenous base. This causes an Arginine amino acid to be replaced with a different amino acid in the *MAD1* protein. The diagram below depicts this amino acid change, and the table shows the tRNA anticodons that encode for some amino acids.



31.8.1 Name the nitrogenous base that is represented by **A** in the tRNA anticodon GCA.

31.8.2 Explain how the mutation that occurred in the *MAD1L1* gene led to the change in the amino acid sequence of the protein (*MAD1*).

31.9 Describe how a gene mutation occurs and how it differs from a chromosomal mutation.

31.10 Name TWO factors that may accelerate the occurrence of mutations.

31.11 Explain fully how it is possible that neutral/silent mutations may be harmless.

WORKED EXAMPLE - LAMARCK'S THEORY

Question

The ostrich is a large flightless bird with small wings and flight muscles. Use Lamarck's laws to explain the inability of ostriches to fly.

NOTE

Use these **6 guidelines to structure your answers for Lamarck's theory in exams.**



Guidelines

Answer

- 1 **Describe the original characteristic** → All ostriches originally had wings that they used to fly.
- 2 **Describe a selection pressure** → A lack of predators or good rainfall ensured abundant availability of food on ground level.
- 3 **Apply the law of use and disuse** → The ostriches used their wings less to fly to escape predators or in search of food.
- 4 **Describe the adaptation** → So their wings and flight muscles became smaller.
- 5 **Apply the law of the inheritance of acquired characteristics** → The acquired characteristics of smaller wings and flight muscles were passed on to the offspring.
- 6 **Describe the effect in the population after many generations** → Eventually all ostriches have smaller wings and flight muscles that are not suitable for flight.

What changed in the environment?

What was used more/less?

What was the result?

What was passed on?

What happens to the characteristic in the population?

NOTE

Changes occur in an environment. All environmental factors that determine which individuals will survive are known as **selection pressures**. Examples include: presence of predators, availability of resources (e.g. water or food), natural phenomena (floods or droughts), etc.

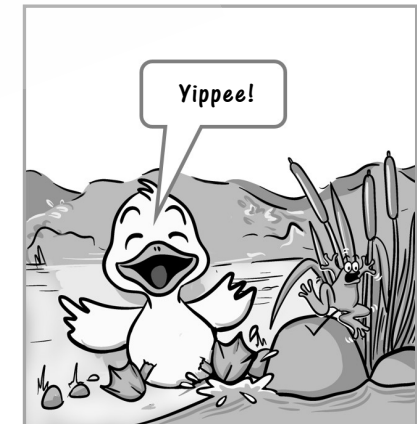


Reasons for rejection of Lamarckism

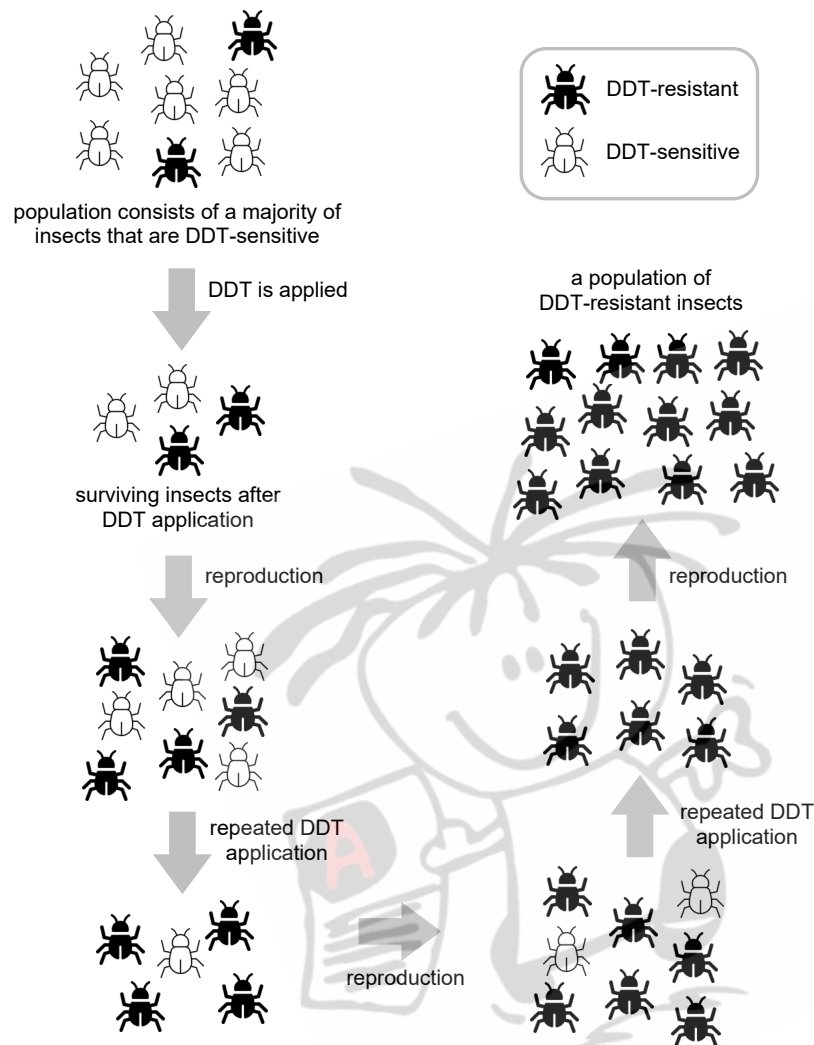
Although Lamarck was **correct** in stating that the **environment can influence the phenotype** (physical appearance) of an organism (e.g. lifting weights increases muscle size), his **theory was rejected** due to his **incorrect conclusions**.

LAMARCK'S INCORRECT CONCLUSION 1

Organisms can desire or will themselves to actively respond/adapt to environmental changes.



- **Organisms cannot desire or will themselves to adapt to their environment, but they must already possess the favourable gene that enables them to adapt and survive in a new environment.**



Representation of the development of insecticide-resistant insects

NOTE



Although DDT is very effective as an insecticide against malaria-carrying mosquitoes, it is banned in many countries as it accumulates in the food chain. It harms the organisms that feed on the mosquitoes, thus decreasing predation and increasing the mosquito population size.

RESISTANCE TO ANTIBIOTICS IN BACTERIA

In the past antibiotics were used on a large scale to kill bacteria. However, a large number of bacteria became increasingly resistant to it.

NOTE

Apply the **7 guidelines** listed on p. 150 – 151 on **Darwin's Theory** to the evolution of antibiotic resistance in bacteria.



The development of drug-resistant bacteria is also an **evolutionary process** based on **natural selection**:

- 1 **Describe the *variation* in the *original population*** → There was variation in the initial bacterial population: some bacteria are **non-resistant** (sensitive) to the antibiotic and others are **resistant** to the antibiotic due to mutations.
- 2 **Describe a *selection pressure*** → Antibiotics are applied to the bacterial environment.
- 3 **Describe the *favourable* and *unfavourable* characteristics** → Bacteria that are **resistant** to antibiotics, are not sensitive to it (**favourable** characteristic). Bacteria that are **non-resistant** to antibiotics, are sensitive to it (**unfavourable** characteristic).
- 4 **Determine who is more *suited for survival*** → More **resistant** bacteria **survive**. More **non-resistant** bacteria **die**.
- 5 **State the *name* of Darwin's *theory*** → This is called **Natural Selection**.
- 6 **Describe the *inheritance* of the *favourable* characteristic** → Antibiotic-resistant bacteria **survive and reproduce** to have more offspring than the antibiotic-sensitive bacteria. The **favourable characteristic** (antibiotic-resistance) is **passed on to the offspring**. The frequency of the resistant allele increases in the population.
- 7 **Describe the *effect* in the *population* after many *generations*** → Eventually there is a higher proportion of antibiotic-resistant bacteria in the population.

Anatomical differences between African apes and humans

Humans and African Apes have many differences.

Pages 171 – 177 elaborate on these differences and more.



foramen magnum:
large opening in the
base of the skull for
the spinal cord to pass
through to the brain



AFRICAN APES

- ▶ small cranium with a smaller, less developed brain
- ▶ foramen magnum in a more backward position at the base of the skull
- ▶ prominent brow ridges, i.e. well-developed
- ▶ prominent cranial ridge
- ▶ prognathous – sloping face with more protruding jaws
- ▶ large jaws
- ▶ large teeth and large canines
- ▶ no chin
- ▶ long, narrow and rectangular palate

SKULL

HUMANS

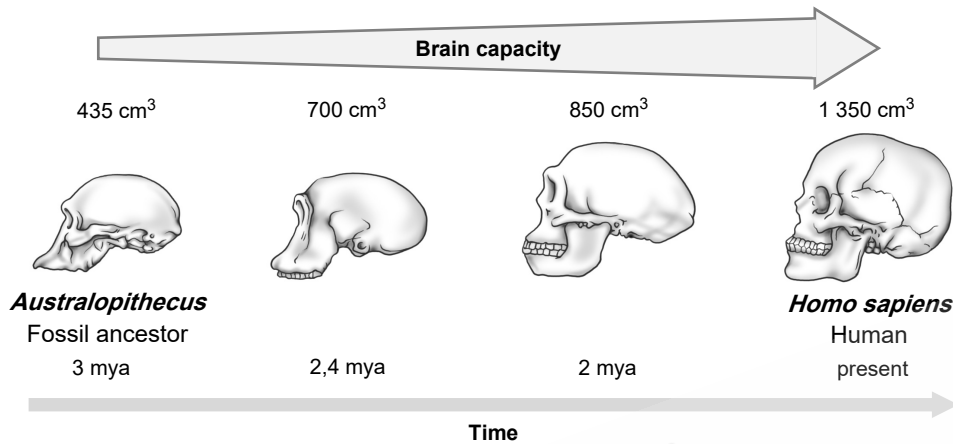
- ▶ large cranium with a larger, more developed brain
- ▶ foramen magnum in a more forward position at the base of the skull
- ▶ reduced brow ridges, i.e. not well-developed
- ▶ no cranial ridge
- ▶ non-prognathous – flatter face with less protruding jaws
- ▶ small jaws
- ▶ small teeth and small canines
- ▶ well-developed chin
- ▶ wider, semicircular curved palate

OTHER FEATURES

- ▶ quadrupedal – knuckle-walkers
- ▶ C-shaped spine
- ▶ arms longer and stronger than legs
- ▶ long and narrow pelvic girdle
- ▶ shorter parallel femurs – knees further apart
- ▶ smaller and weaker knee joints
- ▶ opposable (divergent) big toe with power grip
- ▶ flat feet with no foot arch
- ▶ small and weak heel bone

- ▶ bipedal – walk upright on two legs
- ▶ S-shaped spine
- ▶ arms shorter and weaker than legs
- ▶ short and wide pelvic girdle
- ▶ longer angled femurs – knees closer together
- ▶ larger and stronger knee joints
- ▶ non-opposable (convergent) big toe in line with other toes
- ▶ feet with stable foot arch
- ▶ large and strong heel bone





- ▶ The **cranium** of apes is **small and elongated** and contains a **small, less-developed brain**.
- ▶ Chimpanzee brains have an average size of approximately 395 cm³.
- ▶ **Humans** have a more **rounded skull** with an **enlarged cranium** which contains a **large, highly developed brain**.
- ▶ The average size of the human brain is approximately 1 400 cm³.
- ▶ The more complex human brain gave rise to:
 - ▶ better **hand-eye coordination** (to make and use tools)
 - ▶ **processing of larger** amounts of **information** (complex decision-making)
 - ▶ **faster processing** of information
 - ▶ more **complex activities** (e.g. art, use of fire, religion, etc.)
 - ▶ the development of **language** (for improved communication)

NOTE

The larger brain contributed to the survival of humans because they could successfully adapt to changing environments.



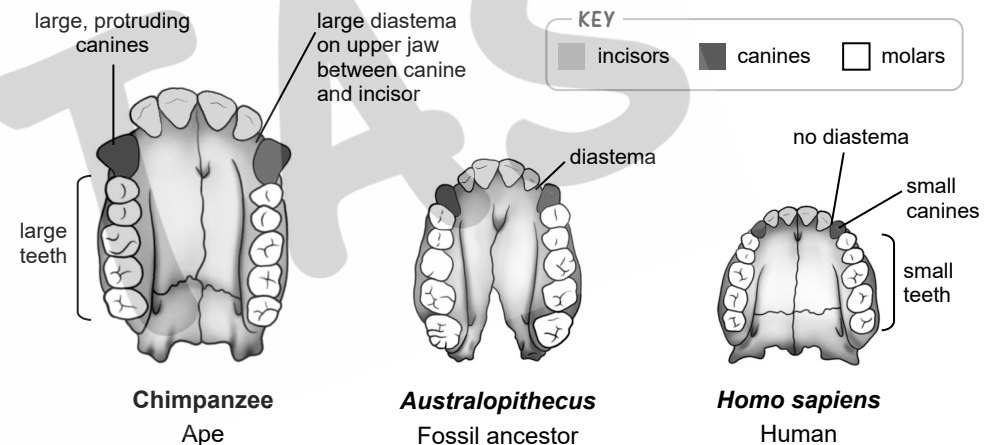
Dentition (teeth)

- ▶ The size of teeth decreased with the course of evolution.
- ▶ **Apes** have **large protruding canines** that are larger than other teeth as they use them for protection and tearing food.

- ▶ In apes, there is a **large gap (diastema)** between the incisors and the canines. It provides space on the upper jaw for the protruding canines of the lower jaw so that the mouth can close.
- ▶ The **human canines** are the **same size** as the **other teeth**, i.e. small and not protruding, so there is **no diastema** (gap).

ENRICHMENT

The **tooth enamel** became **thicker** over time. In apes it is very thin, in early hominins it is thicker and humans have very thick tooth enamel.



Prognathism

- ▶ **Apes** have large, **more protruding jaws (prognathous)** without a chin.
- ▶ Their jaws protrude beyond the upper part of the face, which results in a sloping face.
- ▶ Over time the teeth and jaws became smaller and less protruding.
- ▶ **Humans** have smaller, **less protruding jaws (non-prognathous)** and a well-developed chin.
- ▶ The rounded jaws do not protrude beyond the upper part of the face, which results in a flatter and less sloping face.

GENUS: *Ardipithecus*

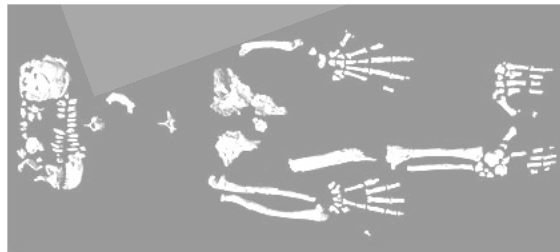
- ▶ *Ardipithecus ramidus* was an early hominin that lived approximately 5.8 – 4.4 million years ago.
- ▶ About 17 *Ardipithecus* fossils were found in the Afar Valley of Ethiopia in 1993.
- ▶ *Ardipithecus* fossils show **intermediate characteristics** (ape-like as well as australopithecine characteristics) indicating that they could be a **transitional species** between apes and *Australopithecus*.



General characteristics of <i>Ardipithecus</i>	
Locomotion	probably bipedal but still climbed trees
Foramen magnum	positioned closer to the front of the skull than apes
Pelvic girdle	wider at the top but narrow and long at the bottom as in apes
Brain capacity	small (300 – 350 cm ³)
Dentition (teeth)	ape-like teeth; large, protruding canines; small diastema
Jaws (prognathism)	more protruding jaws (very prognathous); without a chin (sloping face)
Palate shape	narrow and rectangular (U-shaped)
Cranial ridge and brow ridges	small/no cranial ridge; very prominent brow ridges
Arms	long arms (almost as long as the legs)
Feet	opposable (divergent), grasping big toe as in apes



Skull of
Ardipithecus ramidus



An incomplete skeleton of an *Ardipithecus* fossil called 'Ardi' discovered by Tim White's team

NOTE



The structure of the feet, pelvis, legs and hands indicated that ***Ardipithecus*** was bipedal on the ground, but quadrupedal when climbing trees.

GENUS: *Australopithecus*

- ▶ Australopithecines are regarded as the first bipedal primates.
- ▶ Australopithecines ('ape-men') may be considered **transitional species** between apes and *Homo sapiens* as they have some **intermediate characteristics** (both ape-like and human-like characteristics).
- ▶ The genus name *Australopithecus* literally means 'southern ape'.



NOTE

Individuals belonging to this genus are called **australopithecines**.



- ▶ It is estimated that australopithecines lived in Africa between 4 and 1.4 million years ago.
- ▶ During this time the African forests were gradually replaced by sparse woodlands and grasslands.
- ▶ *Australopithecus* fossils were found mainly in Eastern and Southern Africa.
- ▶ Australopithecines are the closest known relatives of genus *Homo*. Modern humans may have evolved from an *Australopithecus* species, e.g. *Australopithecus afarensis*.



NOTE

Although australopithecines were bipedal, they also climbed trees.

LAETOLI FOOTPRINTS

Australopithecus afarensis

In 1976 unique fossil footprints were discovered in Laetoli, Tanzania by the paleoanthropologist **Mary Leakey**.

- ▶ These 3,8 million year old footprints, belonging to *Australopithecus afarensis*, are one of the oldest fossils indicating evidence of bipedalism as there are no knuckle impressions beside the footprints.
- ▶ The footprints were fossilised as a nearby volcano erupted and covered and preserved the footprints in layers of ash.
- ▶ The feet are very human-like with a strong heel, distinct arch and non-opposable big toe in line with the other toes.
- ▶ The close spacing of the footprints indicates that the organisms had short legs.
- ▶ Other fossils of *Australopithecus afarensis* were found near the footprints in the same sediment layer indicating that this species most likely created the footprints.

	GENUS	<i>Australopithecus</i>
	SPECIES	<i>afarensis</i>
	SCIENTIST	Mary Leakey
	AGE	3,5 mya
	LOCATION	Laetoli, Tanzania
	DATE	1976

ENRICHMENT

The footprints also show a human-like walk – first the heel and then pushing off with the toe.



The Laetoli footprints of adult and child that confirm bipedalism in *Australopithecus afarensis*



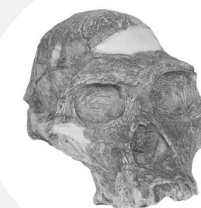
Cast of the Laetoli footprints

MRS PLES

Australopithecus africanus

- ▶ In 1947 a complete adult skull and various bones were found by Dr **Robert Broom** in the Sterkfontein Caves in South Africa.
- ▶ This skull was about 2 – 3 million years old and was classified as *Australopithecus africanus*.
- ▶ The cranium had a smaller brain capacity (485 cm³) similar to a chimpanzee.
- ▶ The position of the foramen magnum suggests that Mrs Ples was bipedal and walked upright.
- ▶ The jaws indicated that there were no protruding canines, and the dentition indicated a diet of mainly plant material.

	GENUS	<i>Australopithecus</i>
	SPECIES	<i>africanus</i>
	SCIENTIST	Robert Broom
	AGE	2 – 3 mya
	LOCATION	Sterkfontein Caves, SA
	DATE	1947



NOTE

After further examination of the dentition, Mrs Ples was reclassified as a male australopithecine in 2018.



***A. africanus*:**
'southern ape of Africa'

TAUNG CHILD

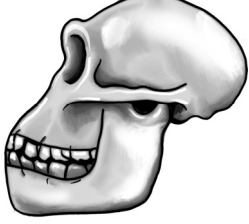
Australopithecus africanus

- ▶ In 1924 the fossil skull of a hominin was found by Professor **Raymond Dart** at Taung, northwest of Kimberley.
- ▶ It was the skull of a child of about 3 – 4 years old.
- ▶ The skull had human as well as ape-like characteristics:
 - ▶ a small brain capacity (340 cm³) similar to apes
 - ▶ small, human-like teeth
 - ▶ foramen magnum in a more forward position (bipedalism)
- ▶ The Taung skull is classified under *Australopithecus africanus* (2 – 3 million years ago).

	GENUS	<i>Australopithecus</i>
	SPECIES	<i>africanus</i>
	SCIENTIST	Raymond Dart
	AGE	2 – 3 mya
	LOCATION	Taung, SA
	DATE	1924

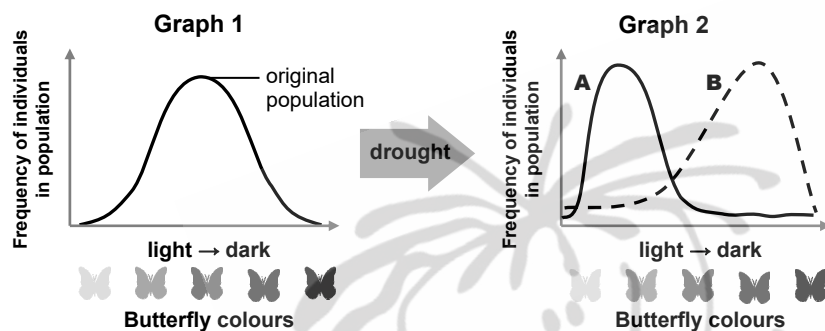


SUMMARY OF HOMININS

Age	Species	Fossil examples	Fossil sites	Palaeontologist	General Characteristics
5,8 – 4,4 mya	<i>Ardipithecus ramidus</i>	Ardi	Ethiopia (Great Rift Valley)	Tim White team	▶ brain capacity: 300 – 350 cm³ ▶ less forward position of foramen magnum than <i>Homo</i> species ▶ very prognathous ▶ very prominent brow ridges ▶ small/no cranial ridge ▶ large, protruding canines ▶ bipedal and tree climbing 
	FOSSILS ONLY FOUND IN AFRICA				
3 – 3,7 mya	<i>Australopithecus afarensis</i>	Lucy	Ethiopia (Great Rift Valley)	Donald Johanson	▶ brain capacity: 375 – 550 cm³ ▶ less forward position of foramen magnum than <i>Homo</i> species ▶ very prognathous ▶ prominent brow ridges ▶ small/no cranial ridge ▶ large, protruding canines ▶ bipedal and tree climbing 
	<i>Australopithecus afarensis</i>	Laetoli footprints	Tanzania (Great Rift Valley)	Mary Leakey	
3,2 – 2 mya	FOSSILS ONLY FOUND IN AFRICA				▶ brain capacity: 428 – 625 cm³ ▶ less forward position of foramen magnum than <i>Homo</i> species ▶ prognathous ▶ prominent brow ridges ▶ small/no cranial ridge ▶ smaller, less protruding canines ▶ bipedal 
	<i>Australopithecus africanus</i>	Mrs Ples	Sterkfontein (Cradle of Humankind)	Robert Broom	
	<i>Australopithecus africanus</i>	Taung Child	Taung (North West, SA)	Raymond Dart	
	<i>Australopithecus species</i>	Little Foot	Sterkfontein (Cradle of Humankind)	Ron Clarke	
1,9 – 1,8 mya	FOSSILS ONLY FOUND IN SOUTHERN AFRICA				▶ brain capacity: 420 cm³ ▶ less forward position of foramen magnum than <i>Homo</i> species ▶ less prognathous ▶ prominent brow ridges ▶ small/no cranial ridge ▶ more human-like teeth, less protruding canines ▶ bipedal 
	<i>Australopithecus sediba</i>	Karabo	Malapa Cave (Cradle of Humankind)	Lee Berger	
	FOSSILS ONLY FOUND IN SOUTHERN AFRICA				

QUESTION 14

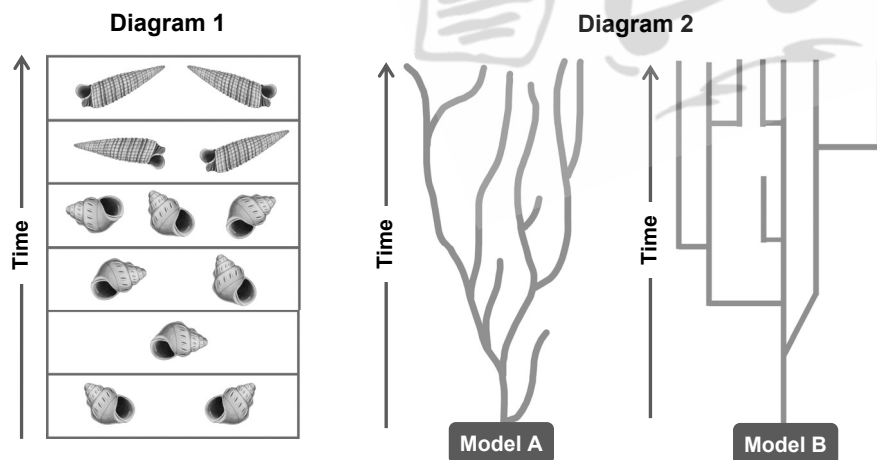
- 14.1 Provide the term for external forces or environmental factors that put pressure on a population and serve as a trigger for natural selection.
- 14.2 Provide any THREE examples of the forces/factors mentioned in QUESTION 14.1.
- 14.3 Graph 1 below shows the frequency of different colours of butterflies in an environment. There are very few light and dark butterflies, most of the population are an intermediate (medium) shade. After a drought, the darker vegetation is destroyed and predators can easily spot the intermediate and darker butterflies on the sandy soil, but the lighter forms are well camouflaged. Which curve (**A** or **B**) in Graph 2 better illustrates the population distribution after the drought? Explain your answer.



- 14.4 What type of variation is illustrated in the colouring of butterflies?

QUESTION 15

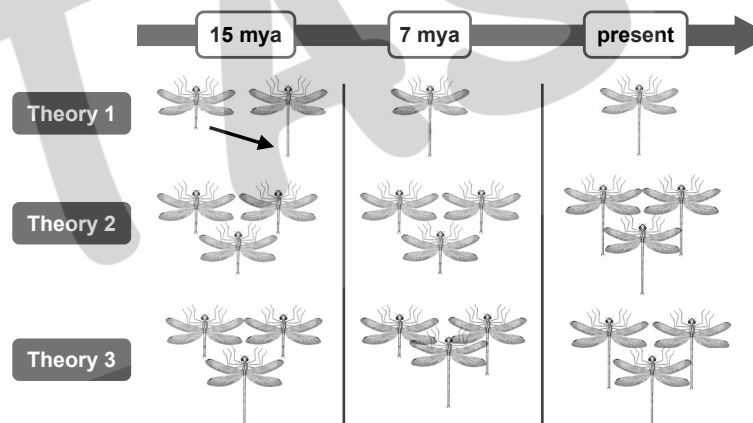
Different scientists have contributed to the development of the theory of evolution over the years. Diagram 1 shows rock layers located close to a river mouth with two types of mollusc shells. Diagram 2 shows two different proposed models (**A** and **B**) for the process of evolution.



- 15.1 For Diagram 2:
- 15.1.1 which model (**A** or **B**) illustrates gradualism
- 15.1.2 which scientist(s) is/are associated with model **A**
- 15.1.3 which scientist(s) is/are associated with model **B**
- 15.2 Distinguish between the two models (**A** and **B**) by providing a definition for each.
- 15.3 Which ONE of the models (**A** or **B**) is the most recently proposed?
- 15.4 Use model **B** to explain the shapes of the shells visible in the rock layers of Diagram 1.
- 15.5 Explain why the fossil record, with all its gaps, tends to support model **B**.
- 15.6 Explain the contribution of the 'Cambrian explosion' in support of the theory of punctuated equilibrium.

QUESTION 16

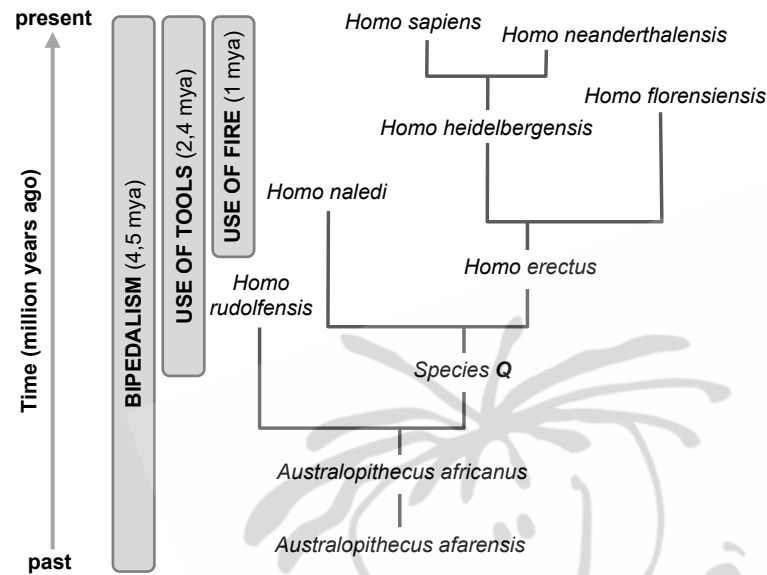
The diagrams below represent three different theories of evolution for the length of dragonfly abdomens.



- 16.1 What does the acronym 'mya' mean?
- 16.2 Give only the NUMBER (1 to 3) of the theory that best represents the following:
- 16.2.1 theory of punctuated equilibrium
- 16.2.2 Charles Darwin's theory of Natural Selection
- 16.2.3 Lamarck's theory of evolution
- 16.3 In which year (**15 mya** or **7 mya**) did a sudden environmental change likely occur for:
- 16.3.1 Theory 1
- 16.3.2 Theory 2
- 16.4 Briefly explain Theory 2.
- 16.5 Explain why the 'theory of evolution' is considered a scientific theory.
- 16.6 State THREE sources of evidence for evolution.

QUESTION 6

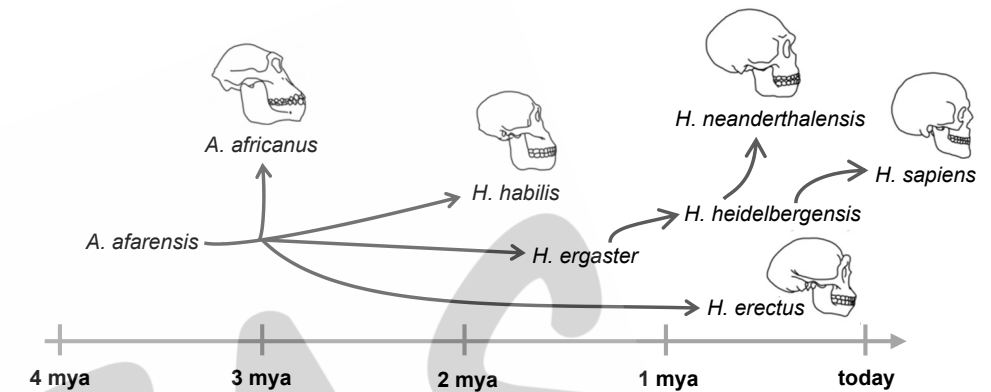
The diagram below represents the possible evolution of humans, the evolution of bipedalism, the use of tools and the use of fire.



- 6.1 Identify the type of diagram shown.
- 6.2 Give the NAME of the species that:
 - 6.2.1 is indicated by **Q** on the diagram
 - 6.2.2 shares a common ancestor with *Homo heidelbergensis*
- 6.3 How many of each of the following are shown in this diagram:
 - 6.3.1 genera
 - 6.3.2 species
- 6.4 Name ONE genus that was bipedal but did not use tools or fire.
- 6.5 According to this diagram, how long did it take hominin species, after the evolution of bipedalism, to start using fire? Show ALL calculations.
- 6.6 Explain why *Homo sapiens* and *Homo neanderthalensis* are more closely related than *Homo sapiens* and *Homo naledi*.
- 6.7 Mrs Ples is a hominin fossil that was discovered in South Africa in 1947.
 - 6.7.1 What genus and species does Mrs Ples's fossil belong to?
 - 6.7.2 Where was Mrs Ples's fossil discovered in South Africa?
 - 6.7.3 Who discovered Mrs Ples's fossil?
- 6.8 Name TWO types of evidence that can be used to support the information in the diagram above.

QUESTION 7

The phylogenetic tree below represents a possible model for human evolution based on the available fossil evidence.



- 7.1 What does the *A.* stand for in *A. afarensis*?
- 7.2 How long ago did the common ancestor for *H. erectus* and *H. heidelbergensis* live?
- 7.3 Which species of the genus *Homo* is the only one still alive today?
- 7.4 The average cranial capacity of *H. sapiens* is 1 400 cm³ compared to 460 cm³ of *A. africanus*. Explain the significance of the difference in cranial capacity of these two species.
- 7.5 Explain any TWO visible structural changes in the skulls that support the idea of a change in diet from raw food to cooked food.
- 7.6 Explain how the location and age of the *Homo* fossils are used to support the 'Out of Africa' hypothesis.
- 7.7 Besides fossil evidence, genetic evidence can also be used to support the theory of human evolution and the 'Out of Africa' hypothesis.
 - 7.7.1 What type of genetic evidence do scientists use to support the 'Out of Africa' hypothesis?
 - 7.7.2 Describe how the genetic evidence in QUESTION 7.7.1. can be used to support the theory of human evolution and the 'Out of Africa' hypothesis.

20.5 Both characteristics are recessive and will only be expressed if both genes are the same, i.e. in a homozygous recessive individual (bbgg).

20.6 black and coarse fur

QUESTION 21

21.1.1 HHBb 21.1.2 hhBb

- All the offspring have white feathers even though the hen was black, i.e. white is dominant over black and the rooster must have been homozygous for white feathers.
- The offspring exhibit both forked and unforked combs even though the rooster and hen both had forked combs, i.e. forked combs are dominant over unforked combs and both parents must have been heterozygous for forked combs.

21.2 HhBB HhBb Hhbb

21.3 black feathers; unforked combs

21.4

gametes	Hb	Hb	hb	hb
HB	HHBb	HHBb	HhBb	HhBb
Hb	HHbb	HHbb	Hhbb	Hhbb
hB	HhBb	HhBb	hhBb	hhBb
hb	Hhbb	Hhbb	hhbb	hhbb

21.5 $\frac{2}{16} \times 32 = 4$ chickens

NOTE

Look for any combination of two h-alleles and two b-alleles. This question does not ask for percentage or a ratio.



QUESTION 22

22.1.1 RRGG

homozygous for red eyes
and grey tail feathers

22.1.2 rrgg

homozygous for black eyes and white tail feathers

22.1.3 RrGg

A Punnett square of a cross between the parents will show that this is the only possible genotype for all F₁ offspring.

22.2 RG Rg rG rg
and
RG Rg rG rg

Use the FOIL method:



$$22.3.1 \quad \frac{3}{16} \times \frac{100}{1} = 18,75\% \approx 19\%$$

$$22.3.2 \quad \frac{4}{16} \times \frac{100}{1} = 25\%$$

$$22.3.3 \quad \frac{4}{16} \times \frac{100}{1} = 25\%$$

NOTE

gametes	RG	Rg	rG	rg
RG	RRGG	RRGg	RrGG	RrGg
Rg	RRGg	RRgg	RrGg	Rrgg
rG	RrGG	RrGg	rrGG	rrGg
rg	RrGg	Rrgg	rrGg	rrgg

QUESTION 23

23.1.1 GgDd

23.1.2 Ggdd

23.2.1 GD, Gd, gD, gd

Use the FOIL method:



23.2.2 Gd, Gd, gd, gd

Use the FOIL method:



23.3.1 50%

Count all the genotypes that have a Gg allele combination:

$$\frac{8}{16} \times 100 = 50\%$$

23.3.2 $\frac{8}{16}$

Count all the genotypes out of 16 possibilities that have a dd allele.

23.3.3 3

Count all the genotypes that have a GgDd allele combination: $\frac{4}{16} \times 12 = 3$ chicks

QUESTION 24

24.1 46

24.2.1 44 + XX

24.2.2 44 + XY

24.3.1 22 + X

24.3.2 22 + X or 22 + Y

24.4.1 Autosomes are chromosomes that are not responsible for sex determination.

24.4.2 Gonosomes are sex-determining chromosomes and are also known as sex chromosomes.

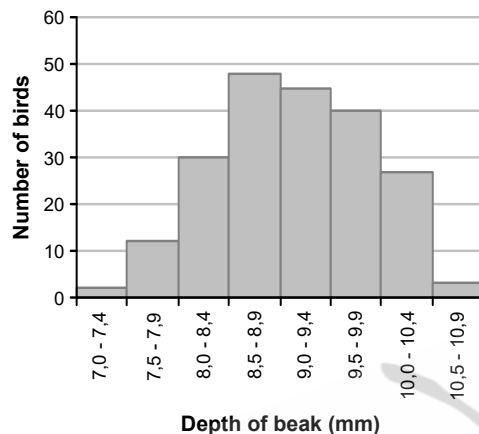
24.5.1 A somatic cell contains the complete set of chromosomes (diploid), while gametes, after Meiosis, only have half the number of chromosomes (haploid).

24.5.2 After the fusion of two gametes during fertilisation, the chromosome number is restored to a diploid number of chromosomes. It keeps the chromosome number in an organism/species constant.

QUESTION 21

21.1

Depth of beaks of a group of finches on the Galapagos Islands



REMEMBER

In histograms the bars touch each other with **no gaps** in between because the data on the x-axis is **continuous**.

21.2 207 $2 + 12 + 30 + 48 + 45 + 40 + 27 + 3$

21.3 163 $30 + 48 + 45 + 40$



21.4 $\frac{27}{207} \times \frac{100}{1} \approx 13\%$

21.5 To calculate an average you need the depth of each individual bird's beak. The table only provides intervals of beak depth for the 207 birds.

21.6 The characteristic gradually changes across a range from one extreme to the other.

- 21.7
- › Crossing over in Prophase 1 of Meiosis – the exchange of genetic material leads to the formation of gametes with different gene combinations.
 - › Random arrangement of chromosomes in Meiosis – this leads to increased variation in the gametes.
 - › Mutations – mutations in the alleles/genes that control depth of beak increase variation in the population.

REMEMBER

Continuous variation characteristics are often controlled by more than one gene and multiple alleles.

QUESTION 22

22.1

Tortoise 1	Tortoise 2
› short neck	› long neck
› rounded shell	› elongated shell
› shorter legs	› longer legs
› larger	› smaller

(1 mark for table + any 2 differences)



22.2.1 tall plants / shrubs / small trees

22.2.2 › The original population / common ancestor of tortoises lived on the mainland of South America.

- › The common ancestor was split into two populations/groups by a geographical barrier, i.e. isolated on the islands by the ocean.
- › The populations/groups could not interbreed and there was no gene flow between them over a long period of time.
- › Due to different environmental conditions on each island, natural selection occurs independently in each population/group. Genotypic and phenotypic differences accumulate between the populations/groups over time.
- › Even if the populations/groups were mixed again, they would not be able to interbreed / produce fertile offspring, because they are now two new species of tortoise (1 and 2).

5 guidelines on Geographic Speciation (p. 158)

22.2.3 › There was variation in the tortoise population that landed on the volcanic island: some tortoises had longer necks and legs and others had shorter necks and legs.

› The island was very dry and there was little vegetation on the ground. This led to competition for food in the higher bushes.

› Tortoises with longer necks and legs could reach more food in the higher branches (favourable characteristic). Tortoises with shorter necks and legs struggled to reach the food (unfavourable characteristic).

› More tortoises with longer necks and legs survived. More tortoises with shorter necks and legs died.

› This is called natural selection.

› Tortoises with longer necks and legs survive to reproduce and have more offspring than tortoises with shorter necks and legs. The favourable characteristics (longer neck and legs) were transferred to the offspring. The alleles for a longer neck and legs increased in frequency in the population.

› Eventually there is a higher proportion of tortoises with longer necks and legs (tortoise species 2).

QUESTION 23

23.1 Predators may mistake it for *R. summersi* which they recognise as poisonous.



7 guidelines for Darwin's Theory (p. 150 – 151)