CAPS

Mind the Gap!

Life Sciences STUDY GUIDE

GRADE 12

basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

Book 2

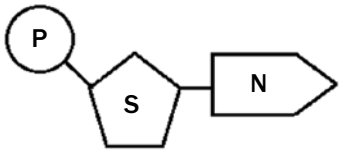
Chapter 1

Paper 2

Nucleic acids

1.1 The structure of DNA and RNA

- Two kinds of nucleic acids are found in a cell, namely **DNA** and **RNA**.
- These two nucleic acids are made of building blocks (or monomers) called **nucleotides.**
- Figure 1.1 (right) shows what a nucleotide looks like.



P – Phosphate group

S – Deoxyribose or ribose sugar

N – Nitrogenous base (adenine, thymine, guanine, cytosine or uracil)

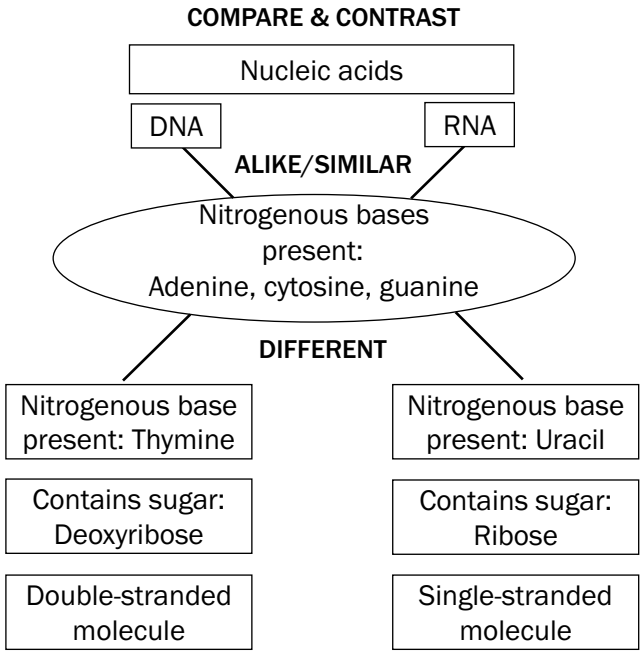
Figure 1.1 A nucleotide

Table 1.1 (below) shows the nitrogenous bases of DNA and RNA.

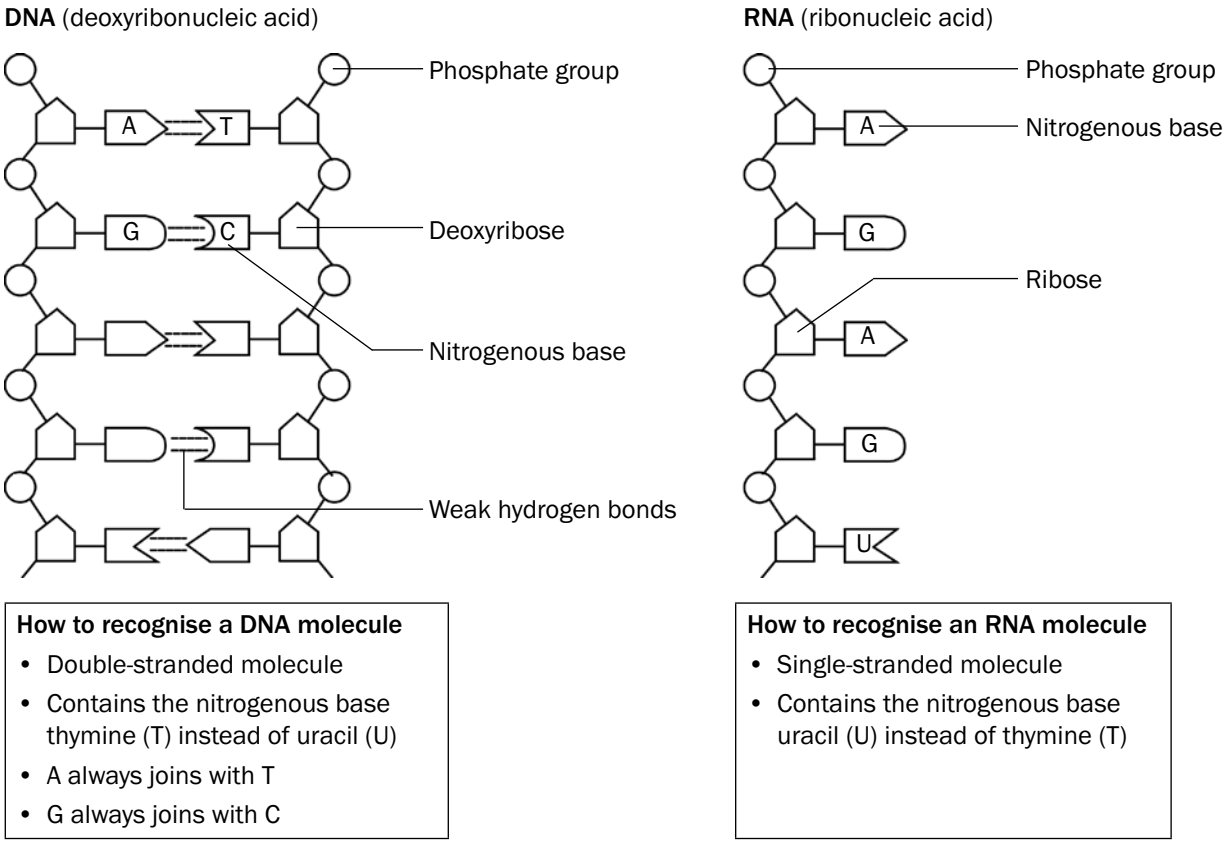
DNA has **four** different nitrogenous bases – **adenine**, **thymine**, **guanine** and **cytosine**.	**RNA** has **four** different nitrogenous bases – **adenine**, **uracil**, **guanine** and **cytosine**.
A Adenine T Thymine Adenine always pairs with thymine. G Guanine C Cytosine Guanine always pairs with cytosine.	A Adenine U Uracil RNA contains uracil instead of thymine. G Guanine C Cytosine

Table 1.1 Nitrogenous bases of DNA and RNA

Figure 1.2 below shows the structure of DNA and RNA. Study the diagrams



in Figure 1.2, and then read the information in the boxes below the diagrams to find out how to tell a DNA molecule from an RNA molecule.



How to recognise a DNA molecule

- Double-stranded molecule
- Contains the nitrogenous base thymine (T) instead of uracil (U)
- A always joins with T
- G always joins with C

How to recognise an RNA molecule

- Single-stranded molecule
- Contains the nitrogenous base uracil (U) instead of thymine (T)

Figure 1.2 The structure of DNA and RNA

1.2 Differences between DNA and RNA

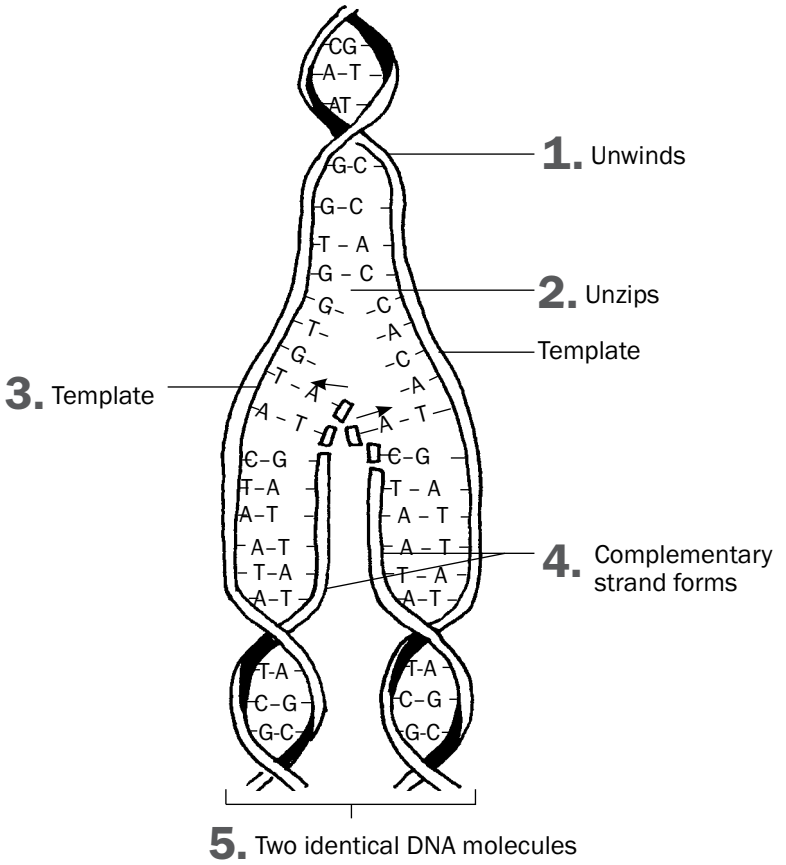
Table 1.2 below summarises the differences between DNA and RNA molecules.

DNA	RNA
1. Double-stranded molecule	1. Single-stranded molecule
2. Contains deoxyribose (sugar)	2. Contains ribose (sugar)
3. Contains the nitrogenous base, thymine	3. Contains the nitrogenous base, uracil

Table 1.2 The differences between DNA and RNA

1.3 DNA replication

DNA replication takes place at interphase before mitosis or meiosis begins. DNA replication is the process during which a DNA molecule makes an exact copy (replica) of itself. This is shown in Figure 1.3 below.



1. The **double helix unwinds**.
2. Weak hydrogen bonds between nitrogenous bases break and two DNA strands **unzip** (separate).
3. Each original DNA strand serves as a **template** on which its complement is built.
4. Free nucleotides build a DNA strand onto each of the original two DNA strands by attaching to their **complementary nitrogenous bases** (A to T and C to G).
5. This results in **two identical DNA molecules**. Each molecule consists of one original strand and one new strand.

Figure 1.3 DNA replication

Significance of DNA replication

DNA replication is important because it:

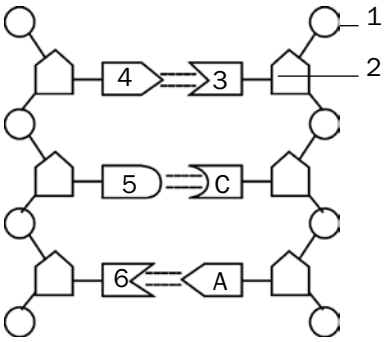
- Doubles the genetic material so it can be shared between the resulting daughter cells during cell division.
- Results in the formation of identical daughter cells during mitosis.

1.4 DNA profiling

Every person except identical twins has her/his own unique DNA profile. It can be described as an arrangement of black bars representing DNA fragments of the person.

It is used to:

- Identify criminals
- Identify dead bodies
- Identify relatives
- Identify paternity



KEY

A – Adenine

C – Cytosine

Figure 1.4 Part of a nucleic acid molecule

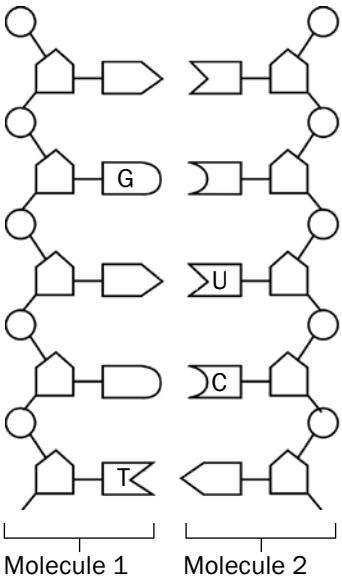


Figure 1.5 Two nucleic acid molecules

Activity 1

1. A DNA molecule contains 600 nitrogen bases. If 20% of this is adenine, determine the number of each nitrogen base in the DNA molecule. (3)

2. Figure 1.4 (left) represents part of a nucleic acid molecule. Study the diagram and answer the questions that follow.

2.1 Identify the nucleic acid shown in Figure 1.4. (1)

2.2 Label the following:

a) Part 1 (1)

b) Part 2 (1)

c) The nitrogenous bases 4, 5 and 6 (3)

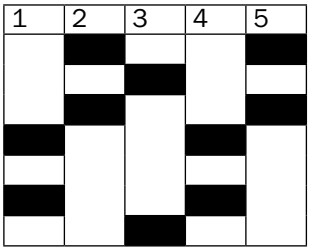
2.3 What is the collective name for the parts numbered 1, 2 and 3? (1)

3. Questions 3.1 and 3.2 are based on Figure 1.5 (left). This is a diagrammatic representation of a **part of two different nucleic acid molecules** found in the cells of organisms during a stage in the process of protein synthesis.

3.1 Name the molecules 1 and 2. (2)

3.2 Give a reason for your answer in question 3.1. (2)

4. The result of profiling various DNA samples in a criminal investigation is shown below



Key:
1. blood sample of victim
2. blood sample of suspect X
3. blood sample of suspect Y
4. first sample of DNA from the crime scene
5. second sample of DNA from crime scene

4.1 Was suspect X or suspect Y involved in the crime? (1)

4.2 Does the DNA of the suspect (from answer 4.1) match the first or second sample? (2)

[17]

Answers to activity 1

1. 20% adenine = 20% thymine✓ 30% cytosine✓ = 30% guanine✓
$\frac{20}{100} \times 600 = 120A = 120T$ $\frac{30}{100} \times 600 = 180C = 180G$ (3)

2.1 DNA✓ (1)

2.2 **a)** Phosphate✓ group (1)

b) Deoxyribose✓ sugar (1)

c) 4 – adenine (A)✓ 5 – guanine (G)✓
6 – thymine✓ (3)

2.3 Nucleotide✓ (1)

3.1 1 – DNA 2 – mRNA/RNA✓ (2)

3.2 DNA contains the nitrogenous base thymine (T).✓
RNA contains the nitrogenous base uracil (U).✓ (2)

4.1 Suspect X was involved. ✓ (1)

4.2 The DNA of suspect X matches with the second sample. ✓✓ (2)

[17]

1.5 Protein synthesis

Protein synthesis is the process by which proteins are made in each cell of an organism to form enzymes, hormones and new structures for cells.

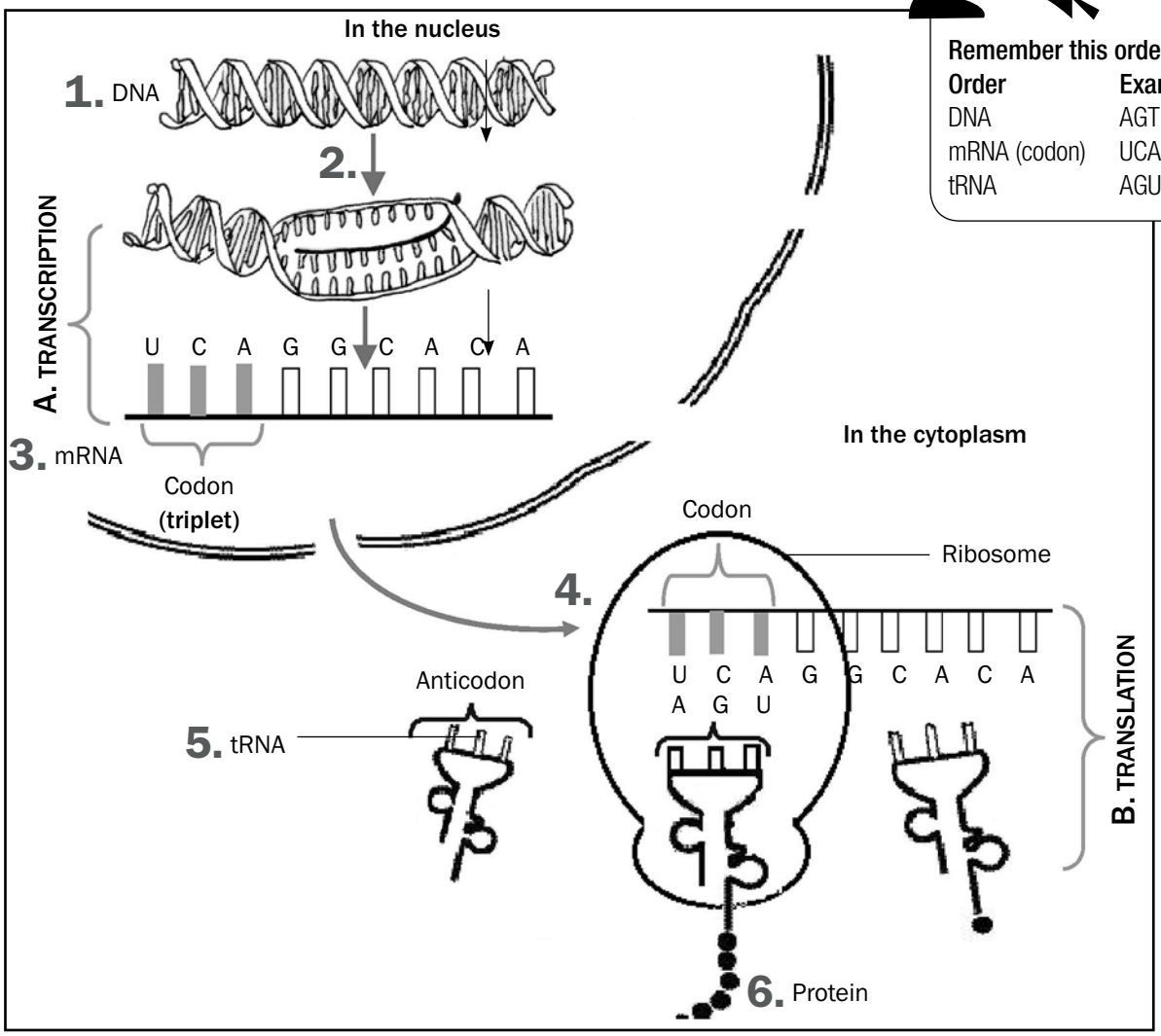


Figure 1.6 The process of protein synthesis

NB

Remember this order:

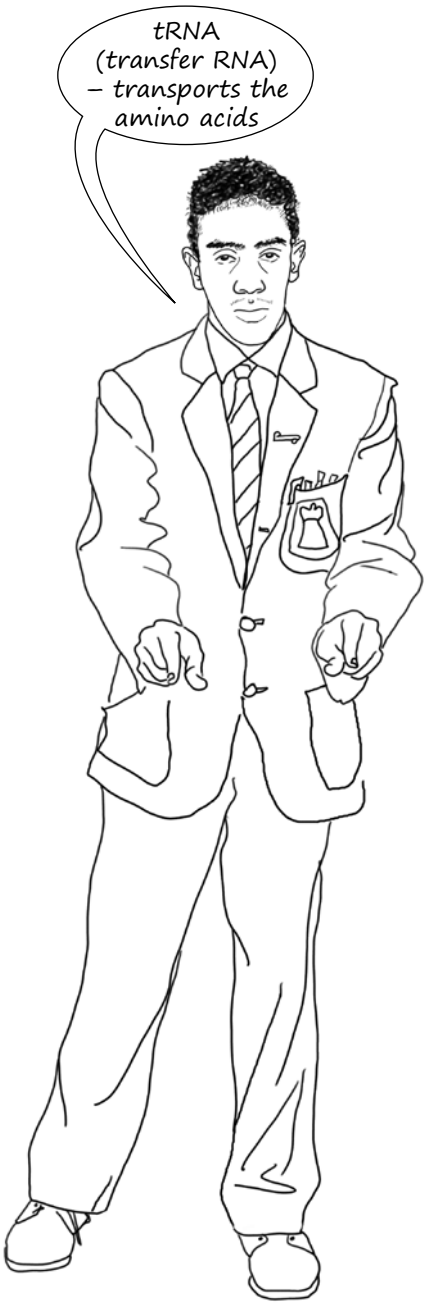
Order	Example
DNA	AGT
mRNA (codon)	UCA
tRNA	AGU

There are two main processes involved in protein synthesis, namely **transcription** and **translation**. They are labelled as A and B in Figure 1.6 above.

Note that the numbers on the diagram correspond with the description below.

A Transcription (takes place in the nucleus)

1. DNA unwinds and splits.
2. One DNA strand acts as a template for forming mRNA.
3. Free nucleotides arrange to form mRNA according to the DNA template. This process is called **transcription**.
4. The mRNA leaves the nucleus through the nuclear pores. Stage B now takes place when mRNA in the cytoplasm attaches to the ribosome.



B Translation (takes place in the cytoplasm on the ribosome)

5. Each tRNA brings a specific amino acid to the mRNA. This is called **translation**.
6. The amino acids are linked together to form a particular protein.

The diagram shown in Figure 1.6 (on page 5) may appear in exam questions in different ways. Do not let the different representations confuse you. Just try to identify the following components by looking for the features listed here:

- **DNA** – double-stranded; look for presence of thymine; found in nucleus only.
- **Nuclear membrane** – has nuclear pores through which mRNA moves.
- **mRNA** – single-stranded; look for presence of uracil; contains a triplet of bases (**codon**) found in nucleus and cytoplasm.
- **Ribosome** – usually mRNA attached to it.
- **tRNA** – contains a triplet of bases (**anticodon**); look for attached amino acid.

Activity 2

Question 1

Study Figure 1.7 (below), which shows the process of protein synthesis, and answer the questions.

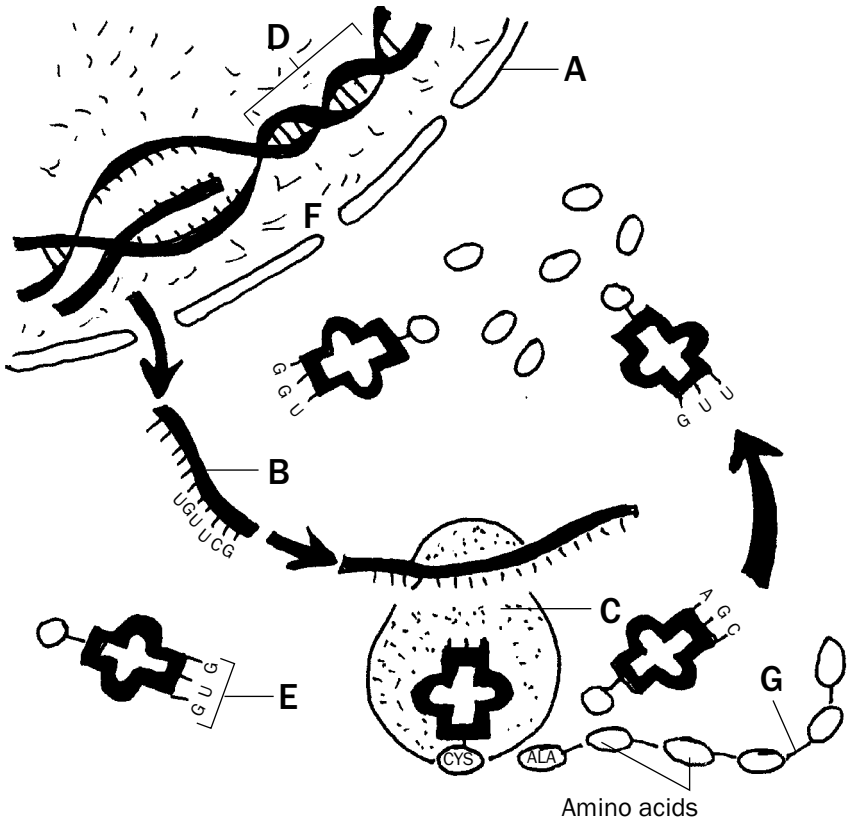


Figure 1.7 Protein synthesis

1.1 Label structures A, B and D. (3)

1.2 State ONE function of molecule D. (1)

exams

For two more problems on **protein synthesis** refer to these National Life Sciences exam papers:

- Life Sciences Paper 1 March 2009 – Question 2.2 on page 9.
- Life Sciences Paper 1 November 2010 – Question 1.5 on page 7.

1.3 Which stage of protein synthesis takes place at F? (1)
1.4 Identify organelle C. (1)
1.5 Name and describe the stage of protein synthesis that takes place at organelle C. (7)
1.6 Write down the codon of anticodon E from top to bottom. (1)
1.7 Name the type of bond (labelled G) between the amino acids. (1)
[15]

Answers to question 1

1.1 A – Nuclear membrane✓
B – mRNA✓
D – DNA✓ (3)
1.2 Carrying hereditary characteristics from parents to their offspring ✓
OR Controls the synthesis (manufacturing) of proteins✓ (1)
1.3 Transcription✓ (1)
1.4 Ribosome✓ (1)
1.5 Translation✓
- The mRNA strand from the nucleus becomes attached✓ to a ribosome with its codons exposed
- each tRNA molecule carrying a specific amino acid✓
- according to its anticodon✓
- matches up with/complements the codon of the mRNA✓
- so that the amino acids are placed in the correct sequence✓
- adjacent amino acids are linked✓
- to form a protein✓ (7)

1.6 CAC✓ (the anticodon is GUG, so the complementary codon is CAC) (1)
1.7 Peptide Bond (1)
[15]

Question 2

Table 1.3 below shows the DNA base triplets that code for different amino acids.

Amino acid	Base triplet in DNA template
Leu (leucine)	GAA
His (histidine)	GTA
Lys (lysine)	TTT
Pro (proline)	GGG
Ala (alanine)	CGA
Trp (tryptophan)	ACC
Phe (phenylalanine)	AAA
Gly (glycine)	CCT

Table 1.3 Different amino acids and their DNA base triplets

Remember this order:

Order	Example
DNA	CGA
mRNA (codon)	GCU
tRNA	CGA

The following is a part of a sequence of amino acids that forms a particular protein molecule:

Ala	**His**	**Trp**	**Leu**	**Lys**

2.1 Name the process by which mRNA is formed from a DNA template. (1)

2.2 How many mRNA codons would be involved in forming the portion of protein shown above? (1)

2.3 Write down the sequence of the first **three** mRNA codons (from left to right) for this portion of the protein. (3)

[5]

Answers to question 2

2.1 Transcription✓ (1)

2.2 5✓ (1)

2.3 GCU✓– CAU✓– UGG✓ (3)

[5]

Chapter 2
Paper 1 and 2

Meiosis

2.1 What is meiosis?

Meiosis is a type of cell division whereby a diploid cell (somatic cell) undergoes two cell divisions, and divides to form four dissimilar haploid cells (sex cells). Diploid cells have two sets of chromosomes, where each chromosome has a homologous partner. Haploid cells only have one set of chromosomes. Chromosomes in haploid cells have no homologous partners.

Before meiosis begins (during interphase), DNA replication takes place. The result is two sets of chromosomes consisting of two identical chromatids joined together with a centromere. This is shown in Figure 2.1 (right).

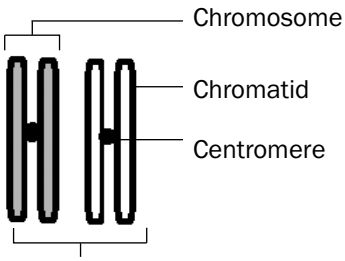


Figure 2.1 Homologous chromosomes

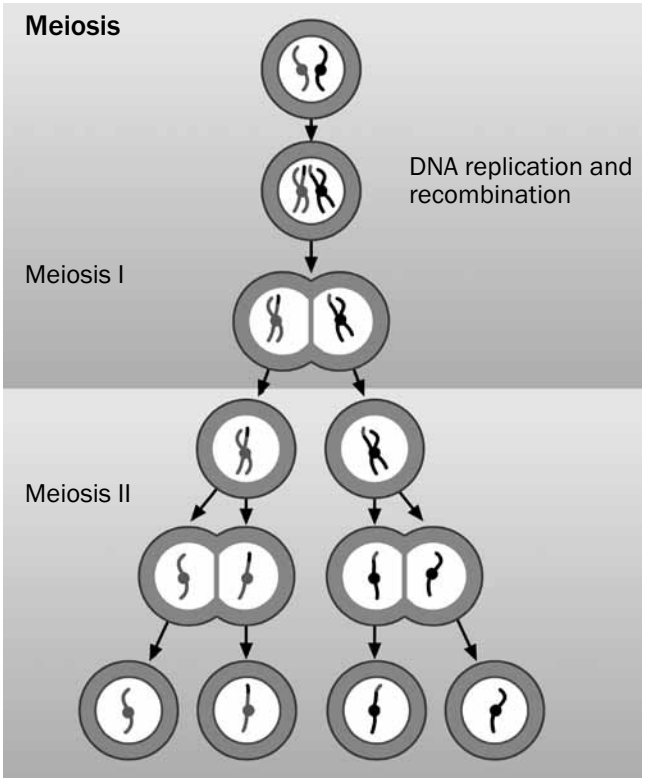
2.2 The process of meiosis in animal cells

Meiosis is the type of cell division used to produce **gametes or sex cells** (sperm and egg cells). A cell undergoing meiosis will divide **twice** – the first division is **meiosis I** and the second is **meiosis II**.

In the first meiotic division, the number of cells is doubled, but the number of chromosomes is not. This results in half as many chromosomes per cell.

In the second meiotic division, the number of chromosomes does not get reduced.

The diagram alongside shows how meiosis starts with a diploid cell and divides twice (meiosis I and II), resulting in four haploid cells.



Now turn the page to find out what happens during each stage of meiosis I and II.

2.2.1 First meiotic division

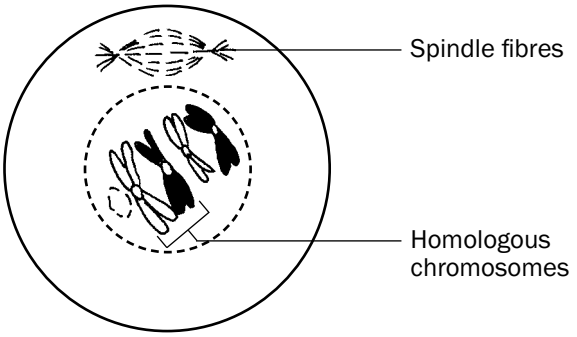


Figure 2.2 Prophase 1

Prophase 1

- Chromosomes shorten and become visible as two chromatids joined by a centromere.
- Homologous pairs of chromosomes are now visible.
- The nuclear membrane and nucleolus disappear.
- The spindle starts to form.
- Chromatids from each homologous pair touch. The point where they touch is called a chiasma.
- DNA is crossed over (swopped) at the chiasma.
- The spindle continues to form.

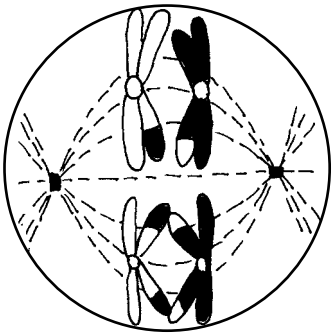


Figure 2.3 Metaphase 1

Metaphase 1

- The spindle extends across the whole cell.
- The homologous chromosomes line up along the equator of the spindle in their homologous pairs.
- One chromosome of each pair lies on either side of the equator.
- The centromere of each chromosome attaches to the spindle fibres.

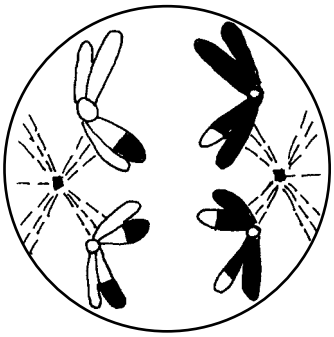


Figure 2.4 Anaphase 1

Anaphase 1

- The spindle fibres shorten and pull each chromosome of each chromosome pair to opposite poles of the cell.

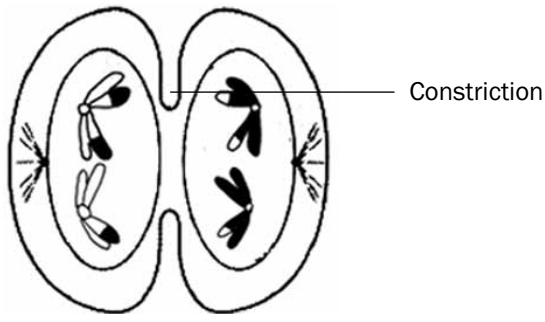


Figure 2.5 Telophase 1

Telophase 1

- The chromosomes reach the poles of the cell.
- Each pole has half the number of chromosomes present in the original cell.
- The cell membrane constricts and divides the cytoplasm in half to form two cells.

2.2.2 Second meiotic division

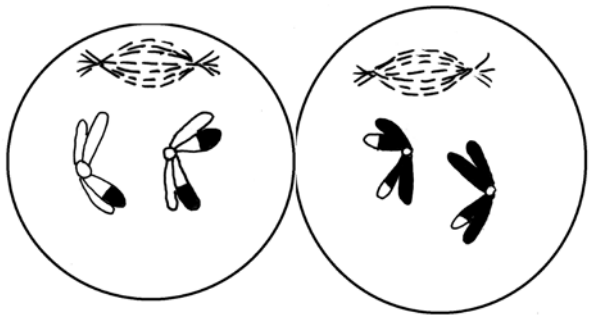


Figure 2.6 Prophase 2

Prophase 2

- Each cell formed during meiosis I now divides again.
- A spindle forms in each of the new cells.

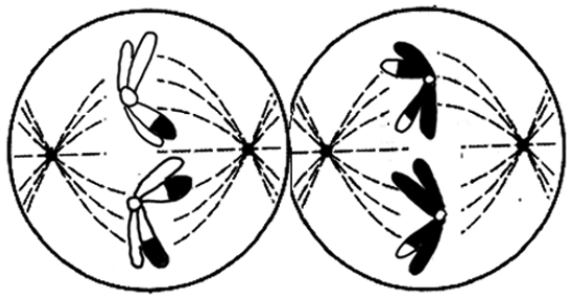


Figure 2.7 Metaphase 2

Metaphase 2

- Individual chromosomes line up at the equator of each cell, with the centromeres attached to the spindle fibres.

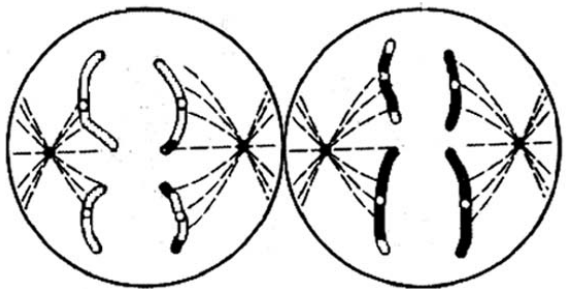


Figure 2.8 Anaphase 2

Anaphase 2

- The spindle fibres start to contract.
- The centromeres split and daughter chromosomes/chromatids are pulled to the opposite poles of each cell.

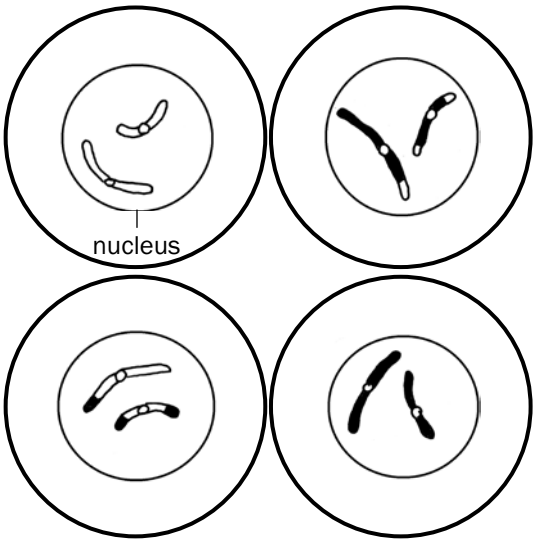


Figure 2.9 Telophase 2

Telophase 2

- The daughter chromosomes/chromatids reach the poles and a new nucleus forms.
- The cell membrane of each cell constricts and the cytoplasm divides into two cells.
- Four haploid daughter cells are formed.
- Each daughter cell has half the number of chromosomes of the original cell.
- The daughter cells are genetically different from each other.

An easy way to remember the events of meiosis is to use the word mnemonic **IPMAT.**

Letter	Phase	Event
I	**I**nterphase	**I** for **in between:** The part of the life cycle of the cell that is in between cell divisions.
P	**P**rophase	**P** for **preparation:** The chromosomes prepare for meiosis by untangling and becoming clearly visible. Crossing over also takes place.
M	**M**etaphase	**M** for **middle:** The chromosomes move to the 'middle' (equator).
A	**A**naphase	**A** for **apart:** The chromosomes/chromatids move apart/move to the poles.
T	**T**elophase	**T** for **terminal:** The final phase of meiosis I/ meiosis II.

2.3 The significance of meiosis

There are two reasons why meiosis is important.

1. It reduces the number of chromosomes by half, in other words from diploid to haploid. This ensures that sex cells have half the number of chromosomes of other somatic cells so that when fertilisation occurs the zygote formed has the correct number of chromosomes. It balances the doubling effect of fertilisation.
2. Crossing over introduces genetic variation. Genetic variation results in offspring that are better adapted to a particular environment and ensures that they will have a better chance of survival.

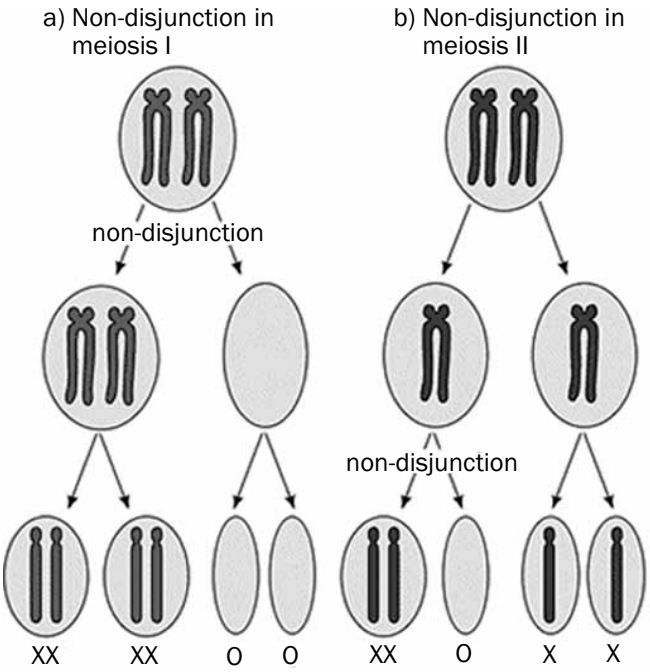


Figure 2.10 Non-disjunction meiosis I and meiosis II
XX : 2 chromosomes X : 1 chromosome O : no chromosomes

2.4 Abnormal meiosis

- Sometimes mistakes occur during the process of meiosis.
- This can happen in Anaphase 1 where the homologous chromosomes may not separate. Also called non-disjunction.
- It can also happen in Anaphase 2 when there is non-disjunction of the sister chromatids.
- If there is non-disjunction of chromosome pair 21 in humans it leads to the formation of an abnormal gamete with an extra copy of chromosome 21.
- If there is fusion between a normal gamete and an abnormal gamete (with extra copy of chromosome 21) it leads to Down Syndrome.

2.5 Differences between meiosis I and meiosis II

Meiosis I	Meiosis II
The chromosomes arrange at the equator of the cell in homologous pairs.	Chromosomes line up at the equator of the cell individually.
Whole chromosomes move to opposite poles of the cell.	Daughter chromosomes/chromatids move to opposite poles of the cell.
Two cells form at the end of this division.	Four cells are formed at the end of this division.
The chromosome number is halved during meiosis I.	The chromosome number remains the same during meiosis II.
Crossing over takes place.	Crossing over does not take place.

Table 2.1 The differences between meiosis I and meiosis II

e.g. Worked example

Study the diagrams below of two stages of meiosis then answer the questions that follow.

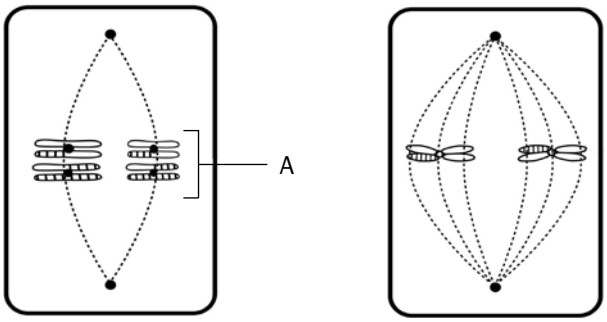


Figure 2.11 Two stages of meiosis

1. State ONE visible reason in Diagram I which indicates that meiosis is taking place. (1)
2. How many chromosomes would be present in each daughter cell at the end of meiosis in this cell? (1)
3. Describe what takes place in the cell after the phase shown in Diagram I. (3)
4. Tabulate TWO visible differences between the phases of meiosis shown in Diagrams I and II. (5)

[10]

Answers to worked example

1. The chromosomes are lined up at the equator of the cell in their homologous pairs.✓

OR

The chromosomes show evidence of crossing over.✓ (1)

2. Two ✓ chromosomes. (1)

3. The next phase is Anaphase 1. The spindle fibres contract.✓ (shorten) and pull each chromosome✓ of each chromosome pair to opposite poles✓ of the cell. (3)

4. ✓

Diagram I (metaphase 1)	Diagram II (metaphase 2)
1. Chromosomes are lined up at the equator in homologous pairs.✓	1. Chromosomes are lined up at the equator individually.✓
2. Four chromosomes are present.✓	2. Two chromosomes are present.✓

(5)

[10]

Activity 1

Question 1

Give the correct word or term for each of the statements or definitions provided below.

1.1	The structure that joins the two halves of a double-stranded chromosome (1)
1.2	A pair of chromosomes, one inherited from each parent, that have the same genes at the same locus (1)
1.3	A single-stranded chromosome formed during Anaphase 2 (1)
1.4	The point of contact between two chromosomes of a homologous pair during crossing over (1)
1.5	One half of a double-stranded chromosome (1)
1.6	The phase in meiosis where crossing over occurs (1)

[6]

Answers to question 1

1.1 Centromere✓ (1)

1.2 Homologous chromosomes✓ (1)

1.3 Daughter chromosome/chromatid✓ (1)

1.4 Chiasma✓/chiasmata✓ (1)

1.5 Chromatid✓ (1)

1.6 Prophase 1✓ (1)

[6]

Question 2

Figure 2.12 (right) represents a process taking place during meiosis. Study the diagram and answer the questions that follow.

2.1 Provide labels for parts A, B, C and D. (4)

2.2 Name the process in meiosis that is illustrated in Figure 2.12. (1)

2.3 State ONE importance of the process you named in question 2.2. (2)

2.4 Draw a diagram of the structure labelled A to show its appearance immediately after the process you named in question 2.2. (2)

[9]

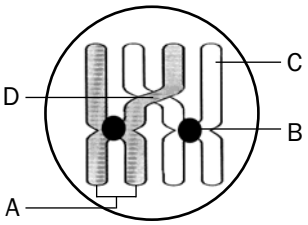


Figure 2.12 Diagram representing a process taking place during meiosis

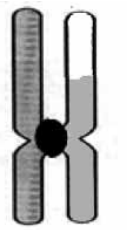
Answers to question 2

2.1 A – Chromosome✓
B – Centromere✓
C – Chromatid✓
D – Chiasma✓/chiasmata (4)

2.2 Crossing over✓ (1)

2.3 It introduces genetic✓ variation✓ (2)

2.4
- A double-stranded chromosome with the strands joined by a centromere✓
- There is evidence of crossing over.✓ (2)



[9]

Question 3

Figure 2.13 (right) represents an animal cell in a phase of meiosis. Study the diagram and answer the questions that follow.

3.1 State whether the phase of meiosis shown in Figure 2.13 is meiosis I or meiosis II. (1)

3.2 Give ONE visible reason for your answer in question 3.1. (1)

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

3.4 How many chromosomes:

a) were present in the parent cell before meiosis began? (1)

b) will be present in each cell at the end of meiosis? (1)

3.5 State ONE place in a human female where meiosis would take place. (1)

3.6 Could the cell represented in Figure 2.13 be that of a human? (1)

3.7 Explain your answer to question 3.6. (2)

3.8 Give TWO reasons why meiosis is biologically important. (2)

3.9 Give the term for the situation when some of the chromosomes do not separate correctly during the phase shown in Figure 2.13. (1)

[13]

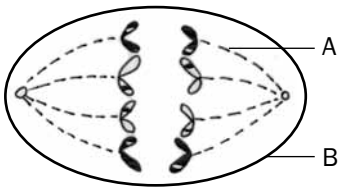


Figure 2.13 Diagram representing a phase of meiosis

Answers to question 3

3.1 Meiosis II✓ (1)

3.2 Daughter chromosomes/chromatids are being pulled to the opposite poles✓ (1)

3.3 A – Spindle fibre✓
B – Cell membrane✓ (2)

3.4 **a)** 8✓
b) 4✓ (2)

3.5 Ovaries✓ (1)

3.6 No✓ (1)

3.7 There are only 4 chromosomes present✓ instead of 23.✓ (2)

3.8 It introduces genetic variation.✓
It balances the doubling effect of fertilisation as it halves the number of chromosomes in the sex cells.✓ (2)

3.9 Non-disjunction✓ (1)

[13]

exams

For four further problems on **meiosis** refer to the following National Life Sciences exam papers:

- Life Sciences Paper 1 February/March 2012: Version 1 – Question 2.1 on page 9.
- Life Sciences Paper 1 November 2010 – Question 2.1 on page 10.
- Life Sciences Paper 1 February/March 2010 – Question 1.4 on page 6.
- Life Sciences Paper 1 November 2009 – Question 1.5 on page 7.

Question 4

The diagram below shows the nuclei of the four cells that resulted from meiosis of chromosome pair 21 in a woman.

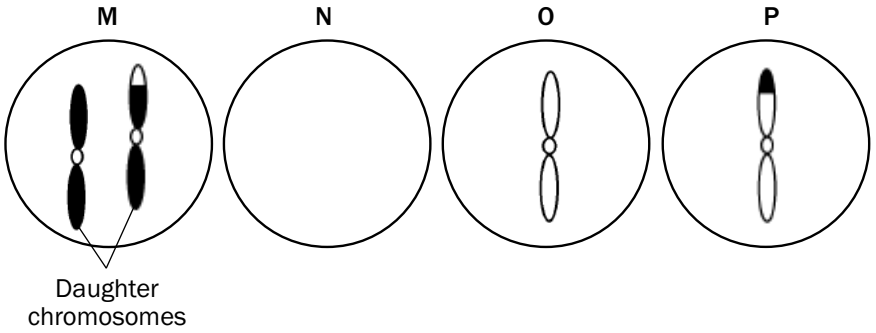


Figure 2.14: Diagram that shows the nuclei of four cells resulted from meiosis

4.1 Explain why nucleus **N** does NOT have a chromosome pair 21. (2)

4.2 Name and explain the disorder that will result if diagram **M** represents an egg cell that fuses with a normal sperm cell. (3)

[5]

Answers to question 4

4.1 During Anaphase 1 the chromosome pair 21 does not separate✓/ non-disjunction. Gamete M will have an extra copy of chromosome number 21 and therefore gamete N does not have a copy of chromosome 21✓ (2)

4.2 Down syndrome✓/Trisomy 21 if gamete M fuses with normal sperm having 1 copy of chromosome 21 ✓ the resulting zygote will have 3 copies of chromosome 21✓ (3)

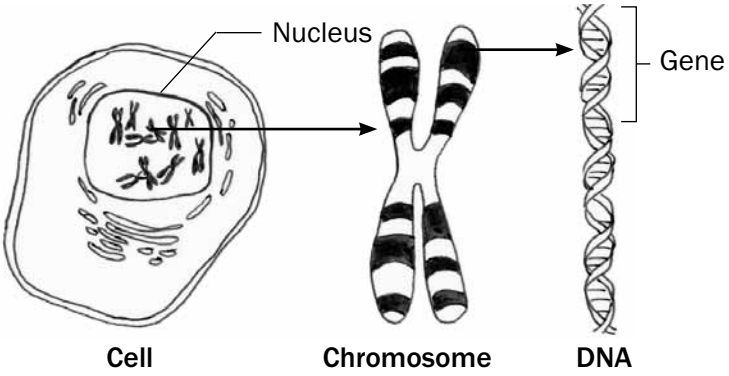
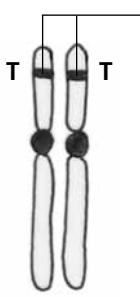
[5]

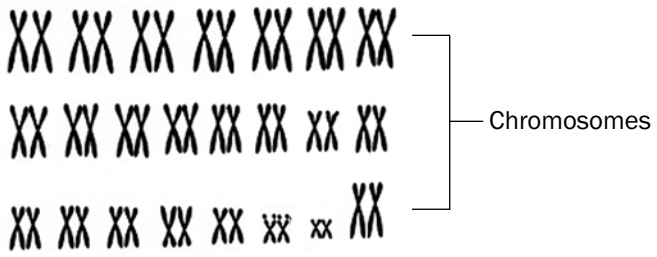
Chapter 5
Paper 2

Genetics

5.1 Key concepts

Make **mobile notes** (see instructions on page x) to learn these key concepts.

Term	Explanation	Diagram/Additional notes
Gene	A small portion of DNA coding for a particular characteristic.	
Alleles	Different forms of a gene which occur at the same locus (position) on homologous chromosomes.	**Dominant allele (T) – tall plant** **Recessive allele (t) – short plant**
Genotype	Genetic composition (make-up) of an organism.	
Phenotype	The physical appearance of an organism determined by the genotype, e.g. tall, short.	
Dominant allele	An allele that is expressed (shown) in the phenotype when found in the heterozygous (Tt) and homozygous (TT) condition.	 • Homozygous dominant (both alleles are dominant) • Genotype TT • Phenotype – tall
Recessive allele	An allele that is masked (not shown) in the phenotype when found in the heterozygous (Tt) condition. It is only expressed in the homozygous (tt) condition.	 • Homozygous recessive (both alleles are recessive) • Genotype tt • Phenotype – short
Heterozygous	Two different alleles for a particular characteristic, e.g. Tt.	 • Heterozygous (one dominant and one recessive allele) • Genotype Tt • Phenotype – tall
Homozygous	Two identical alleles for a particular characteristic, e.g. TT or tt.	

Term	Explanation	Diagram/Additional notes	
Monohybrid cross	Only one characteristic or trait is being shown in the genetic cross.	*Example*: Flower colour only, e.g. yellow flower or white flower **OR** shape of seeds only, e.g. round seeds or wrinkled seeds.	
Complete dominance	A genetic cross where the dominant allele masks (blocks) the expression of a recessive allele in the heterozygous condition.	In this type of cross the allele for tall (T) is dominant over the allele for short (t). The offspring will therefore **be tall** because the dominant allele (T) masks the expression of the recessive allele (t).	Tall (TT) × short (tt) Tall (Tt)
Incomplete dominance	A genetic cross between two phenotypically different parents produces offspring different from both parents but with an intermediate phenotype.	*Example:* If a red-flowered plant is crossed with a white-flowered plant and there is incomplete dominance – the offspring will have **pink flowers (intermediate colour).**	Red flower – White flower Pink flowers
Co-dominance	A genetic cross in which both alleles are expressed equally in the phenotype.	*Example:* If a red-flowered plant is crossed with a white-flowered plant and there is co-dominance the offspring has **flowers with red and white patches.**	Red flower × White flower Flowers with red and white patches
Multiple alleles	More than two alternative forms of a gene at the same locus.	*Example:* Blood groups are controlled by three alleles, namely I^A, I^B and i.	
Sex-linked characteristics	Characteristics or traits that are carried on the sex chromosomes.	*Examples:* Haemophilia and colour-blindness The alleles for haemophilia (or colour-blindness) are indicated as superscripts on the sex chromosomes, e.g. X^HX^H (normal female), X^HX^h (normal female), X^hX^h (female with haemophilia), X^HY (normal male), X^hY (male with haemophilia).	
Karyotype	The number, shape and arrangement of all the chromosomes in the nucleus of a somatic cell.		
Cloning	Process by which genetically identical organisms are formed using biotechnology.	*Example:* Dolly the sheep was cloned using a diploid cell from one parent; therefore it had the identical genetic material of that parent.	
Genetic modification	The manipulation of the genetic material of an organism to get desired changes.	*Example:* The insertion of human insulin gene in plasmid of bacteria so that the bacteria produce human insulin.	
Human genome	The mapping of the exact position of all the genes in all the chromosomes of a human.	*Example:* Gene number 3 on chromosome number 4 is responsible for a particular characteristic.	

Activity 1

Choose an item from COLUMN 2 that matches a description in COLUMN 1. Write only the letter (A to I) next to the question number (1–5), for example **6. J**.

COLUMN 1	COLUMN 2
1. The allele that is not expressed in the phenotype when found in the heterozygous condition	A. Gene
2. Different forms of a gene which occur at the same locus on homologous chromosomes	B. Recessive
3. A sex-linked condition where blood fails to clot properly	C. Haemophilia
4. The pair of chromosomes in a diploid organism that have the same size and shape and control the same set of characteristics	D. Dominant
5. The physical and functional expression of a gene	E. Homologous
	F. Genotype
	G. Phenotype
	H. Alleles
	I. Karyotype

[5]

Answers to activity 1

1. B✓ **2.** H✓ **3.** C✓ **4.** E✓ **5.** G✓ (5 × 1)

[5]

5.2 Genetic crosses

Use the following genetic **problem format or template** to solve all monohybrid genetic problems:

- **P_1** Phenotype × ✓
- Genotype × ✓
- ✓ ✓ *Meiosis* / **Gametes** / *Fertilisation* × ✓
- **F_1** Genotype ✓
- Phenotype ✓

OR

Gametes		

1 mark for correct gametes
1 mark for correct genotypes

[6]

1. The problem on the next page shows that a cross between a heterozygous parent (Tt) and a homozygous recessive (tt) parent produces F_1 offspring that are 50% heterozygous (Tt) and 50% homozygous recessive (tt).
2. A cross between a homozygous dominant (TT) parent and a homozygous recessive (tt) parent produces F_1 offspring that are 100% heterozygous (Tt).
3. A cross between a homozygous dominant (TT) and a heterozygous (Tt) parent produces F_1 offspring that are 50% homozygous dominant (TT) and 50% heterozygous (Tt).
4. A cross between two heterozygous (Tt) parents produces F_1 offspring that are 25% homozygous dominant (TT), 50% heterozygous (Tt) and 25% homozygous recessive (tt).

5.2.1 Complete dominance

This refers to a genetic cross where the dominant allele masks (blocks) the expression of a recessive allele in the heterozygous condition.

The following problem represents a genetic cross which shows **complete dominance**:

e.g. Genetic problem 1

In humans the ability to roll the tongue is due to a dominant allele. A man who is heterozygous for tongue-rolling and a woman who cannot roll her tongue have children. Use the symbols **T** and **t** for the alleles of the tongue-rolling characteristic and represent a genetic cross to determine the possible genotypes and phenotypes of the children. **(6)**

Read the problem carefully and note the following steps:

- Identify the **phenotypes** of the man and the woman (**parents/P_1**), i.e. the man is a tongue-roller and the woman is a non-tongue-roller. .....**Step 1**
- Identify the **genotypes** of the two parents, i.e. the man is **heterozygous** (Tt) and the woman can only be a non-tongue-roller if she is **homozygous recessive** for this characteristic, i.e. she must have the genotype (tt) ..... **Step 2**
- The next step is to show how the alleles are separated through the process of **meiosis** into separate **gametes**, i.e. in the man the gametes (sperm) will contain either the 'T' allele or the 't' allele. In the woman the egg can only contain the 't' allele.....**Step 3**
- The next step shows that **fertilisation** takes place. Indicate all possible combinations of how sperm cells fuse with a possible egg cell to show the possible **genotypes** of the **F_1 generation** that could arise.....**Step 4**
- Interpret the **phenotypes** of all the possible genotypes from the cross .....**Step 5**

Solution to genetic problem 1

	P_1	Phenotype	Tongue-roller × Non-tongue-roller✓	.....**Step 1**
		Genotype	Tt × tt✓	.....**Step 2**
		Meiosis		
✓	✓	**Gametes**	T and t × t ✓	.....**Step 3**
		Fertilisation		.....**Step 4**
	F_1	Genotype	Tt tt ✓	.....**Step 4**
		Phenotype	Tongue-roller Non-tongue-roller✓	..... **Step 5**

(Max 6 marks)

5.2.2 Incomplete dominance

This refers to a genetic cross between two phenotypically different parents producing an offspring different from both parents but with an **intermediate phenotype**. The following problem represents a genetic cross that shows **incomplete dominance**.

e.g. Genetic problem 2

A homozygous snapdragon plant with red flowers (**R**) was cross-pollinated with a homozygous snapdragon plant with white (**W**) flowers. All the plants that grew from the cross had **pink flowers**. Represent a genetic cross to show the possible genotypes and phenotypes of the F_1 generation of plants.

Solution to genetic problem 2

	P_1	Phenotype	Red	×	White✓	**Step 1**
		Genotype	RR	×	WW✓	**Step 2**
		Meiosis				
✓	✓	**Gametes**	R	×	W✓	**Step 3**
		Fertilisation				**Step 4**
	F_1	Genotype	RW✓			**Step 4**
		Phenotype	Pink✓			**Step 5**

5.2.3 Co-dominance

This refers to a genetic cross in which both alleles are equally expressed in the phenotype.

The following problem represents a genetic cross which shows **co-dominance.**

e.g. Genetic problem 3

A plant with white flowers was cross-pollinated with a plant with red flowers. All the plants that grew from the cross had flowers with **equal distribution of red and white colour**. Represent a genetic cross to show the possible genotypes and phenotypes of the F_1 generation of plants.

Solution to genetic problem 3

	P_1	Phenotype	Red	×	White✓	**Step 1**
		Genotype	RR	×	WW✓	**Step 2**
		Meiosis				
✓	✓	**Gametes**	R	×	W✓	**Step 3**
		Fertilisation				**Step 4**
	F_1	Genotype	RW✓			**Step 4**
		Phenotype	Flower with equal distribution of red and white colour✓			**Step 5**

5.2.4 Inheritance of sex

The following problem represents a genetic cross which shows **inheritance of sex**.

e.g. Genetic problem 4

A couple has three sons and the woman is pregnant again. Show diagrammatically by means of a genetic cross what the percentage chance is of the couple having a baby girl.

Solution to genetic problem 4

	P_1	Phenotype	Male	×	Female✓ ..... **Step 1**
		Genotype	XY	×	XX✓ ..... **Step 2**
		Meiosis			
✓	✓	**Gametes**	X and Y	×	X✓ ..... **Step 3**
		Fertilisation			..... **Step 4**
	F_1	Genotype	XX,		XY✓ ..... **Step 4**
		Phenotype	Female,		Male✓ ..... **Step 5**

50% chance✓

5.2.5 Inheritance of sex-linked characteristics

Sex-linked characteristics are characteristics (traits) that are carried on the sex chromosomes.

The following problem represents a genetic cross which shows the inheritance of sex-linked characteristics.

e.g. Genetic problem 5

Haemophilia is a sex-linked hereditary disease that occurs as a result of a recessive allele on the X-chromosome (X^h). A normal father and heterozygous normal mother have children. Represent a genetic cross to determine the possible genotypes and phenotypes of their children.

The alleles for haemophilia are indicated as superscripts on the sex chromosomes, e.g. X^HX^H (normal female), X^HX^h (carrier/heterozygous normal female), X^hX^h (female with haemophilia), X^HY (normal male), X^hY (male with haemophilia).

Solution to genetic problem 5

	P_1	Phenotype	normal father x	heterozygous/carrier normal mother✓	**Step 1**
		Genotype	X^HY x	X^HX^h ✓	**Step 2**
		Meiosis			
✓	✓	**Gametes**	X^H and Y x	X^H and X^h✓	**Step 3**
		Fertilisation			**Step 4**
	F_1	Genotype	$X^H X^H$, $X^H X^h$,	X^H Y, X^h Y✓	**Step 4**
		Phenotype	2 normal daughters	1 normal son, 1 son with haemophilia✓	**Step 5**

Activity 2

Question 1

Try solving this problem on your own before you look at the solution.

Fur colour in mice is controlled by a gene with two alleles. A homozygous mouse with black fur was crossed with a homozygous mouse with brown fur. All offspring had black fur. Using the symbols B and b to represent the two alleles for fur colour, show diagrammatically a genetic cross between a mouse that is heterozygous for fur colour and a mouse with brown fur. Show the possible genotypes and phenotypes of the offspring. (6)

Question 2

In rabbits the dominant allele (B) produces black fur and the recessive allele (b) produces white fur. Use a genetic cross to show the possible phenotypes and genotypes of the F_1 generation for fur colour if two heterozygous rabbits are crossed. (6)

exams

For two further problems on **genetic crosses**, refer to the following National Life Sciences exam papers:

- Life Sciences Paper 1 November 2010 – Question 2.2 on page 11.
- Life Sciences Paper 1 November 2011 Version 1 – Question 2.1 on page 8.

Answers to activity 2

Question 1

	P_1	Phenotype	Black ×	Brown✓
		Genotype	Bb ×	bb✓
		Meiosis		
✓	✓	**Gametes**	B and b ×	b✓
		Fertilisation		
	F_1	Genotype	Bb and bb✓	
		Phenotype	Black and brown✓	

(Max 6)

Question 2

	P_1	Phenotype	Black × Black ✓	
		Genotype	Bb × Bb✓	
✓		*Meiosis*		
	✓	**Gametes**	B, b × B, b✓	
		Fertilisation		
	F_1	Genotype	BB ; Bb ; Bb ; bb✓	
		Phenotype	Black ;	White✓

any (6)

5.2.6 Dihybrid cross

- A dihybrid cross involves the inheritance of two characteristics. Mendel explained the results obtained from dihybrid crosses according to his Law of Independent Assortment.
- According to the Law of Independent Assortment, alleles of a gene for one characteristic segregate independently of the alleles of a gene for another characteristic. The alleles for the two genes will therefore come together randomly during gamete formation.
- This means that the two characteristics are transmitted to the offspring independently of one another.
- The above law only applies if the genes for the two characteristics are not on the same chromosome.

Steps you should follow in working out a dihybrid cross:

e.g. Example

In pea plants, the allele for tallness (T) is dominant and the allele for shortness (t) is recessive. The allele for purple flowers is dominant (P) and the allele for white flowers is recessive (p). Two plants, heterozygous for both tallness and purple flowers, were crossed.

STEP	What to do generally	What to do in this problem
Step 1	Identify the phenotypes of the two plants for each of the two characteristics.	According to the statement of the problem, both parents are tall and have purple flowers.
Step 2	Choose letters to represent the alleles for the gene responsible for each characteristic.	Use the letters, e.g. **T** for tall, **t** for short, **P** for purple, and **p** for white as provided in the question.
Step 3	Write the genotypes of each parent.	According to the statement of the problem, both parents are heterozygous for each characteristic. Their genotype will therefore be **TtPp**.
Step 4	• Determine the possible gametes that each parent can produce. • Remember that each parent will have two alleles for each gene. • The gametes of each parent will have only one allele for each gene because of segregation during meiosis. • Remember that because of the principle of independent assortment an allele for one gene could appear in the same gamete with any of the alleles for the other gene.	• Each parent has the genotype TtPp. • If we represent the alleles for each gene in the following format, then we can see how these alleles could come together randomly (principle of independent assortment) to form the four types of gametes: TP; Tp; tP and tp as shown below.
Step 5	Enter the possible gametes at the top and side of a Punnett square.	Please refer to the solution that follows.

Alleles	T	t
P	**TP**	**tP**
p	**Tp**	**tp**

Step 6	• Because of random fertilisation, gametes from both parents could fuse in different combinations to form the offspring. • In the punnet square, write down the genotypes of the offspring that will result from each possible combination of gametes.	Please refer to the solution that follows.
Step 7	Determine the phenotypes of the offspring from the genotypes obtained in the punnet square.	Please refer to the solution that follows.

Solution to the problem

P_1 Phenotype Tall, Purple × Tall, Purple ..... **Step 1**

Genotype TtPp × TtPp ..... **Step 2,3**

Meiosis and Fertilisation

gametes	TP	Tp	tP	tp
TP	TTPP	TTPp	TtPP	TtPp
Tp	TTPp	TTpp	TtPp	Ttpp
tP	TtPP	TtPp	ttPP	ttPp
tp	TtPp	Ttpp	ttPp	ttpp

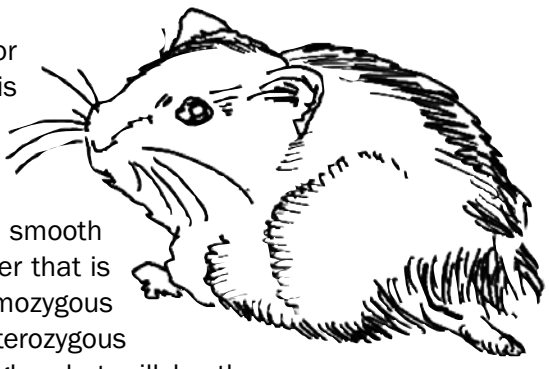
— **Steps 4-6**

F_1 Genotype 9 different genotypes, as in the table above

Phenotype 9 tall, purple flowered plants (T–P–);
3 short, purple flowered plants (ttP–);
3 tall, white flowered plants (T–pp), and
1 short, white flowered plant (ttpp)..... **Step 7**

Activity 3

Question



In hamsters, the allele for black coat colour (B) is dominant over the allele for white coat colour (b). The allele for rough coat (R) is dominant over the allele for smooth coat (r). If you cross a hamster that is heterozygous black and homozygous rough, with one that is heterozygous black and heterozygous rough, what will be the phenotypes and genotypes of the offspring? (Use the steps 1–7 to arrive at an answer).

Answer to activity 3

P_1 Phenotype: Black, Rough coat × Black, Rough coat ...**Step 1**

Genotype: BbRR × BbRr ..... **Step 2,3**

Meiosis and Fertilisation

gametes	BR	BR	bR	bR
BR	BBRR	BBRR	BbRR	BbRR
Br	BBRr	BBRr	BbRr	BbRr
bR	BbRR	BbRR	bbRR	bbRR
br	BbRr	BbRr	bbRr	bbRr

Steps 4-6

F_1 Genotype: 6 different genotypes, as in the table above

Phenotype: 12 with a black, rough coat and 4 with a white, rough coat .....**Step 7**

5.3 Mutations

A mutation is any sudden unexpected change in the genetic structure of a cell. Mutations occur suddenly and randomly and may be caused by many environmental agents such as X-rays and certain chemicals.

Mutations may be harmful or harmless to the organism in which they occur. **Harmful mutations** cause changes in DNA that can cause errors in protein sequencing, that can result in partially or completely non-functional proteins. **Harmless mutations** have no effect on the structure or functioning of the organism. **Useful mutations** can be advantageous to the organism and they are passed on from parent to offspring.

Gene mutations are mutations that affect a single or a few base pairs in just a single gene, while **Chromosomal aberrations** refer to changes in the normal structure or number of chromosomes.

Mutations result in new genotypes as we move from one generation to the next. This leads to variation within a species.

Gene mutations can cause genetic disorders:

- **Haemophilia:** Absence of the protein needed for the formation of blood clots due to a mutant gene.
- **Colour blindness:** Absence of the proteins that make up either the red or green cones/photoreceptors in the eye.
- **Albinism:** Absence of the protein that forms the pigment melanin.

Chromosomal aberrations e.g. Down syndrome is where there is an extra chromosome (47 instead of 46) in the zygote.

5.4 Pedigree diagrams

A **pedigree diagram** is used to study the inheritance of characteristics in a family over a number of generations. A pedigree diagram is also called a **family tree**.

Remember the following steps when interpreting pedigree diagrams:

Step 1 Study any key and opening statement/s and look for dominant and recessive characteristics and **phenotypes**.

Step 2 Write in the phenotypes of all the individuals as given in the problem.

Step 3 Fill in the genotype of all the individuals with the recessive condition – it must have two recessive alleles (two lower case letters, e.g. ff).

Step 4 For every individual in the diagram that has the recessive condition, it means that each allele was obtained from each of the parents. Work backwards and fill in one recessive allele for each parent.

Step 5 If the parents showed the dominant characteristic, fill in the second letter which represents the dominant allele (a capital letter, e.g. F).

Step 6 Any other individual showing the dominant characteristic will most likely be homozygous dominant (FF) or heterozygous dominant (Ff).

Activity 4

The pedigree diagram in Figure 5.1 shows inheritance of eye colour in humans over three generations of a family. Brown eye colour (B) is dominant over blue eye colour (b). Study the diagram and then answer the questions that follow.

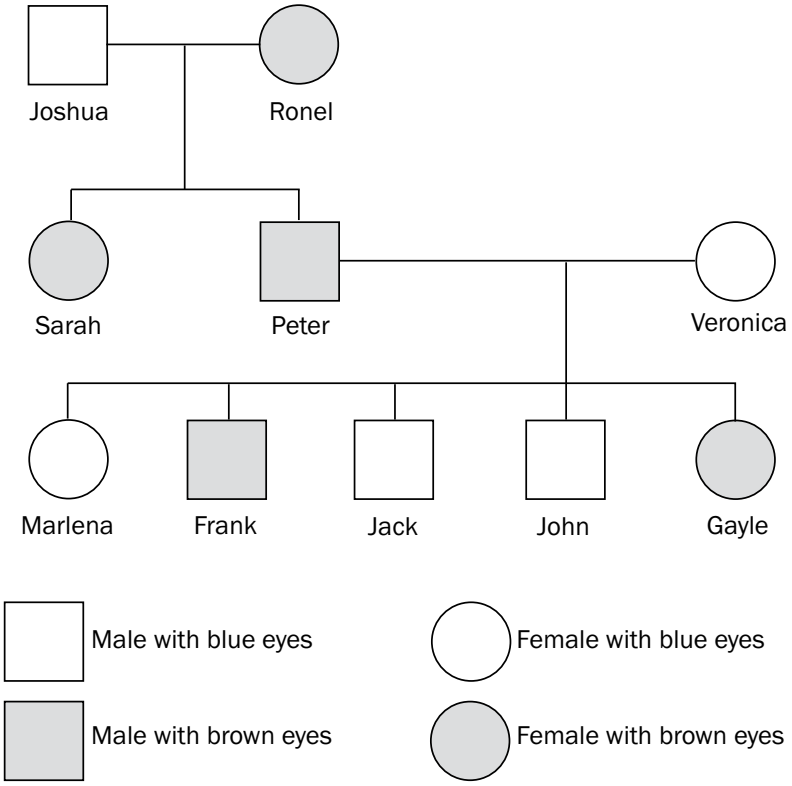


Figure 5.1 Pedigree diagram showing inheritance of eye colour

Note the following in the pedigree diagram on page 38:

- Squares represent males and circles represent females.
- The horizontal line between a square (Joshua) and a circle (Ronel) shows that they have mated.
- The vertical line flowing from the horizontal line represents the offspring (Sarah and Peter) of the two parents (Joshua and Ronel).
- **Brown eye colour (B) is dominant over blue eye colour (b)** – stated in problem. ..... Step **1**
- Joshua, Jack and John are males with blue eyes.
- Veronica and Marlena are females with blue eyes.
- Peter and Frank are males with brown eyes.
- Ronel, Sarah and Gayle are females with brown eyes.

  ..... Step **2**
- Joshua, Veronica, Marlena, Jack and John will have the genotype 'bb'. The recessive characteristic only shows up in the homozygous condition ..... Step **3**
- *Example:* The genotype of Peter is 'Bb' – working backwards from the offspring Marlena or Jack or John who are homozygous recessive. This means that one of the recessive alleles of Marlena, Jack and John, i.e. 'b', must have come from parent Peter and the other one from parent Veronica ..... Steps **4** and **5**
- Ronel could be homozygous dominant (BB) or heterozygous dominant (Bb) ..... Step **6**

Questions

1. How many members of the family have blue eyes? (1)

2. Is Veronica homozygous or heterozygous for eye colour? (1)

3. Write down the genotype of:

- **a)** Joshua (2)
- **b)** Ronel (2)
- **c)** Frank (2)

4. If Frank marries a woman with the same genetic composition as Sarah, what is the percentage probability of them having a child with brown eyes? (1)

[9]

Answers to activity 4

1. 5✓ (1)

2. Homozygous✓ (1)

3. **a)** bb✓✓ (2)

b) BB/Bb✓✓ (2)

c) Bb✓✓ (2)

4. 75%✓ (1)

[9]

exams

For two more problems on **pedigree diagrams** refer to these National Life Sciences exam papers:

- Life Sciences Paper 1 March 2010 – Question 1.5 on page 7.
- Life Sciences Paper 1 March 2012 Version 1 – Question 2.4 on page 11.

5.5 Genetic engineering

Genetic engineering is the process whereby the genes on the DNA are changed, transferred or manipulated to produce a different organism.

Activity 5

Question

State FOUR disadvantages and FOUR advantages of genetic engineering. **[8]**

Answer to activity 5

Four disadvantages of genetic engineering:

- Expensive✓/research money could be used for other needs
- Interfering with nature✓/immoral
- Potential health impacts✓
- Unsure of long-term effects✓ (4)

Four advantages of genetic engineering:

- Production of medication/resources cheaply✓
- Control pests with specific genes inserted into a crop✓
- Using specific genes to increase crop yields✓/food security
- Selecting genes to increase shelf-life of plant products✓ (4)

[8]

5.6 Genetic counselling

Couples with a risk of a genetic disease can undergo **genetic counselling** to enable them to make informed decisions on whether they want to have children or not.

Activity 6

Question

A young couple wants to have a child, but they are aware of a serious genetic disorder in one of their families that could be carried through to their offspring. State THREE benefits of genetic counselling in this case. **[3]**

Answer to activity 6

Three benefits of genetic counselling:

- To be given advice on the risk of transferring the defective gene✓/ to find the probability of passing on the defective gene to the offspring
- To be given an explanation of the procedure involved in DNA testing✓
- To be given an explanation of the results of DNA testing✓ **[3]**

Chapter 10

Evolution

A theory is an explanation of something that has been observed in nature which can be supported by facts, generalisations, tested hypotheses, models and laws.

A hypothesis is a possible solution to a problem.

10.1 Evidence for evolution

- **Fossil evidence:** The evidence that shows characteristics that make us similar to, or different from African apes comes largely from a study of fossils (thousands of fossil fragments).
- **Genetic evidence:** Scientists state that organisms are closely related and are likely to have a common ancestor if they have:
  - Identical DNA structure
  - Similar sequence of genes
  - Similar portions of DNA with no functions and
  - Similar mutations (mitochondrial DNA)

  Species that are closely related have a greater similarity to each other than distant species.
- **Cultural evidence:** Cultural evidence from studies of tools and weapons, as well as language is also used to show similarities and differences between humans and African apes.

10.2 Sources of variation

The genotypes and therefore phenotypes (appearance) of individuals of the same species are different from each other because:

- **Crossing over** in Prophase I of meiosis involves an exchange of genetic material, leading to new combinations of maternal and paternal genetic material in each new cell resulting from meiosis.
- **Random arrangement of maternal and paternal chromosomes** at the equator during metaphase allows different combinations of chromosomes/chromatids to go into each new cell resulting from meiosis, making them different.
- **Random fertilisation** between different egg cells and different sperm cells formed by meiosis result in offspring that are different from each other.
- **Random mating** between organisms within a species leads to a different set of offspring from each mating pair.
- **A mutation** changes the structure of a gene or chromosome and therefore the organism's genotype. Since the genotype influences the phenotype, it creates organisms with new, different characteristics from one generation to the next.

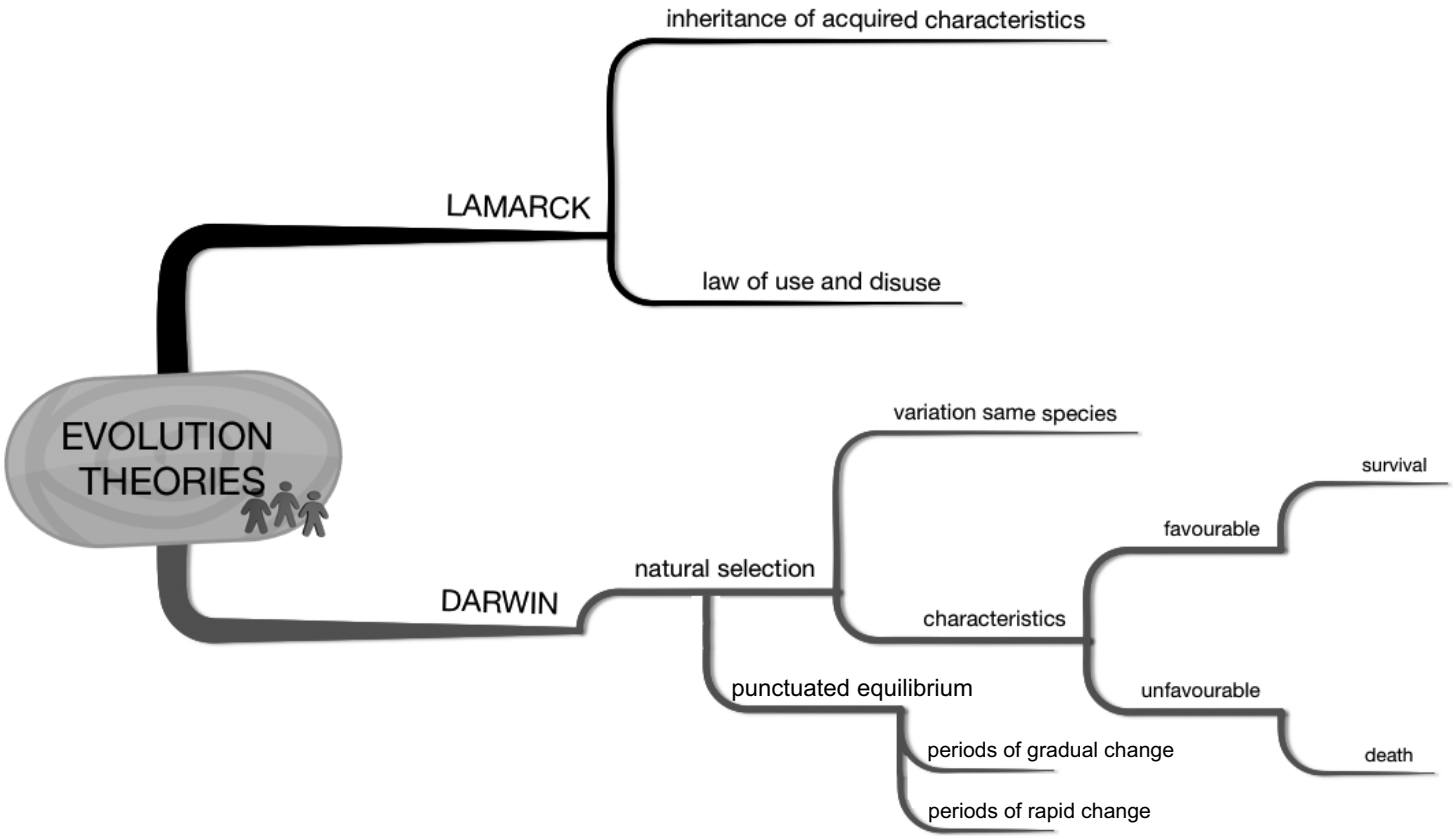
10.3 Theories of Lamarck and Darwin

Jean-Baptiste Lamarck explained evolution using the following two 'laws':

1. **The inheritance of acquired characteristics:**
   Characteristics developed during the life of an individual (acquired characteristics) can be passed on to their offspring.
2. **The law of use and disuse:**
   As an organism uses a structure or organ more regularly, it becomes better developed or enlarged. If an organism does not use a structure or organ frequently, it becomes less developed or reduced in size and may disappear altogether.

Charles Darwin explained evolution in terms of **natural selection** which states that:

- There is a great deal of **variation** among members of the same species.
- Organisms with **favourable characteristics**, which enable them to cope with challenges in the environment, survive.
- Organisms which do not have favourable characteristics that allow them to cope with challenges in the environment, die.



10.4 Applying the ideas of Lamarck and Darwin

Figure 10.1 below shows a series of changes involving cacti plants over a period of time. Some notes are included on the events at A, B and C.

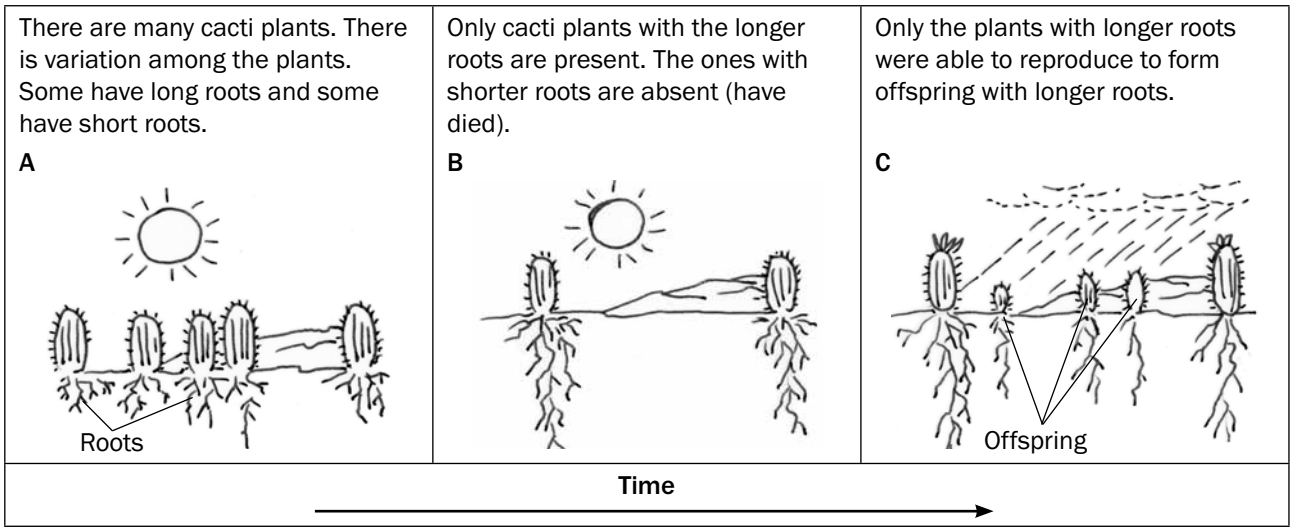


Figure 10.1 Changes in cacti plants over time

We can use Figure 10.1 to describe how Darwin would have explained how modern cacti plants may have developed longer roots as compared to their ancestors with shorter roots.

The second column in Table 10.1 below gives **Darwin's** explanation of how modern cacti plants may have developed longer roots. The first column contains questions that guide the explanation from one point to the next. You will be able to use the same questions to guide you when answering questions on Darwin's theory using any other example, for example the development of longer necks in modern giraffes.

Guiding questions	Darwin's explanation
Describe the variation in the population.	As a result of **genetic variation**✓in the cacti population, some cacti plants had **longer roots than others.**✓
What was the challenge?	As a result of **drought** ✓, competition for water occurred.
What was the result of the challenge?	Plants with **shorter roots died**✓ and those with **longer roots survived.**✓
What is this called?	This is called **natural selection.**✓
What happened to the favourable characteristic?	The allele for longer roots **was passed on to subsequent generations.**✓
What was the result of this?	Eventually all the plants had **longer roots.**✓

Table 10.1 Darwin's explanation for changes in cacti plants over time

The second column in Table 10.2 below states how **Lamarck** would have explained how modern cacti plants may have developed longer roots when compared to their ancestors with shorter roots. The first column contains guiding questions that will help you answer other questions on Lamarck's theory using any other example, for example the development of longer necks in modern giraffes.

Guiding questions	Lamarck's explanation
What was the original characteristic at the start?	All cacti had **short roots**✓ originally.
What did the organism do?	Cacti **frequently stretched**✓ their roots.
Why did the organism do this?	They did this to reach deeper for **water in the soil.**✓
What was the result?	As a result, the **roots became longer.**✓
What happened to this new characteristic?	The characteristic of long roots acquired in this way was then **passed on to the next generation.**✓
What was the result of this?	Eventually all the plants had **longer roots.**✓

Table 10.2 Lamarck's explanation for changes in cacti plants over time

Activity 1

Use the guiding questions in Tables 10.1 and 10.2.

Questions

1. Write an account showing how Lamarck would have explained the development of longer necks in modern giraffes. (5)
2. Write an account showing how Darwin would have explained the development of longer necks in modern giraffes. (7)
3. Explain why Lamarck's theory was rejected. (2)

[14]

Answers to activity 1

1.
- All giraffes had **short necks**✓ originally.
- These giraffes **frequently stretched**✓their necks.
- They did this to reach **the leaves that were available only higher up on the trees.**✓
- As a result, their **necks became longer.**✓
- The characteristic of long necks acquired in this way was then **passed on to the next generation.**✓
- Eventually all the giraffes had **longer necks.**✓ (5)

Answers to activity 1 (continued)

2.
- As a result of **genetic variation**✓ in the giraffe population some giraffe had **longer necks than others.**✓
- As a result of **leaves being available only higher up on trees,**✓ giraffes competed for these leaves.
- Giraffes with **shorter necks died.**✓
- Giraffes with **longer necks survived.**✓
- This is **natural selection.**✓
- The allele ✓ for longer necks was **passed on to subsequent generations.**✓
- Eventually all the giraffes had **longer necks.**✓ (7)

3. There is no evidence✓ to show that acquired characteristics are inherited✓/There is no evidence that structures used more frequently become more developed or vice versa (2)

[14]

exams

For more questions on **Lamarck and Darwin,** refer to the following National Life Sciences exam papers:

- Life Sciences Paper 2 November 2008 – Question 2.3 on page 12.
- Life Sciences Paper 2 November 2009 – Question 2.2 on page 9.
- Life Sciences Paper 2 March 2010 – Question 2.1 and 2.2 on page 9.
- Life Sciences Paper 1 November 2010 – Question 3.1 and 3.2 on page 11.
- Life Sciences Paper 1 November 2011: Version 1 – Question 3.3 on page 10.
- Life Sciences Paper 1 March 2012: Version 1 – Question 4.2 on page 14.

10.5 Differences between natural selection and artificial selection

For a long time, humans have been doing breeding experiments to develop organisms with a selected set of desirable characteristics, for example increased quality and quantity of milk produced by cows, or drought resistance and increased sugar content in sugar cane.

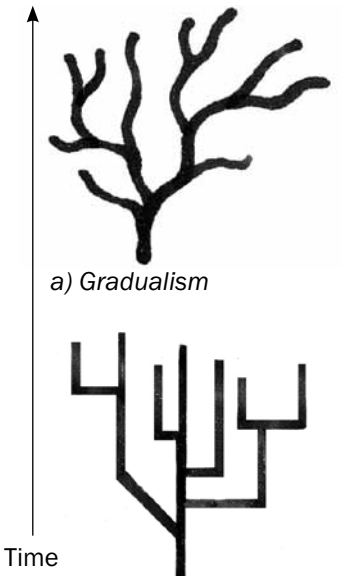
This is achieved by **artificial selection**, which is a similar process to **natural selection**. However, artificial selection differs from natural selection in the following ways:

Natural selection	Artificial selection
The **environment or nature** is the selective force.	**Humans** represent the selective force.
Selection is in response to **suitability to the environment.**	Selection is in response to **satisfying human needs.**
Occurs within **a species.**	May involve **one or more species** (as in cross breeding).

Table 10.3 The differences between natural selection and artificial selection

10.6 Punctuated Equilibrium

Based on the explanations of Lamarckism and Darwinism, it is thought that evolution takes place through an accumulation of small or gradual changes that occur over a long period of time. This is supported by the many transitional fossils in the fossil record which show the progressive change over time.



a) Gradualism

b) Punctuated equilibrium

Figure 10.2 Phylogenetic trees that show a) gradualism and b) punctutated equilibrium

Punctuated equilibrium is a hypothesis that explains the speed at which evolution takes place through natural selection:

- According to punctuated equilibrium, evolution is not always gradual as proposed by Lamarckism and Darwinism.
- Evolution involves long periods of time where species do not change or change very little (known as equilibrium).
- This alternates with (is punctuated by) short periods of time where rapid changes occur.
- As a result, new species are formed in a short period of time, relative to the long periods of no/little change.
- This is supported by the absence of transitional fossils (usually termed 'missing links') indicating the period of rapid change.

10.7 Speciation

As a result of natural selection taking place over a period of time, the characteristics of organisms may change to such an extent that they cannot reproduce with the original members of that species to produce fertile offspring. We say that they have become a **new species**. This is called **speciation**.

We can describe the process of speciation as follows:

10.7.1 Speciation

A population of a particular species may **become split by a geographical barrier**, e.g. a river. As a result, the two parts of the population cannot interbreed. There is no gene flow between the two populations.
Natural selection occurs independently in each population. This is due to **different environmental conditions**. As a result, the two populations become **genotypically and phenotypically different** over a period of time. Even if the two populations mixed at a later time, they will not be able to interbreed again. We say that one or both parts of the population have become a **new species = speciation**.

10.7.2 Mechanism for reproductive isolation

Geographic isolation causes speciation. Reproductive isolation isolates the gene pool of a species. Examples of reproductive isolation:

- Breeding at different times of the year.
- Species-specific courtship behaviour.
- Adaptation to different pollinators in plants.
- Infertile offspring.

exams

For more questions on **speciation**, refer to these National Life Sciences exam papers:

- Life Sciences Paper 2 November 2008 – Question 3.3 on page 13.
- Life Sciences Paper 2 November 2009 – Question 2.1 on page 9.
- Life Sciences Paper 2 March 2010 – Question 3.2 on page 13.
- Life Sciences Paper 2 March 2011 – Question 3.1 on page 9.
- Life Sciences Paper 1 November 2011: Version 1 – Question 3.4 on page 10.
- Life Sciences Paper 1 March 2012: Version 1 – Question 3.4 on page 12.

Activity 2

1. Use the information in Figure 10.3 below to explain how a new species of rabbit has arisen because of a geographical barrier. [9]

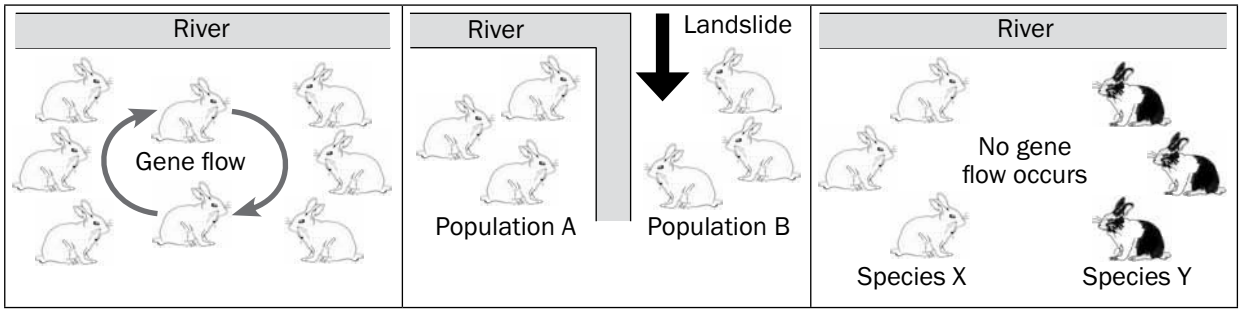


Figure 10.3 Speciation in a rabbit population

2. The diagram below represents the changes in a population of bacteria over time as a result of exposure to an antibiotic over time.

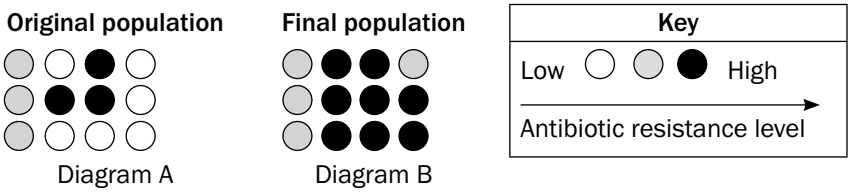


Figure 10.4. Development of antibiotic resistance in a bacteria population

Explain, in terms of natural selection, the shift in the resistance level of the bacteria illustrated above. [8]

Answer to activity 2

1.
- A population of rabbits become **split✓ by a geographical barrier/river.✓**
- As a result, the two parts of the population **cannot interbreed.✓**
- There **is no gene flow✓** between the two populations.
- **Natural selection occurs independently✓** in each population due to **different environmental conditions✓** on either side of the river.
- As a result, the two populations become **genotypically and phenotypically different✓**over a period of time.
- Even if the geographical barrier is removed (ie the river returns to its normal course at some later time), the rabbits will **not be able to interbreed again.✓**
- We say that one or both parts of the rabbit population have become a **new species✓**. [9]

2. **There is a large degree of variation in the bacteria population✓**
- When the antibiotic was first used, it killed off a large number of bacteria✓
- But some bacteria were resistant to the antibiotic✓ and survived✓
- Those that survived were able to reproduce✓
- Increasing the population of resistant bacteria✓
- Continued use of the antibiotic had little effect on the resistant bacteria✓
- Hence the resistant bacteria increased✓
- And non-resistant bacteria decreased✓ [8]

10.8 Human evolution

So far in this chapter you have seen that:

- As a result of **natural selection**, the characteristics of organisms can change over time due to changing environmental conditions
- **New species** can arise when a group of organisms change so much that they can no longer reproduce with the original species (this is called speciation).

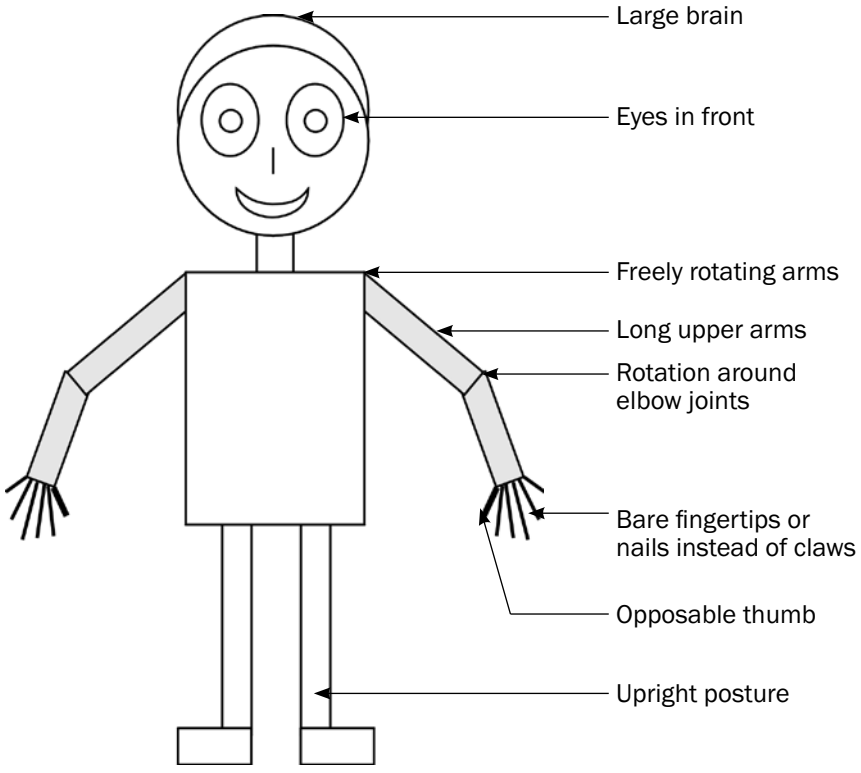
Natural selection and speciation can also be used to explain **how humans have evolved**.

Scientists identify trends in human evolution by comparing humans to other primates in terms of similarities and differences. The differences point to the existence of different species, while the similarities point to a possible common ancestor.

10.8.1 Similarities between humans (*Homo sapiens*) and African apes

Figure 10.5 below shows characteristics of humans that are similar to that of African apes.

Figure 10.5 Characteristics humans and African apes have in common



Now try this:

1. Cover the labels on Figure 10.5 and try to list the common features of humans and African apes by looking at the parts that the arrows are pointing to.
2. Write down the EIGHT similarities without looking at the diagram.

10.8.2 Differences between humans (*Homo sapiens*) and African apes

Table 10.4 below is a comparison between the anatomical characteristics of Humans (*Homo sapiens)* and African apes according to the features listed in the first column.

FEATURE	Humans (*Homo sapiens*)	African Apes
Cranium	Large cranium/brain	Small cranium/brain
Brow Ridges	Brow ridges are not well developed	Brow ridges well developed
Spine	More curved spine (S-shaped spine)	Less curved spine (C-shaped spine)
Pelvic girdle	Short, wide pelvis	Long, narrow pelvis
Canines	Small canines	Large canines
Palate shape	Small and semi-circular	Long and rectangular
Jaws	• Small jaws • Less protruding jaws/less-prognathous	• Large jaws • More protruding jaws/more prognathous
Cranial ridges	No cranial ridge	Cranial ridge across the top of the cranium
Foramen Magnum	Foramen magnum in a forward position	Foramen magnum in a backward position

Table 10.4: The anatomical differences between humans and African apes.

Now try this:

1. Study the differences listed in Table 10.4 above by referring to the features shown in Figure 10.6 below.

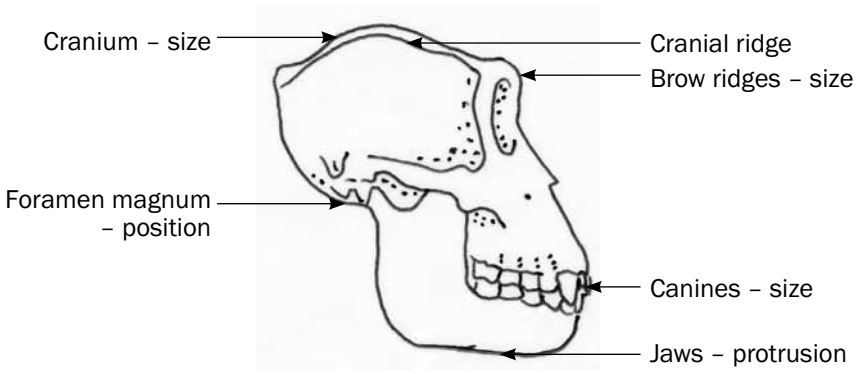


Figure 10.6 Labelled diagram of an African ape skull

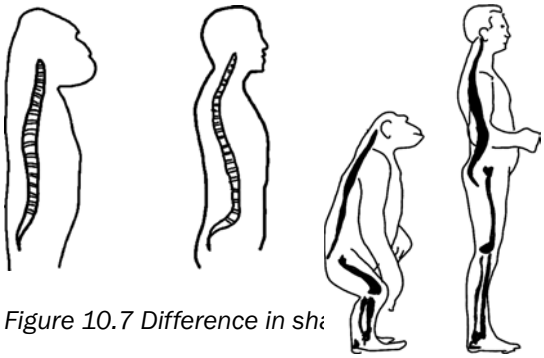


Figure 10.7 Difference in sha

2. Now write down the differences using the above diagrams but without referring to Table 10.4.

Activity 3

Question 1

Study the two skulls shown in Figure 10.8 below and answer the questions that follow.

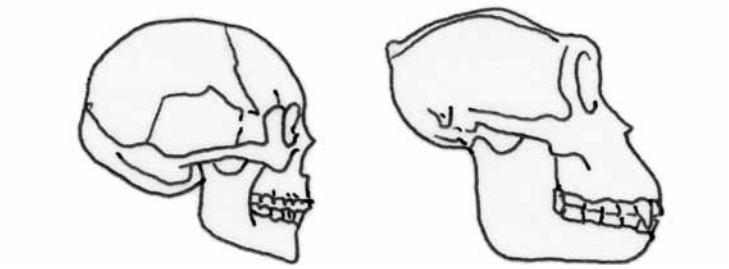


Figure 10.8 Skull diagrams of two organisms

1.1 Which skull (A or B) is that of a non-human primate? (1)

1.2 List FIVE OBSERVABLE reasons (based only on features that are visible in the diagram) for your answer in question 1.1. (5)

[6]

Answers to question 1

1.1 Skull B✓ (1)

1.2 Pronounced brow ridge✓
Protruding jaw/prognathous✓
Large canine✓
Small cranium✓
Cranial ridge across the top of the cranium✓ (5)

[6]

Question 2

The diagrams in Figure 10.9 below represent the skulls of three organisms: Taung child (*Australopithecus africanus*), a modern human (*Homo sapiens*) and a gorilla (*Gorilla gorilla*). The arrow indicates the position of the foramen magnum (the opening that allows the spinal cord to connect with the brain). Study the diagrams and answer the questions that follow:

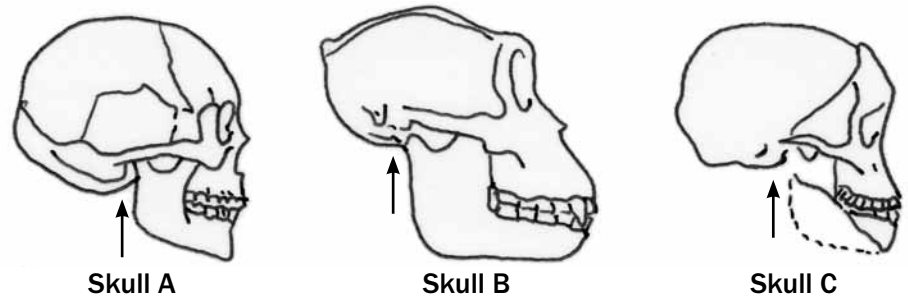


Figure 10.9 Skull diagrams showing the position of the foramen magnum

2.1 Identify the organisms that are represented by each of skulls A, B and C. (3)

2.2 Assuming that the diagrams were drawn to scale, list THREE observable differences between the skulls of organisms A and B. (6)

2.3 By looking at the position of the foramen magnum (indicated by the arrows), state which TWO organisms are best adapted for walking on two legs rather than four legs. (2)

2.4 Explain, using observable features, why the organism to which skull C belongs can be regarded as a transitional species (a species that is in the process of changing). (3)

[14]

Answers to question 2

2.1 A – *Homo sapiens*/human✓
B – *Gorilla gorilla*/gorilla✓
C – *Australopithecus africanus* (Taung child)✓ (3)

2.2

Skull A	Skull B
Brow ridge reduced/absent✓	Pronounced brow ridge✓
Non-prognathous/non-protruding jaw✓	Prognathous/protruding jaw✓
Poorly developed canines✓	Large canines✓
No cranial ridges✓	Cranial ridges present✓
Large cranium✓	Small cranium✓

(any 3 × 2) (6)

2.3 *Homo sapiens*/human✓ AND *Australopithecus africanus* (Taung child)✓ (2)

2.4 It has features of the skull that are intermediate✓ between that of skulls A and B, e.g. jaw protrudes more than in skull A but less than in skull B✓, face not flat in skull of B but flat in skull A. (3)

[14]

exams

For more questions on **human evolution**, refer to the following National Life Sciences exam papers:

- Life Sciences Paper 2 November 2008 – Question 3.1 on page 13.
- Life Sciences Paper 2 March 2009 – Question 1.5 on page 8.
- Life Sciences Paper 2 March 2010 – Question 4.2 on page 16.
- Life Sciences Paper 1 November 2010 – Question 3.3 on page 12.
- Life Sciences Paper 2 March 2011 – Question 3.2 on page 10.
- Life Sciences Paper 1 November 2011: Version 1 – Question 3.1 and 3.2 on pages 9 and 10.

10.8.3 Major phases in hominid evolution

The table below shows the characteristics of different organisms (as obtained from a study of their fossils) that are thought to be in the same line that led to the evolution of modern humans. The fossils are dealt with in the order in which they appeared on Earth (as calculated by the age of the fossil using dating techniques).

Organism	When organism existed	Fossil site	Discovered by	Characteristics
Ardipithecus ramidus	5 – 4 mya	North-East Ethiopia	Tim White	Brain size: 300–350 ml Forward position of foramen magnum Very prognathous (more protruding jaws) Heavy brow ridges Pelvis structure: bipedal and tree climbing
Australopithecus afarensis	4 – 2,7 mya	Ethiopia, Kenya, Tanzania	Donald Johanson	Brain size: 375–550 ml Forward position of foramen magnum Very prognathous Heavy brow ridges Canines large and pointed Long arms No cranial ridge
Australopithecus africanus	3 – 2 mya	Taung; Sterkfontein	Raymond Dart	Brain size: 428–625 ml Forward position of foramen magnum Prognathous Brow ridges Teeth large, canines not long Long arms No cranial ridge
Australopithecus sediba	1,9 – 1,8 mya	Malapa Cave – in the cradle of humankind	Lee Burger	Brain size: 420 ml Less prognathous Brow ridges Large teeth, canines not long Long arms No cranial ridge
Homo habilis	2,2 – 1,6 mya	Tanzania	Louis and Mary Leakey	Brain size: 650 ml Less prognathous Less pronounced brow ridges Human-like teeth – smaller canines Long arms
Homo erectus	2 – 0,4 mya	Java in Indonesia and then Swartkrans	Eugene Dubois	Brain size: 900 ml Prognathous Cranial ridges Short canines Longer legs and shorter arms
Homo sapiens	200 000 years ago – present	Makapansgat in Limpopo; Border Cave in KZN; Blombos Cave in the Western Cape	Tim White	Brain size: 1200–1800 ml No brow ridges Small teeth Short arms

Activity 4

1. What general observation can you make about the characteristics as one moves from the earlier to the later organisms listed in the table? (2)
2. Use information in the table to describe the specific evolutionary trend (how each of the features changed over time) relating to each of the following characteristics:
   - **2.1** Brain size
   - **2.2** Position of foramen magnum
   - **2.3** Prognathous jaws
   - **2.4** Dentition
   - **2.5** Development of brow ridges 5 × 2 (10)
3. State the significance of the changes that occurred as they apply to each of the following characteristics:
   - **3.1** Brain size
   - **3.2** Position of foramen magnum
   - **3.3** Prognathous jaws
   - **3.4** Dentition
   - **3.5** Development of brow ridges 5 × 2 (10)
4. Explain how the information in the table provides evidence for the 'Out of Africa' hypothesis. (2)

[24]

Answers to activity 4

1. There is a gradual change in the characteristics✓ over a period of time. ✓ (2)
2. **2.1** Brain size: Increase✓ in brain size✓
   - **2.2** Position of foramen magnum: Movement to a more✓ forward position✓
   - **2.3** Prognathous jaws: Change from more prognathous✓ to less prognathous✓
   - **2.4** Dentition: Decrease in the size✓ of the teeth✓OR decrease✓ in the size✓ of the canines
   - **2.5** Development of brow ridges: Brow ridges become less✓ developed✓ 5 × 2 (10)
3. **3.1** Brain size: Increased brain size allows for processing information more quickly ✓and for processing a larger amount of information. ✓
   - **3.2** Position of foramen magnum: More forward position of the foramen magnum✓ indicates bipedalism. ✓ A decrease in the length of the arms indicates a decreased dependency on its use in locomotion and therefore shows a more advanced stage of bipedalism. This is usually accompanied by an increase in the length of the legs.
   - **3.3** Prognathous jaws: A less prognathous jaw indicates a smaller jaw. ✓ A small jaw is sufficient since there was a change from eating raw food to eating cooked food. ✓
   - **3.4** Dentition: The change from large to smaller teeth✓was due to the change in diet from raw food to cooked food✓

Answers to activity 4 (continued)

3.5 Development of brow ridges: Brow ridges became less developed since the action of the smaller jaws✓did not create forces great enough for the skull to have increased strength from the brow ridges✓ 5 × 2 (10)

4. The information in the table shows that fossils of the different organisms that are considered to have existed in the same line as humans✓ were all found in Africa. ✓ (2)

[24]

10.8.4 Out of Africa hypothesis

The '**Out of Africa**' **hypothesis** states that modern humans originated in Africa and then migrated out of Africa to the other continents.

The following lines of evidence have been used to support this hypothesis:

- The oldest fossils of australopithecines/*Homo habilis*/bipedal organisms have been found in Africa.
- The oldest fossils of *Homo erectus* have been found in Africa.
- Analysis of **mutations** in mitochondrial DNA shows that the oldest female ancestors of humans are from Africa.

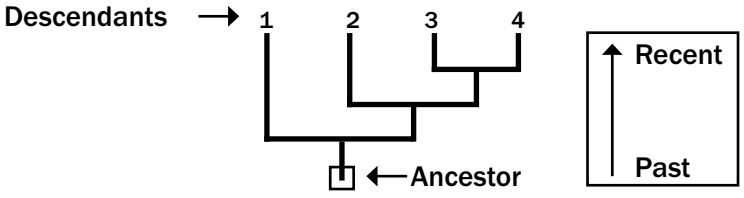
10.8.5 Phylogenetic trees

A **phylogenetic tree** (or evolutionary tree) represents the possible evolutionary relationships among a set of organisms or groups of organisms. The tips of the tree represent descendants (often <u>species</u>) and the points where the tree branches represent the <u>common ancestors</u> of those descendants.

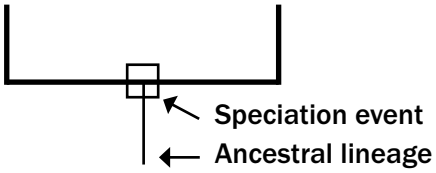
hint

Hints on interpreting phylogenetic trees

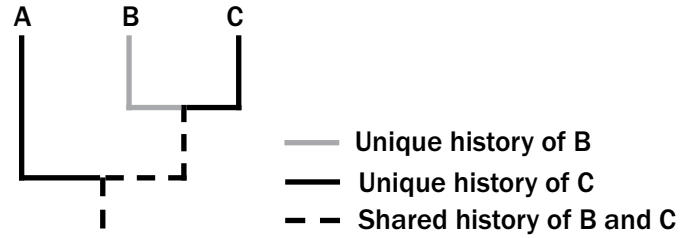
Reading a phylogenetic tree is similar to understanding a family tree. The root of the tree represents the **ancestor** and the tips of the branches represent the **descendants** of that ancestor. As you move from the root of the tree to its tips, you are moving forward in time.



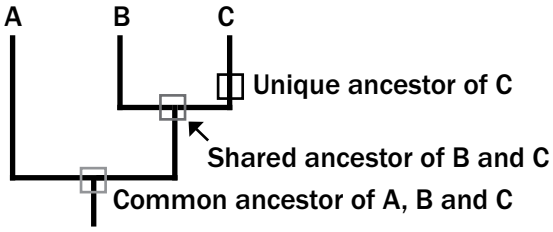
When speciation occurs, it is represented as branching on the tree.
A single ancestral lineage gives rise to two or more daughter lineages.



Each lineage has a part of its history that is unique and parts that are shared with other lineages.



Similarly, each lineage has ancestors that are unique to that lineage and common ancestors that are shared with other lineages.



Worked example

Look at the phylogenetic tree in Figure 10.10 and read the following information:

- Start in the past (4,5 mya) and read towards the present. This means that the oldest common ancestor of all the hominids on this tree is *A. ramidus.*
- Each branch on the tree represents a point where the common ancestor split into one, two or more groups. In this case, the new species that evolves is shown as a side branch while the original species continues its evolutionary line up the trunk of the tree. For example, *A. aethiopicus* forms a side branch with *A. africanus* evolving from the common ancestor that existed at point X (this took place about 3 mya).
- Progression up the 'trunk of the tree' represents a movement in time from the past to the present. This shows the relationships between the hominids through time. Hominids that share a recent common ancestor are the most closely related to each other. For example, *P. robustus* shares a most recent common ancestor with *P. boisei*, namely *A. africanus*.

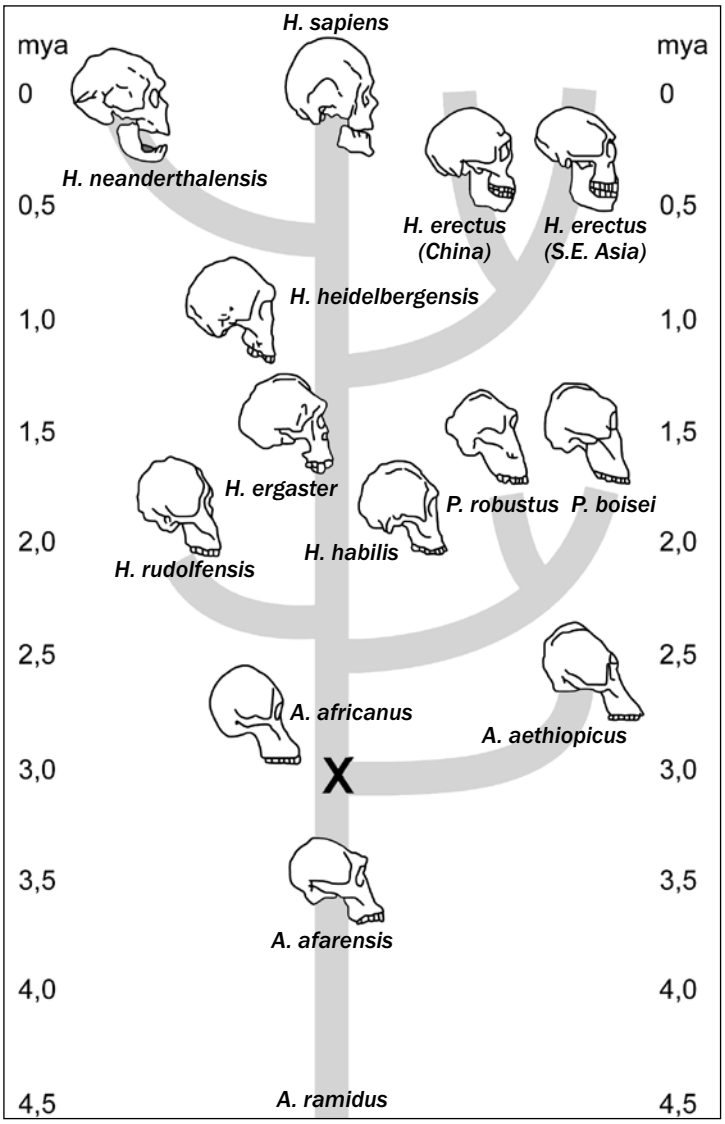


Figure 10.10 A phylogenetic tree

Questions

Let us look at the type of questions that can be asked about this phylogenetic tree:

1. Give the common ancestor of *H. neanderthalensis* and *H. sapiens*. (1)
2. How long ago did *H. rudolfensis* split from its common ancestor? (2)
3. Name the direct ancestor of *H. ergaster*. (1)
4. How long has it taken *H. heidelbergensis* to evolve from *A. afarensis*? (3)
5. Give the common ancestor of all the hominids. (1) **[8]**

Answers

1. *H. heidelbergensis*✓ (1)
2. 2,4✓ million years ago✓/mya (2)
3. *H. habilis*✓ (1)
4. 3,8 million years ago – 0,7 million years ago✓ = 3,1✓million years✓ (3)
5. *A. ramidus*✓ (1) **[8]**

Activity 5

Study the phylogenetic tree in Figure 10.11 below and answer the questions based on it.

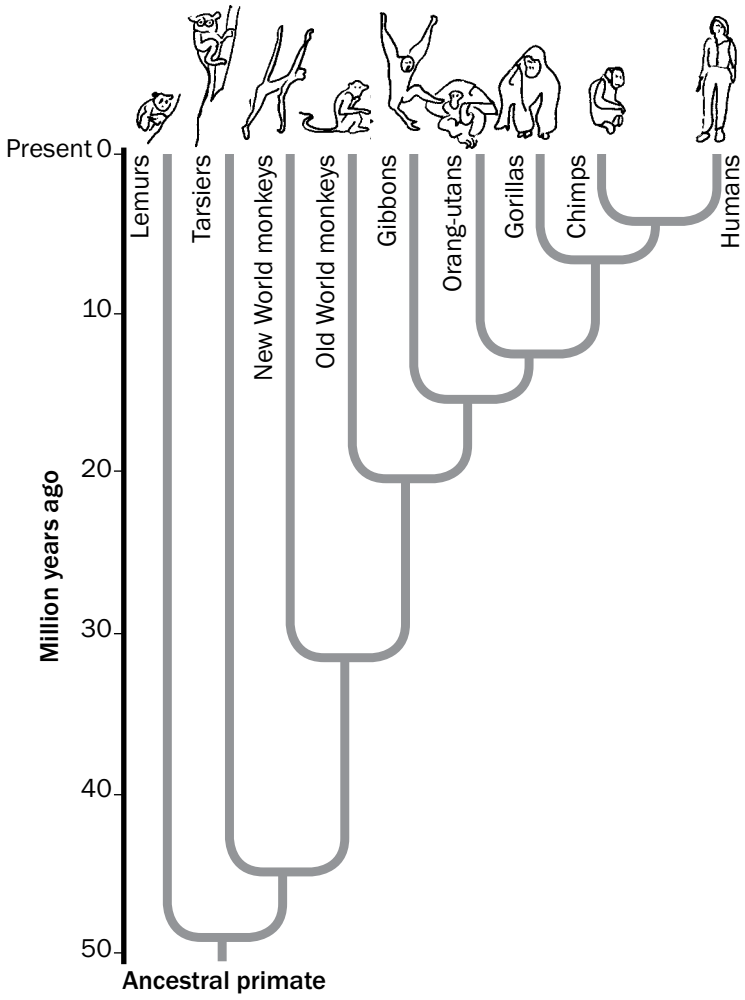


Figure 10.11 Phylogenetic tree

Questions

1. How long ago did the ancestral primate live on earth? (2)
2. Name the organism that shares the most distant common ancestor with humans. (1)
3. Name the organism that is most closely related to humans. (1)
4. How many years ago did the New World monkeys split from the common ancestor that gave rise to the Old World monkeys? (2)
5. For how long did the common ancestor that evolved into the gibbons exist? Show your working. (3)
6. Humans and gorillas share many common characteristics with primates. List THREE of these common characteristics. (3)

[12]

exams

For more questions on **phylogenetic trees**, refer to these National Life Sciences examination papers:

- Life Sciences Paper 2 November 2009 – Question 1.5 on page 7.
- Life Sciences Paper 2 March 2009 – Question 3.4 on page 11.
- Life Sciences Paper 2 March 2010 – Question 1.4 on page 6.
- Life Sciences Paper 2 March 2011 – Question 1.4 on page 5.
- Life Sciences Paper 1 March 2012: Version 1 – Question 1.4 on page 8.

Answers to activity 5

1. 50✓ million years ago✓/mya (2)
2. Lemurs✓ (1)
3. Chimpanzee✓ (1)
4. 33✓ million years ago✓/mya (2)
5. 22 million years – 15 million years✓ = 7✓million years✓ (3)
6.
   - Large brain✓
   - Eyes in front✓
   - Freely rotating arms✓
   - Long upper arms✓
   - Rotation around elbow joints✓
   - Bare fingertips or nails instead of claws✓
   - Opposable thumb✓
   - Upright posture✓

   (any 3) (3)

[12]

Try to give your own answers to the terminology questions in activity 5 before you look at the answers on the next page! If you do not know an answer, try to find it in your textbook or class notes.

Activity 6

Question 1

Give the correct biological term for each of the following descriptions. Write only the term next to the question number (1.1 to 1.17).

1.1 The development of new species from existing species.

1.2 A study of the distribution of organisms in different parts of the world.

1.3 Similar structures in different organisms indicating common ancestry.

1.4 Having a pointed face because of projecting jaws and nose.

1.5 A group of similar organisms that can breed to produce fertile offspring.

1.6 A group of organisms of the same species that occupy a particular habitat.

1.7 Only organisms with favourable characteristics survive.

1.8 Using parents with particular desirable characteristics to obtain a combination of these desirable characteristics in the offspring
1.9 An opening in the skull through which the spinal cord passes
1.10 Locomotion involving the use of a pair of hind limbs only
1.11 Mechanisms that prevent different species from reproducing with each other
1.12 The study of fossils which provides evidence for evolution
1.13 Sudden change to the genetic composition of an organism
1.14 Branched diagram showing evolutionary relationships among organisms
1.15 Remains of organisms that have existed in the past
1.16 Genus to which Little Foot, Mrs Ples, Karabo and the Taung Child belong
1.17 Genotypic and phenotypic differences among organisms of the same species

[17]

Answers to activity 6

1.1 Speciation✓
1.2 Biogeography✓
1.3 Homologous✓
1.4 Prognathous✓
1.5 Species✓
1.6 Population✓
1.7 Natural selection✓
1.8 Artificial selection✓
1.9 Foramen magnum✓
1.10 Bipedal✓
1.11 Reproductive isolation✓
1.12 Paleontology✓
1.13 Mutation✓
1.14 Phylogenetic tree✓
1.15 Fossils✓
1.16 *Australopithecus*✓
1.17 Variation✓

[17]

Chapter 12

Skills

12.1 Drawing graphs

Graphs and charts condense large amounts of information in a format that is easier to understand, showing important points clearly and effectively.

1. **Line graphs** show the relationship between two types of information where the independent variable is continuous. Line graphs are useful in showing trends over time and are often used for biological data.
2. **Bar graphs** show different categories of data and are used when the independent variable is not a set of continuous numbers or continuous groups (discontinuous data). They are best used to compare values across categories.
3. **Histograms** have connected bars displaying continuous data. They are used when the values of the independent variables are continuous but fit into categories or groups that follow on after each other.
4. **Pie charts** are circular charts used to compare parts of the whole. They are divided into sectors that are equal in size to the quantity represented. They are used for discontinuous data.

12.1.1 How to draw a line graph

Step 1

Identify the **dependent** and the **independent** variables from the information you are given (usually in table format).

- **Dependent:** This is the variable or factor that is being measured, i.e. the temperature in degrees Celsius in this example.
- **Independent:** This is the variable that the investigator can change. The dependent variable changes as the independent variable changes, i.e. the time in hours in this example.

Time (hours)	Temperature (°C)
0	16
5	24
9	28
13	26
17	21
20	19
24	17

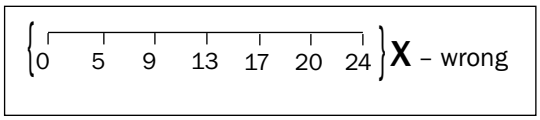
Table 12.1 Air temperature recorded over a 24 hour period

Step 2

Draw a **set of axes** and label the X and Y axes. The dependent variable goes on the Y-axis and the independent variable on the X-axis. Include the unit in each label, e.g. temperature in °C and time in **hours**. Do **NOT** forget to label the axes.

Step 3

Choose a **scale** for the X and the Y axes. Make sure that the scale includes the highest numbers in the table for each of the variables. Do not use the values for the Y-axis directly from the table unless they have **regular intervals**.



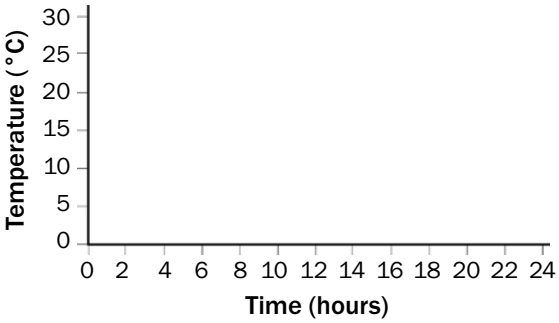


Figure 12.2 Draw the axes and choose a scale

Step 4

Place a dot at the point where the two values for each result intersect (meet). In the example, the point where 5 hours and 24 °C intersect on the graph is indicated by the second dot on the graph. Plot all the points using the information in the table.

Step 5

Join the dots using a ruler until all the dots have been joined in sequence.

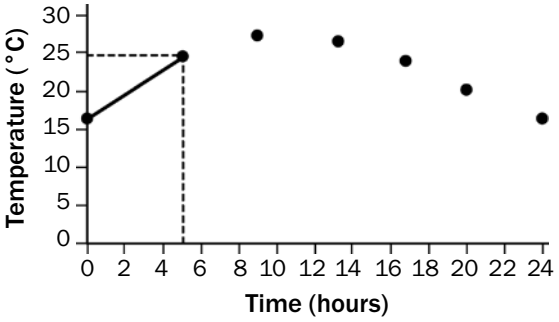
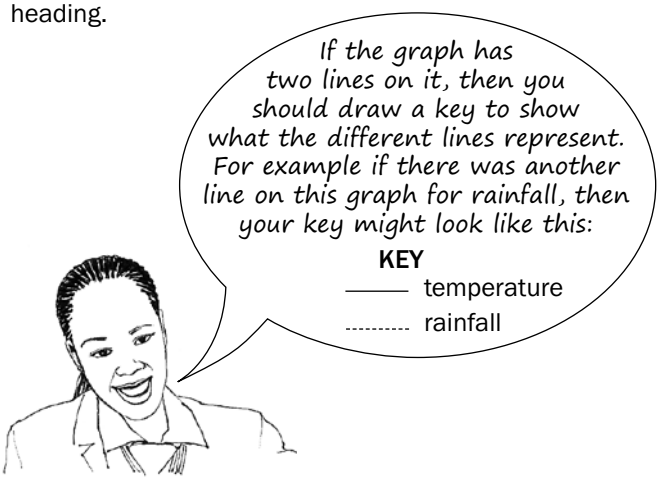


Figure 12.3 Plot the points on the graph and join them

Step 6

Give the graph a **heading or caption**. The heading or caption should include both variables. In this case both air temperature and the time period of 24 hours must be mentioned in the heading.



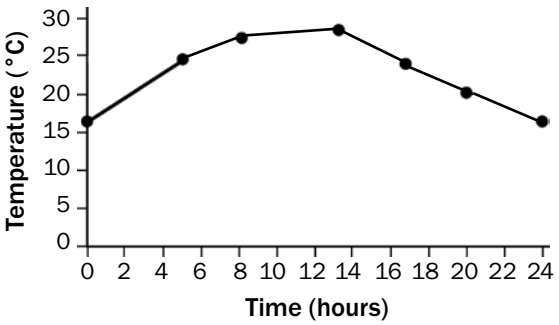


Figure 12.4 Final line graph with heading

12.1.2 How to draw a bar graph

Steps 1 to 3

To draw a bar graph, you follow the same first three steps that you followed to draw a line graph. Use the table to identify the dependent and independent variables. Draw the axes and choose a scale. Note that there will be no units when labelling the X- and the Y-axes in this particular graph.

Point number	Number of organisms
1	10
2	12
3	8
4	8
5	4

Table 12.2 Number of organisms found in the water at different points along a river

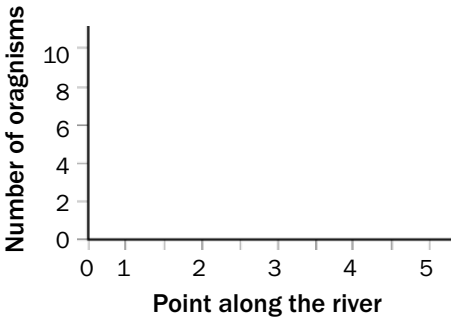


Figure 12.5 Draw the axes and choose a scale

Step 4

Draw a bar to show that 10 organisms were found at point number 1 on the river. Then draw bars to represent the number of organisms found at each of the points along the river.

Since this is a bar graph, the **bars should not touch** as the points along the river have **no direct relationship** with each other.

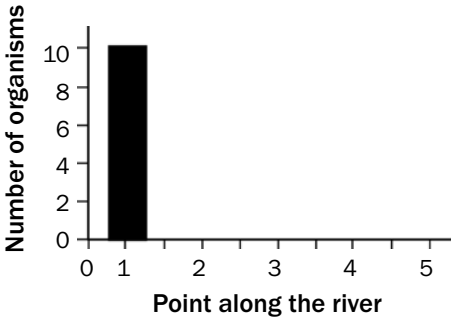


Figure 12.6 Draw the first bar

Step 5

Give the graph a heading or caption. See step 6 under the line graph for instructions how to give your graph a heading or caption.

Bar graph to show the number of organisms at different points along a river

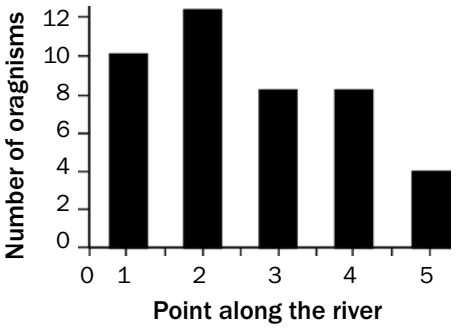


Figure 12.7 Final bar graph with heading

12.1.3 How to draw a histogram

A histogram is drawn in exactly the same way as a bar graph. The only difference is that a histogram is used when the independent variable is groups of information along a continuous scale. Note that in a histogram, the bars are drawn **without any spaces** between them. Use the information in Table 12.3 below to draw a histogram. Your graph should look like the one in Figure 12.8 below.

Range (%)	Number of pupils
0–19	0
20–39	5
40–59	11
60–79	16
80–100	3

Table 12.3 Number of learners with a particular percentage (%) score

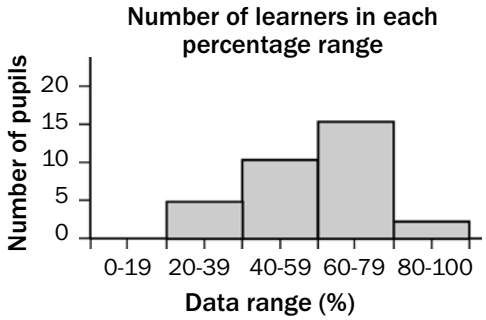


Figure 12.8 Final histogram with heading

NOTE:

When the independent variable is continuous data (an infinite number of values are evenly distributed), we use a line graph or histogram.

When the independent variable is discontinuous data (a fixed number of values that do not form an ordered scale), we use a bar graph or pie chart.

12.1.4 How to draw a pie chart

Step 1

Add all the data in the table together. In this case, you will add all the numbers in the 'Number of women' column to find out how many women took part in the investigation.

34 + 38 + 22 + 30 + 76 = 200

When you do the calculations for the pie chart, then '200' will be the denominator (the number that you divide by).

Contraceptive	Number of women
Sterilisation	34
Pill	38
Condom	22
Rhythm method	30
None	76

Table 12.4 Table of contraceptive use by a sample group of women

Step 2

Convert your data to angles. Divide each number by 200. Then, since there are 360° in a circle, the angles are worked out by multiplying by 360.

$\frac{34}{200} \times 360 = 61{,}2°$ (round down to 61°)

$\frac{38}{200} \times 360 = 68{,}4°$ (round down to 68°)

$\frac{22}{200} \times 360 = 39{,}6°$ (round up to 40°)

$\frac{30}{200} \times 360 = 54°$

$\frac{76}{200} \times 360 = 136{,}8$ (round up to 137°)

NB

Check that your calculations are correct. All the degrees should add up to 360°. In our example:

61° + 68° + 40° + 54° + 137° = 360°

If the degrees don't add up to 360°, you have done something wrong. Go back and check your work.

Step 3

Use a mathematical compass to draw a circle.

Step 4

Draw in one radius on the circle. Start at the exact middle of the circle and draw a line to the edge of the circle

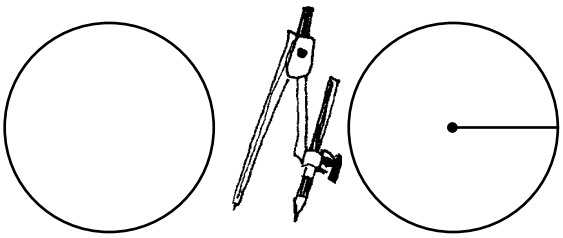


Figure 12.9 Draw a circle and then draw a radius

Step 5

Use a mathematical protractor to measure out the sectors of the pie chart according to the angles you calculated in step 2.

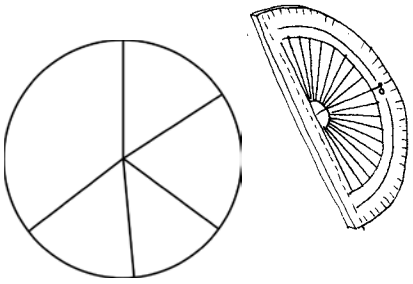


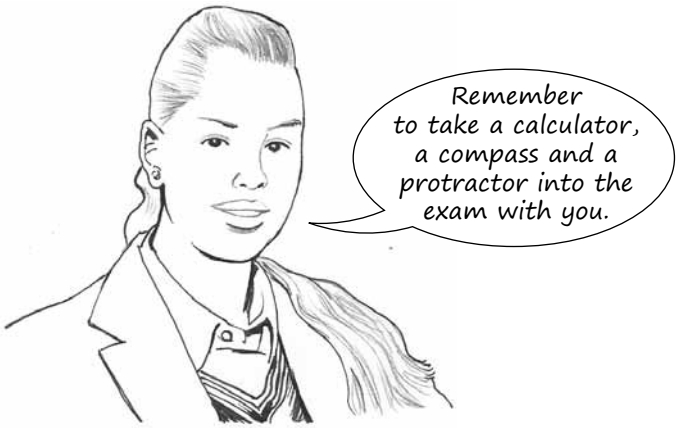
Figure 12.10 Measure out the sectors

Step 6

Label each of the sections of the pie chart with the correct information. In this example, each section should be labelled with the correct contraceptive method used by women (OR provide a key for the different sections).

Step 7

Give the pie chart a heading or caption. Remember that both variables should be included in the heading or caption. In this example the two variables are the type of contraceptive and the number of women.



Pie chart to show contraceptive use among a sample group of women

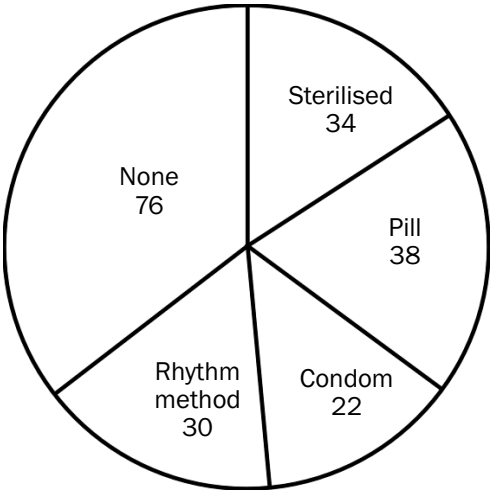


Figure 12.11 Final pie chart with heading

12.2 Answering essay questions

The essay in the final examination is allocated 20 marks. Answering this question requires planning. Let us look at the planning steps using the following essay question, which appeared in the *Life Sciences Paper 2 March 2012: Version 1* exam paper, as an example.

Describe the role of the hypothalamus and the adrenal glands in bringing about changes to the blood vessels of the human skin and **explain** why these changes take place.

Content (17)
Synthesis (3)
(20)

Step 1

Read the essay question thoroughly to determine the **topics** that are being covered. Underline the **key words** in the essay question that provide clues to the different topics:

Nervous system – since the hypothalamus (a part of the brain) is involved
Endocrine system – since adrenal glands are involved
Temperature regulation – since this involves blood vessels of the skin

Step 2

Interpret and analyse the essay question. Identify the **aspects or processes** that are required from each of the topics identified. You may need to read the question more than once to enable you to do this.

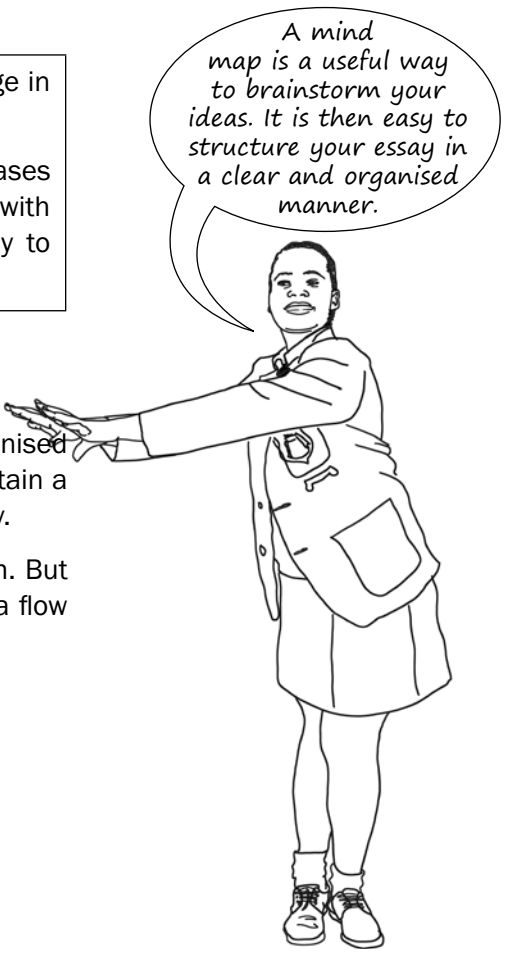
Hypothalamus – What effect does it have on the blood vessels of the skin?
Adrenal glands – What effect do they have on the blood vessels of the skin?

If you cover the above in your essay you will only be answering the '**describe**' part required by the essay question.

Note that the essay also requires an '**explanation**' of why these changes take place. For the explanation, you need to **elaborate on the functions** of the hypothalamus and the adrenal gland that involve the blood vessels of the skin as follows:

Hypothalamus – controls body temperature by stimulating a change in the diameter of the blood vessels of the skin.

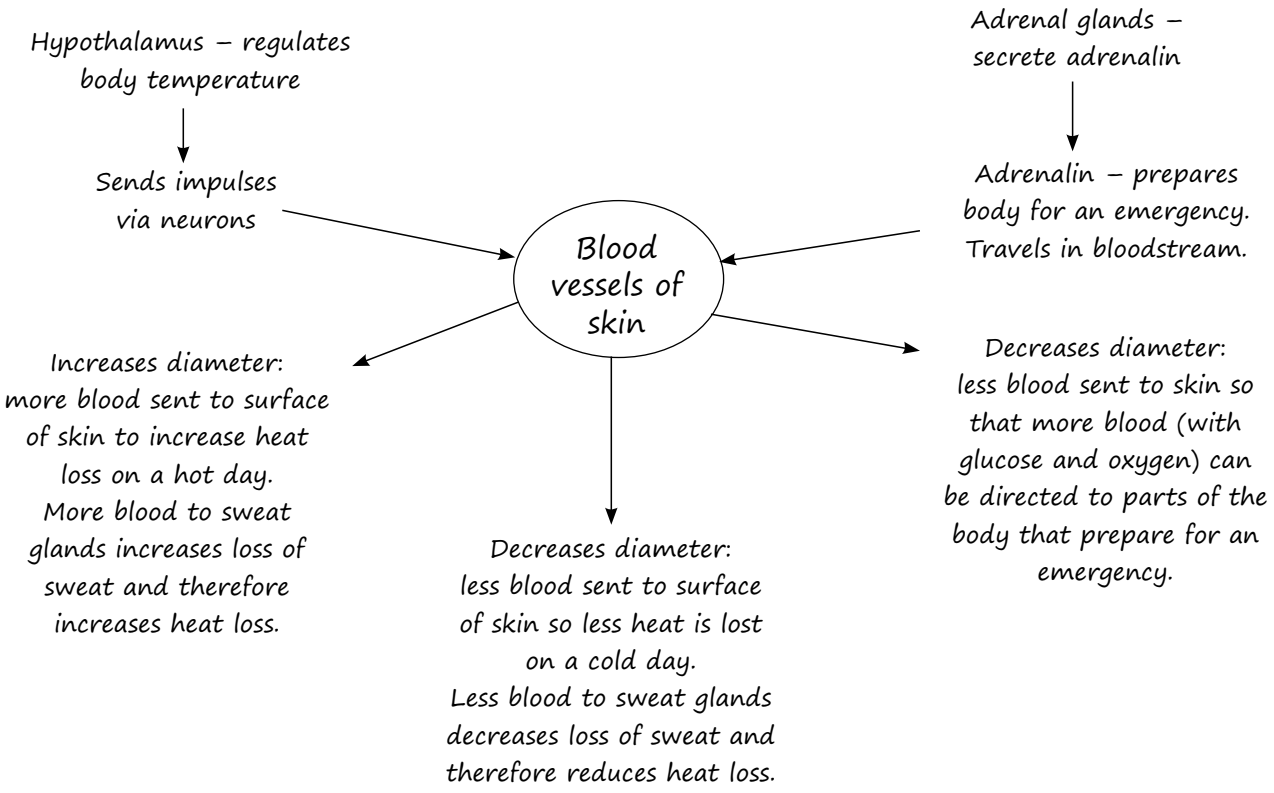
Adrenal glands secrete adrenalin into the bloodstream, which decreases the diameter of the blood vessels of the skin so that more blood (with oxygen and glucose) can be directed to other parts of the body to prepare for an emergency.



Step 3

Write the first draft of your essay in a logical and organised manner, linking each aspect that is discussed. This will help you obtain a high mark from the 3 marks allocated for the synthesis of your essay.

Your plan or draft of the essay may take the form of a flow diagram. But note that you final answer to the essay **CANNOT** be in the form of a flow diagram.

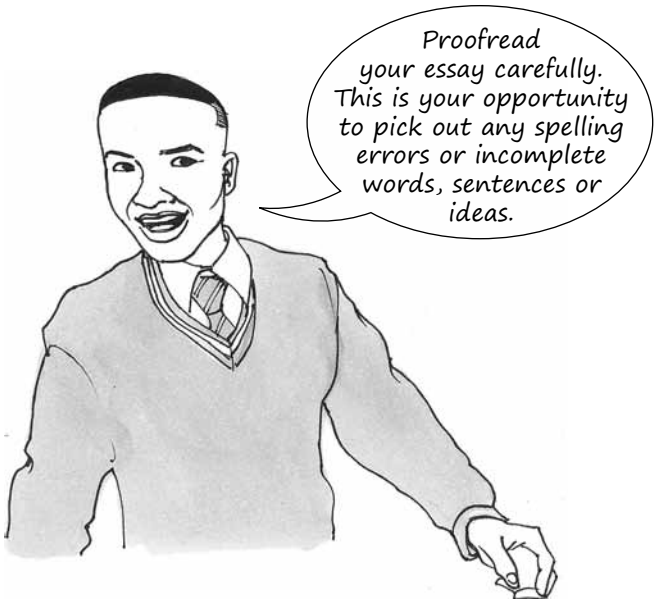


Step 4

Write out the final version of your essay. Put a line across the plan of your essay so that the marker assesses your final answer and not your plan or draft.

Step 5

Now read the question again one more time to **check if your answer corresponds to the question.**



12.3 Line drawings

In the exam, you may be asked to draw a **labelled diagram**. Keep these tips in mind if you are asked to draw a labelled diagram:

- Draw in pencil and use neat, strong lines.
- Do not use shading in your diagram.
- Your diagram must not be too small. It must be clear and correctly proportioned.
- The label lines must point directly to the structure that is being labelled.
- The label lines should not have arrow points.
- If possible, label lines should all end at the same point so that the labels are neatly aligned.
- Label lines should **never cross**. If two label lines cross, neither label will be marked.
- Print the labels neatly in pen.
- Finally, give your diagram a descriptive heading that states exactly what it illustrates.

To enable you to practise your drawing and labelling skills, we have included the diagrams from this guide on the following pages.

Appendix 1: Blank drawings

In this section you will find a number of key diagrams from this study guide. These blank diagrams can help you prepare for the exam in two ways:

1. You can use them to practise your drawing and labelling skills. You may be asked to draw a diagram in the exam, so make sure you follow the guidelines set out on page 113 when you redraw and label a diagram.
2. These diagrams are a valuable study aid. They summarise key information and important processes in Life Sciences. If you can label all these diagrams correctly on your own, without looking at them in the text, you'll be well prepared for the exam.

The following diagrams are included:

Topic 1: DNA: The code of life
Nucleotide
DNA
RNA
Replication of DNA
Protein synthesis

Topic 2: Meiosis
Homologous chromosomes
Stages in meiosis I
Stages in meiosis II

Topic 3: Reproduction
Male reproductive system
Sperm cell
Female reproductive system
Hormonal control of the menstrual cycle
Fertilisation and gestation

Topic 4: Responding to the environment: humans
Brain
Neuron
Reflex arc
Eye
Accommodation
Pupillary mechanism
Ear

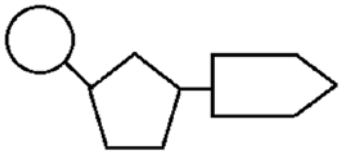
Topic 5: Human endocrine system
Name, position and functions of glands

Topic 6: Homeostasis in humans
Skin regulating temperature on a hot and cold day

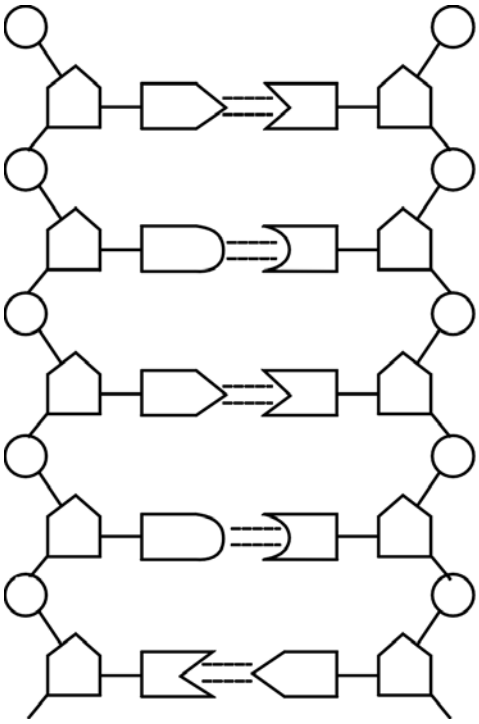
Topic 7: Evolution
Characteristics we share with the African apes
Characteristics that make us different from the African apes

Topic 1: DNA: The code of life

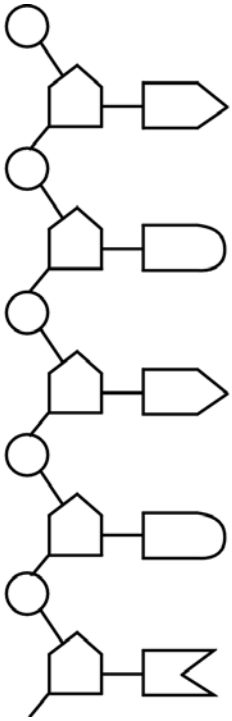
1. **Nucleotide**



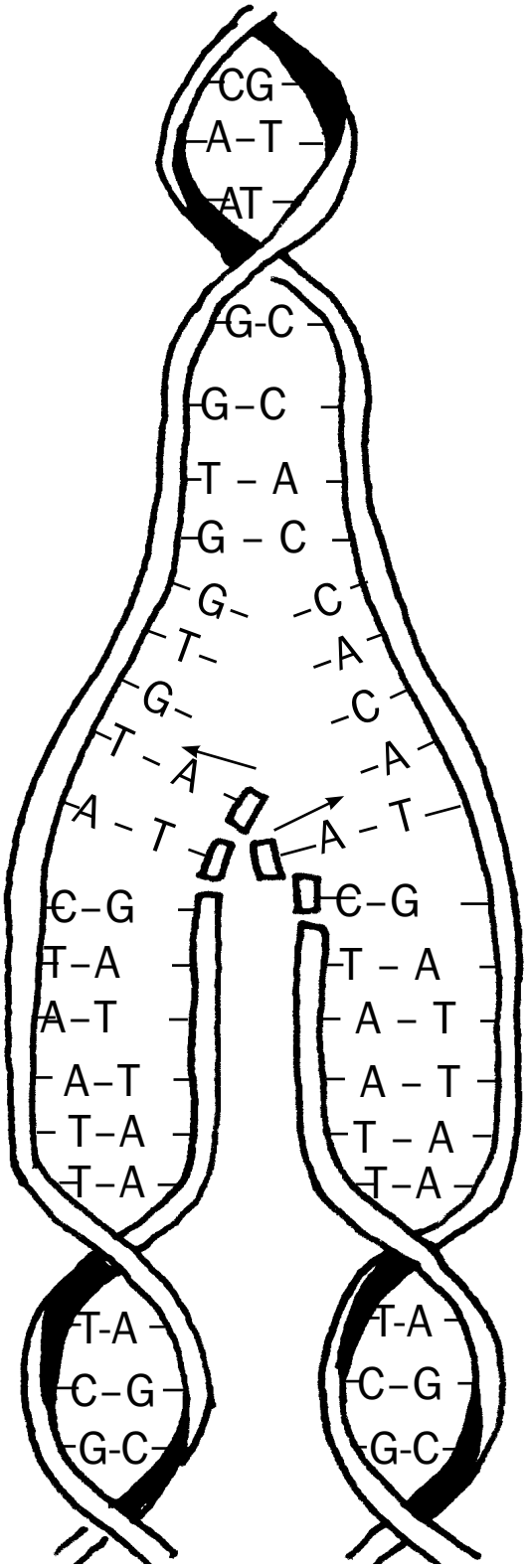
2. **DNA**



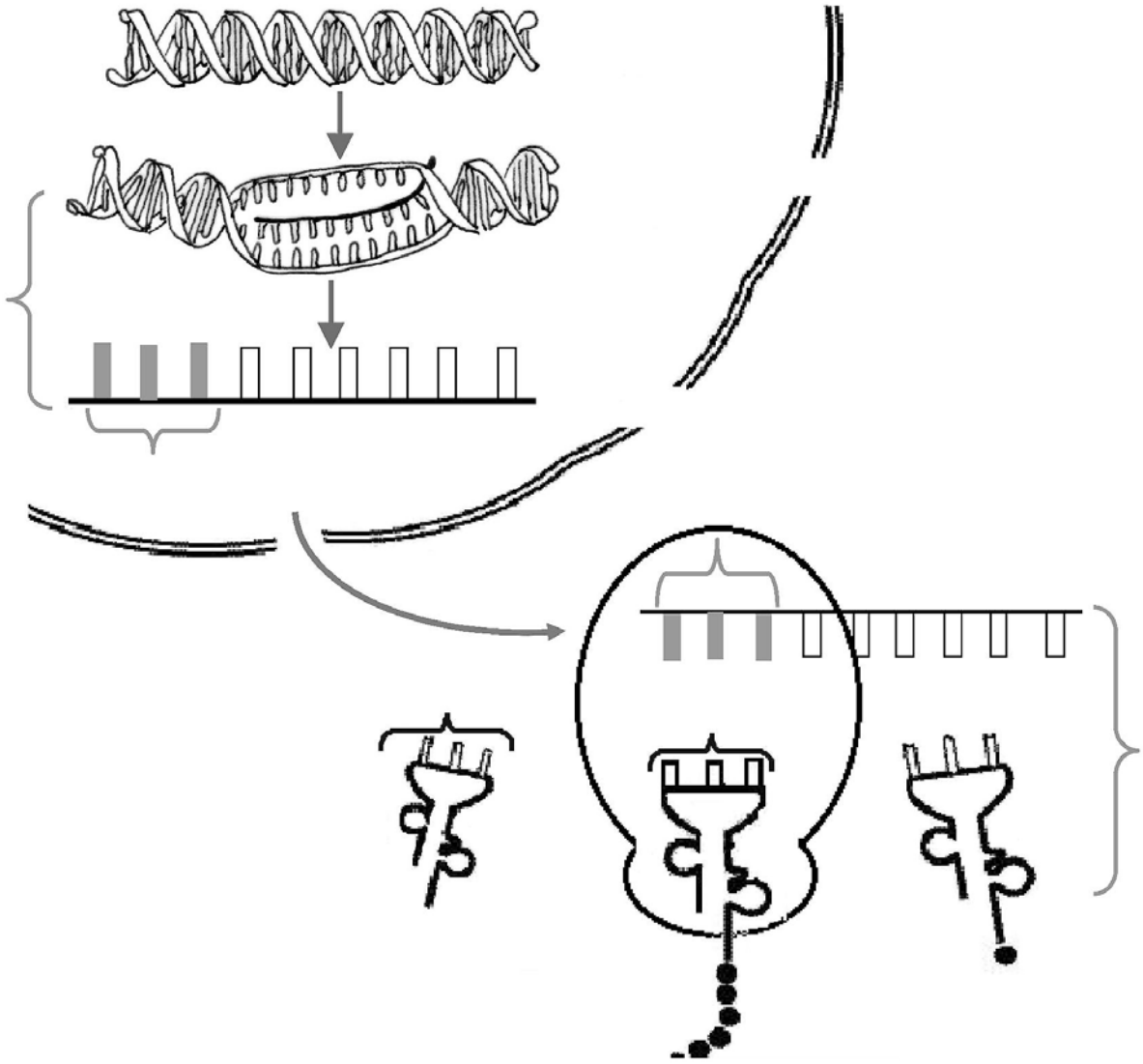
3. **RNA**



4. Replication of DNA

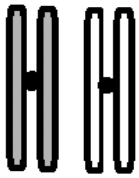


5. Protein synthesis

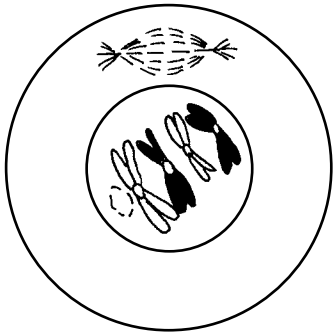
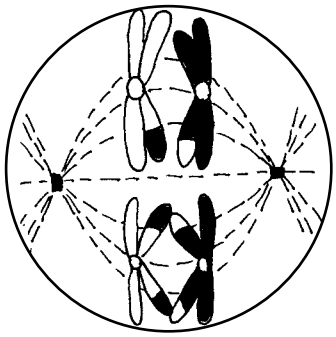
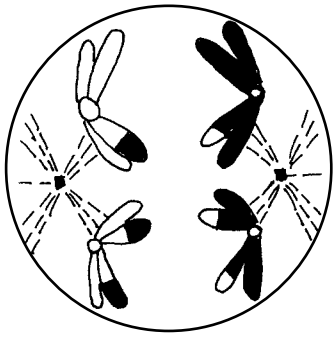
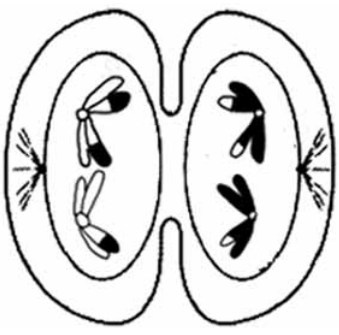


Topic 2: Meiosis

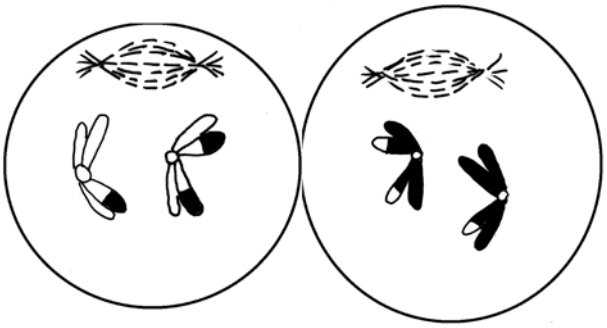
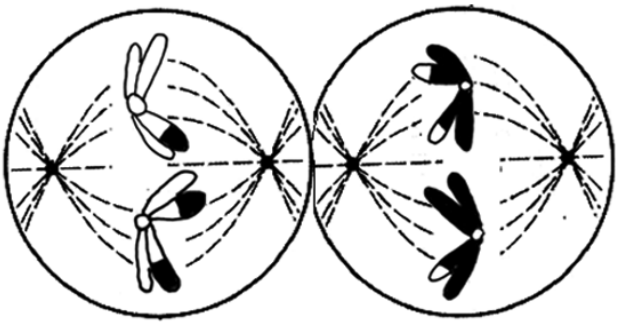
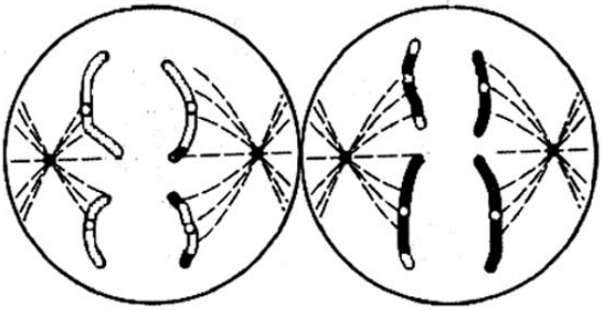
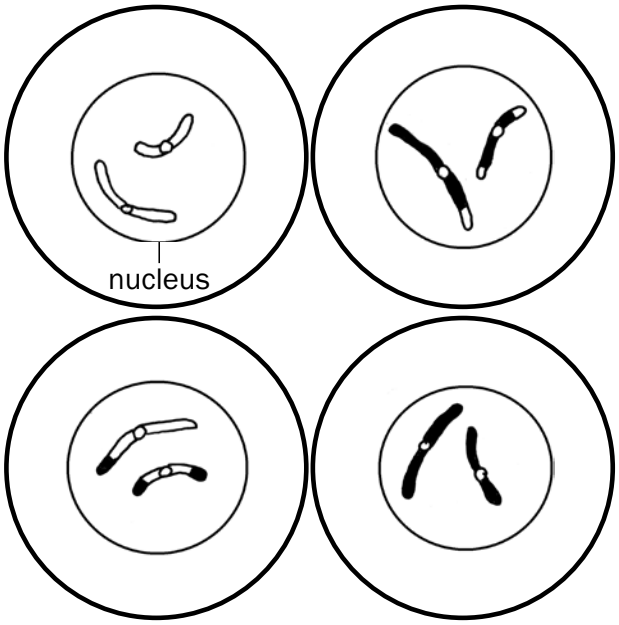
1. **Homologous chromosomes**



2. **Meiosis I**

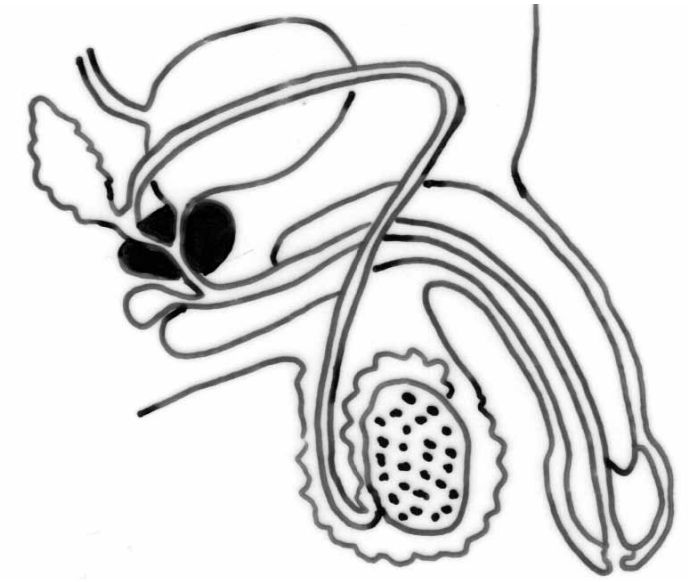
	
	
	
	

3. Meiosis II

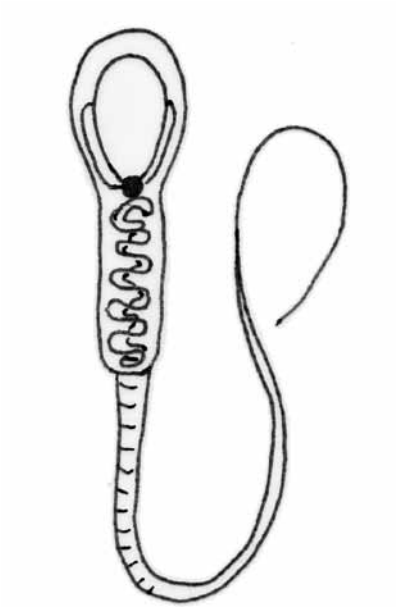
	
	
	
	

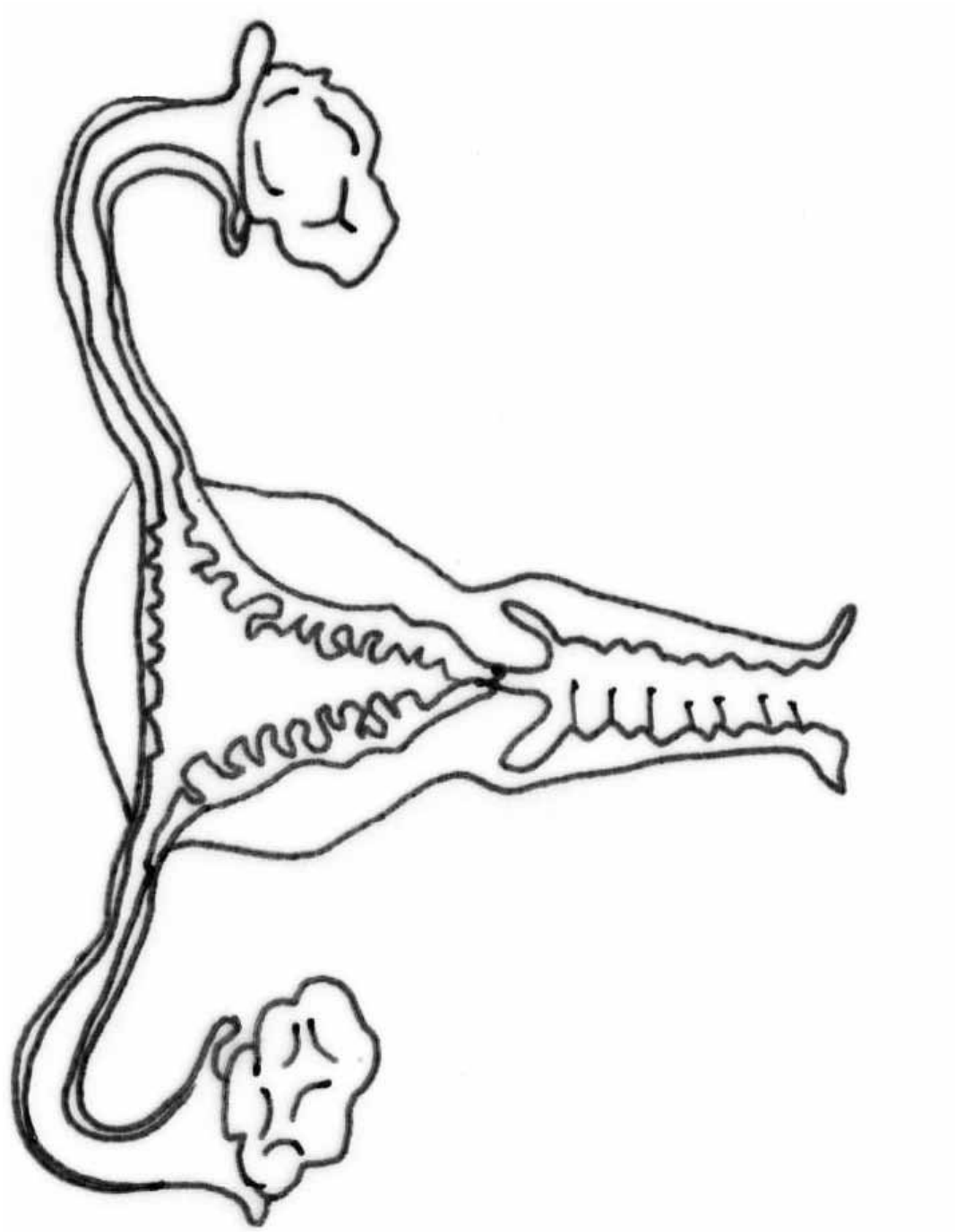
Topic 3: Human reproduction

1. Male reproductive system



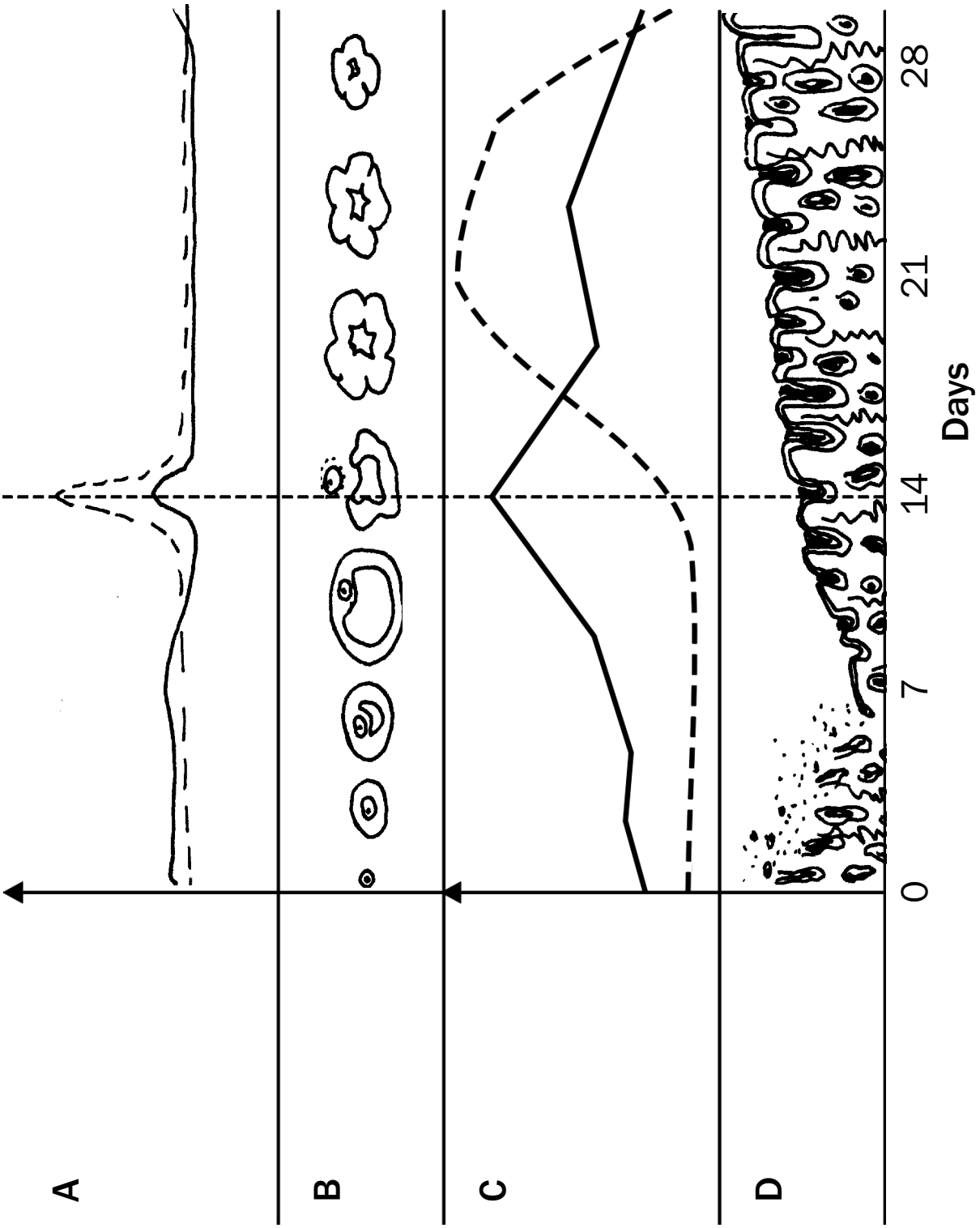
2. Sperm cell



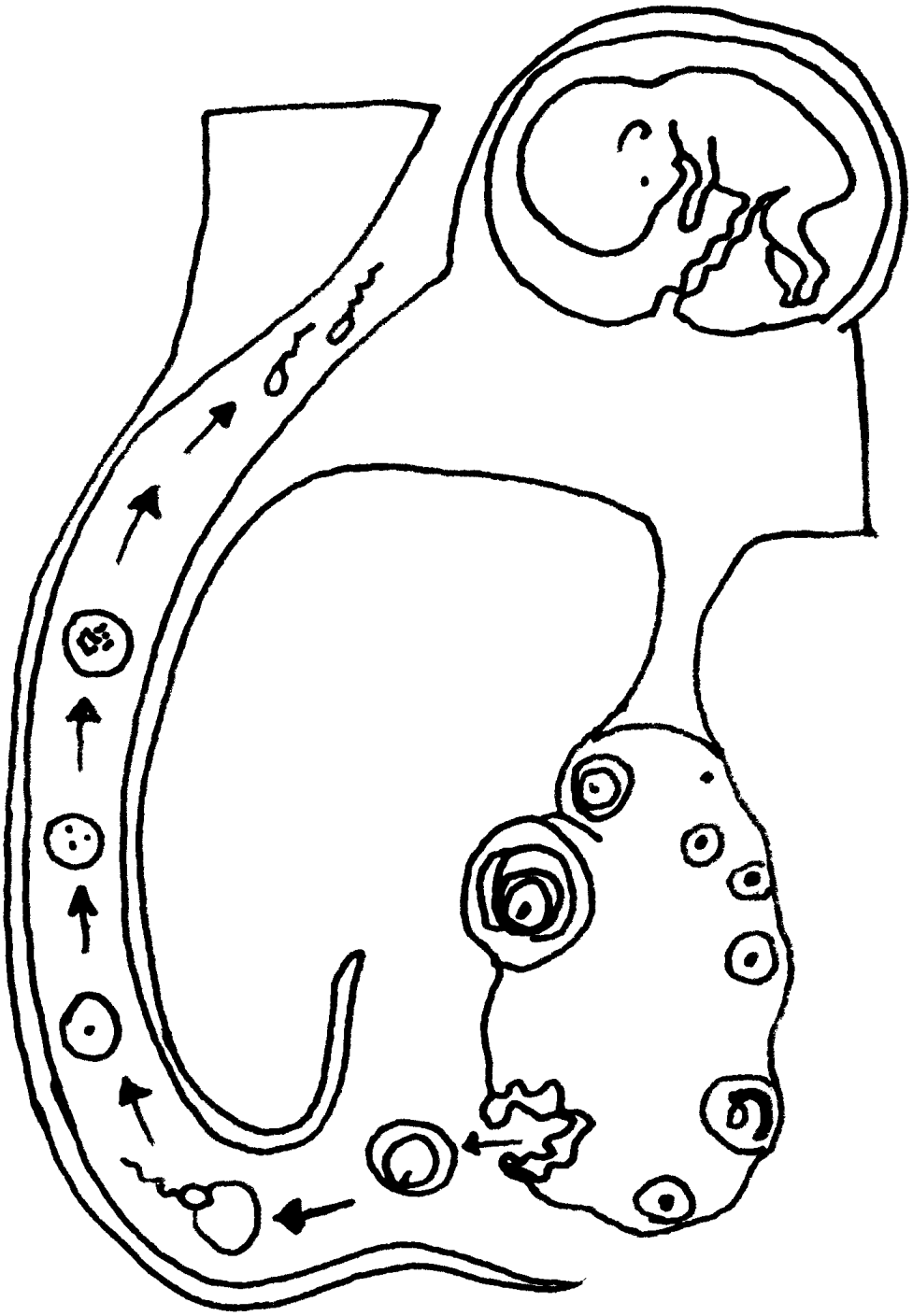


3. Female reproductive system

4. Hormonal control of the menstrual cycle

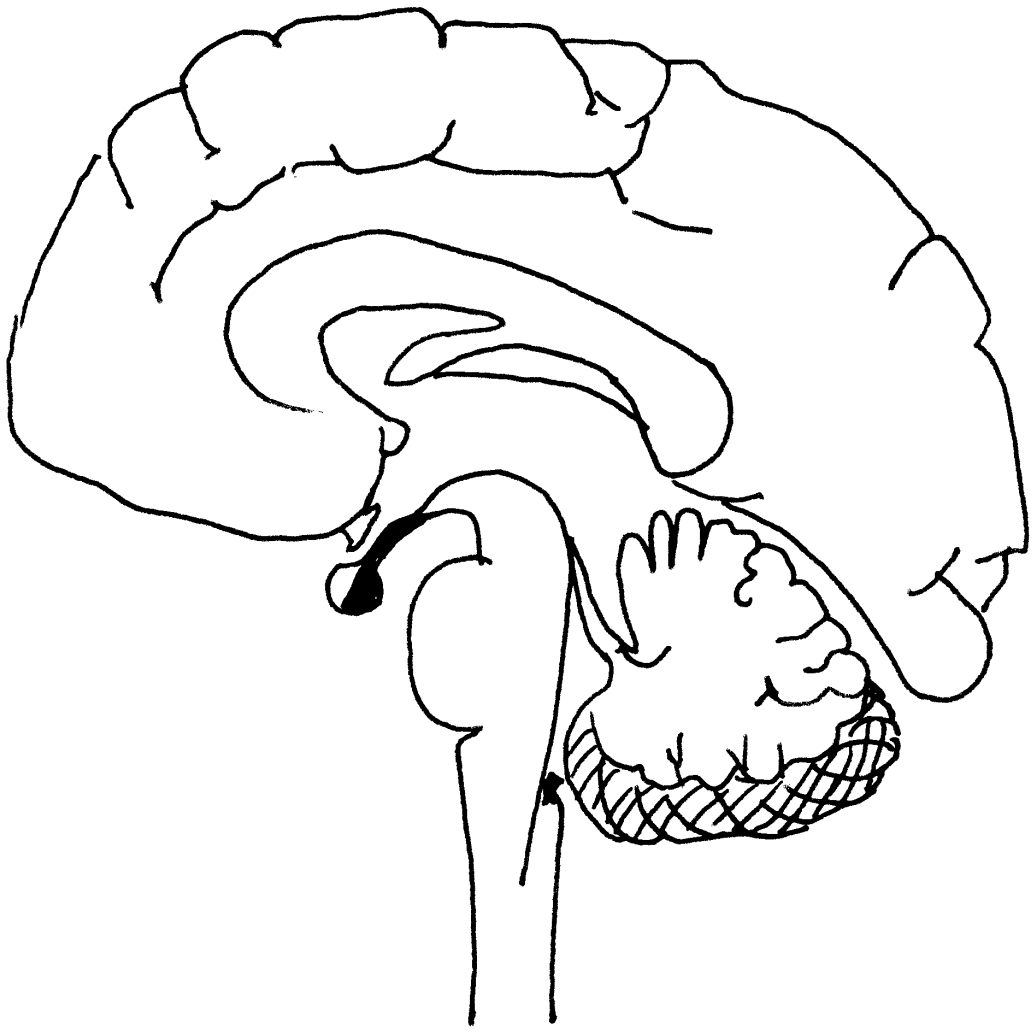


5. Fertilisation and gestation

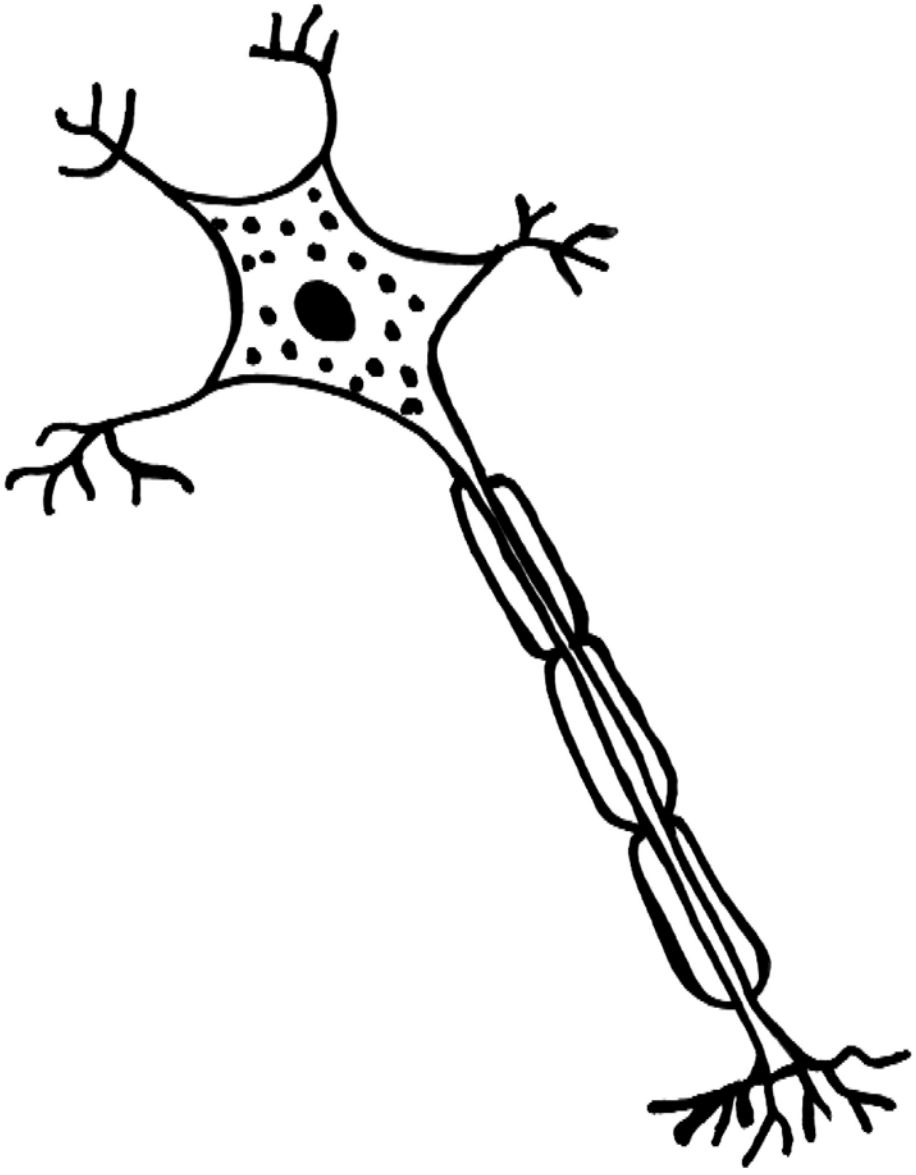


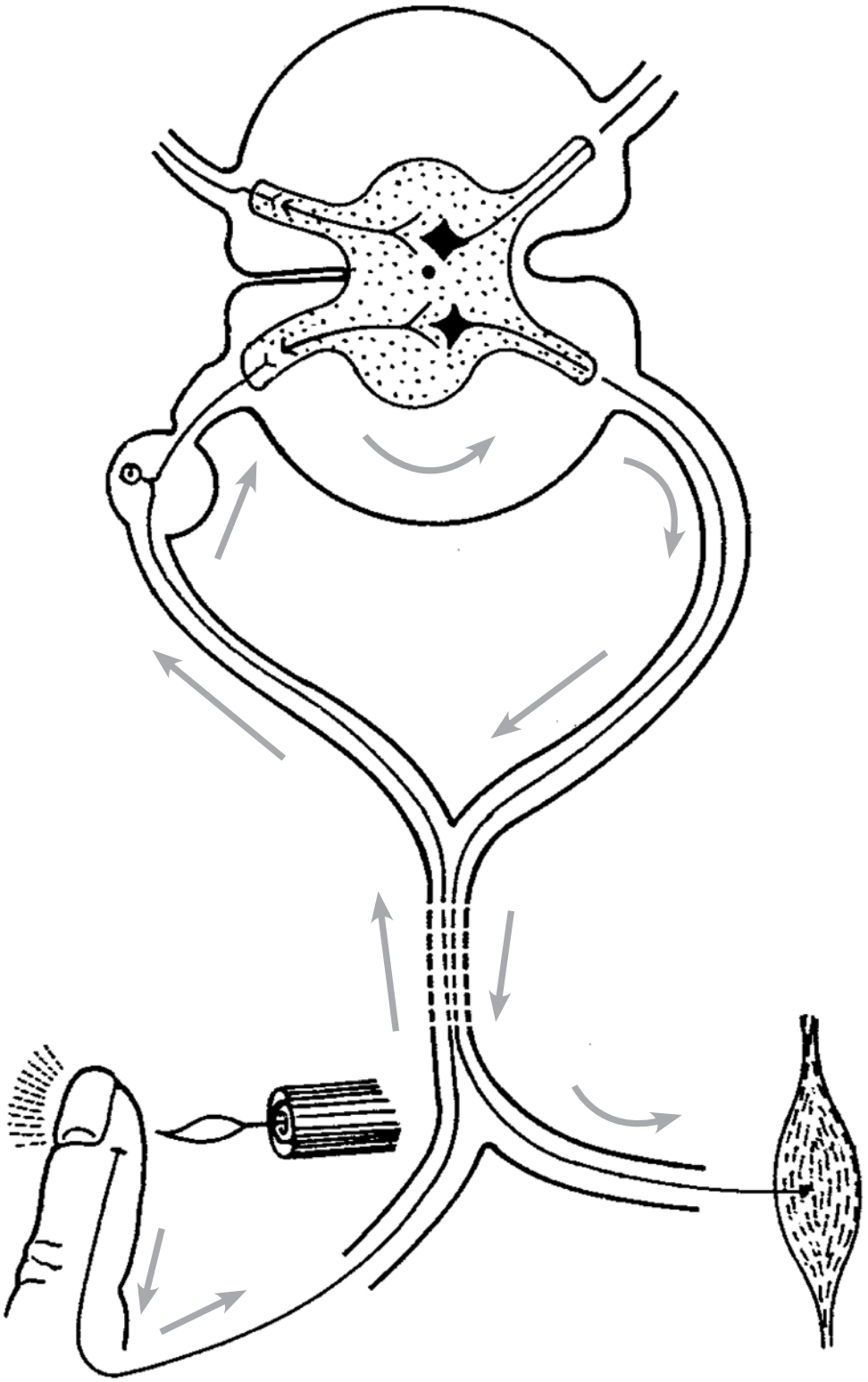
Topic 4: Responding to the environment – humans

1. Brain



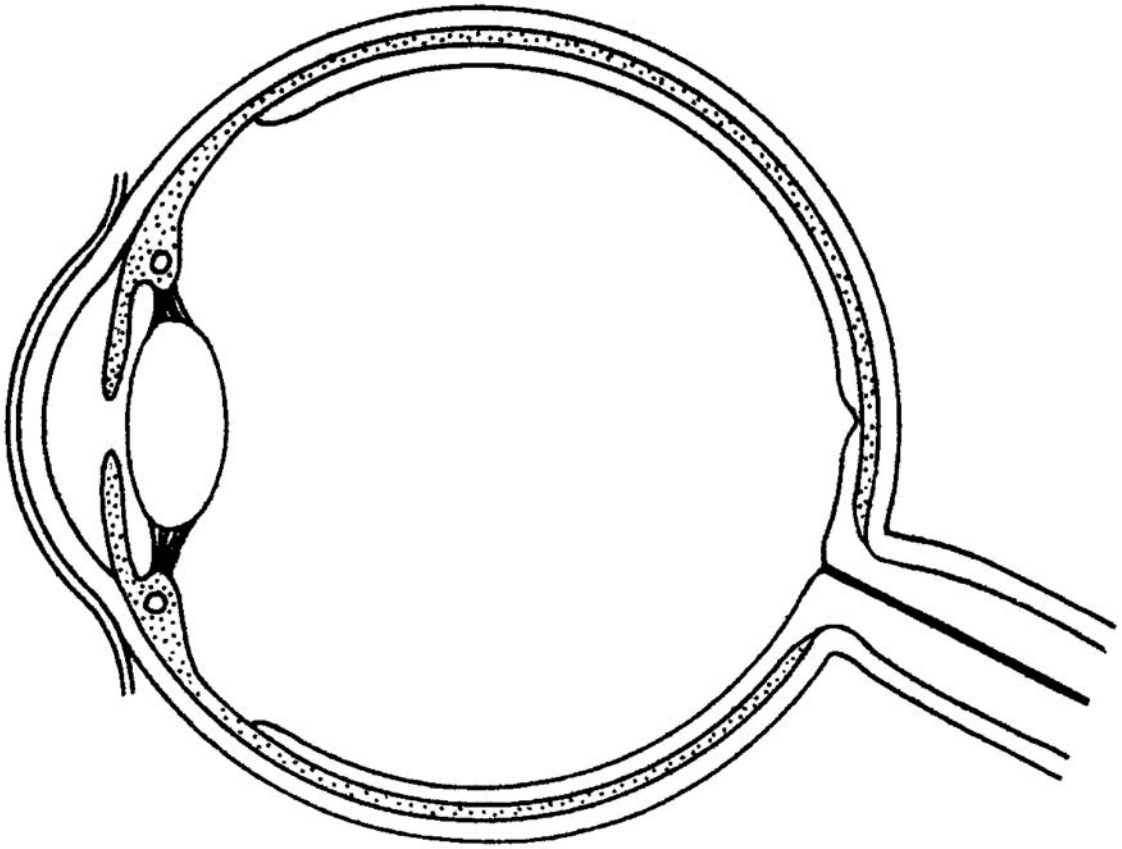
2. Neuron



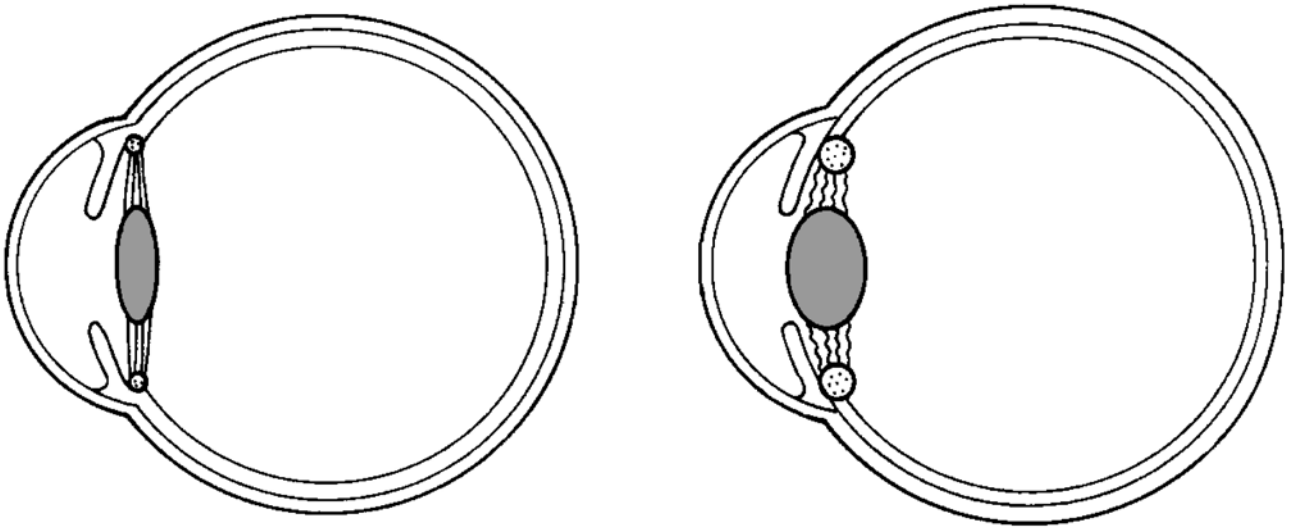


3. Reflex arc

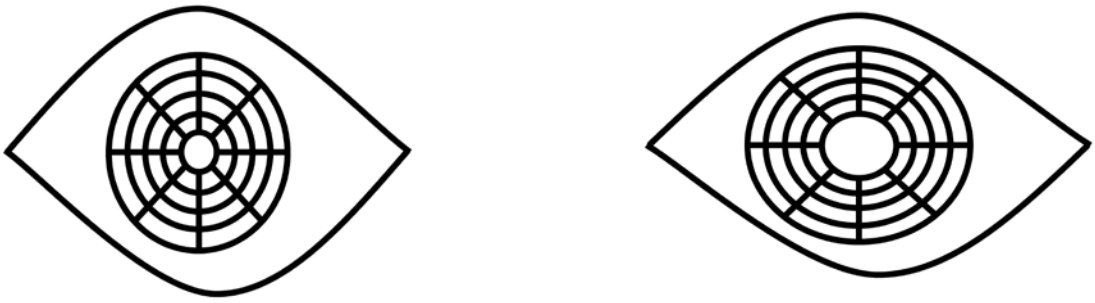
4. Eye



5. Accommodation



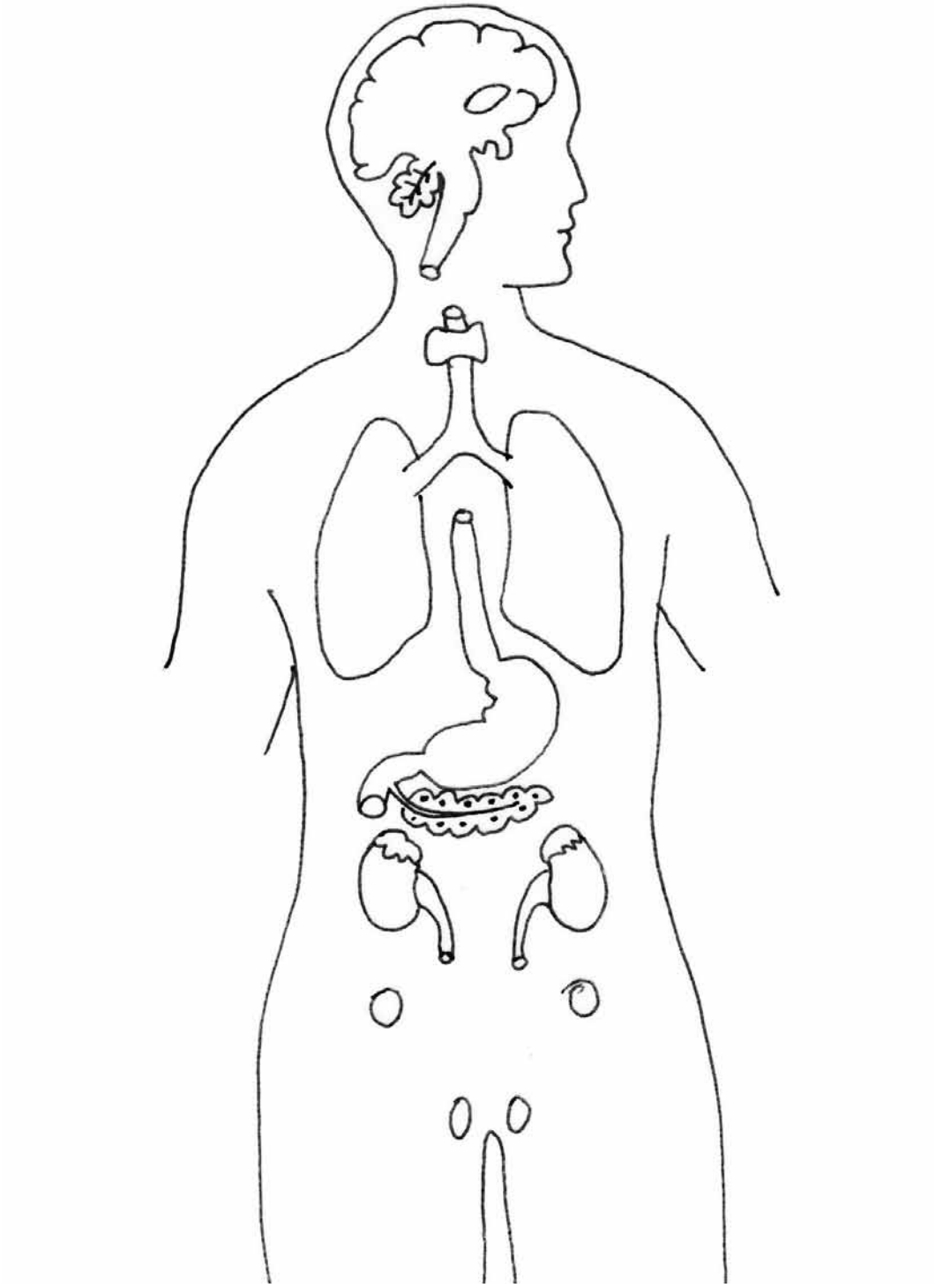
6. Pupillary mechanism



7. Ear

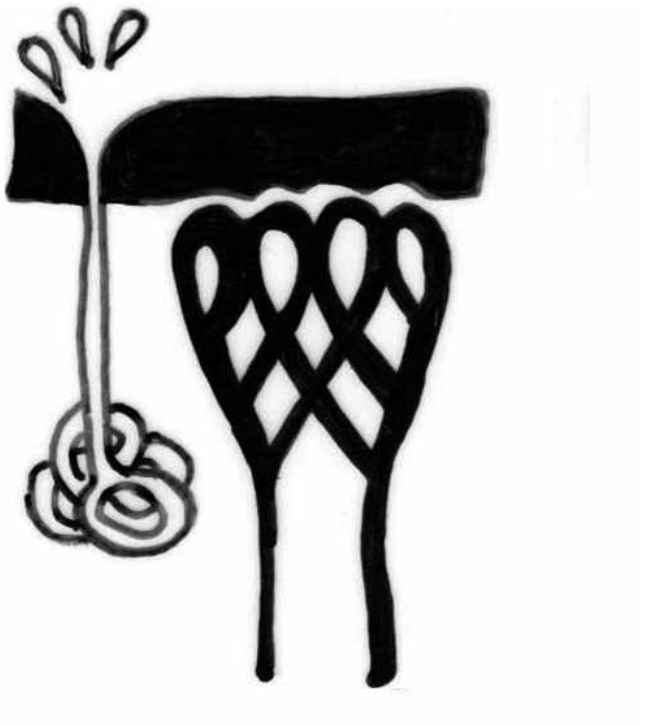
Topic 5: Human endocrine system

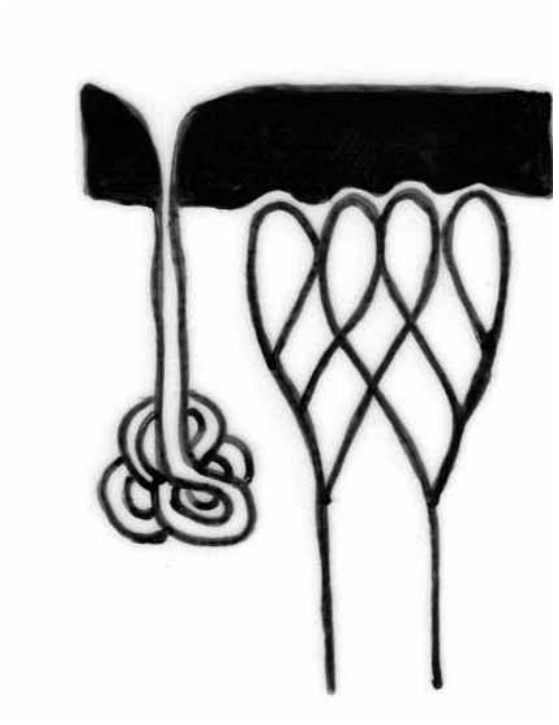
1. Name, position and functions of glands



Topic 6: Homeostasis in humans

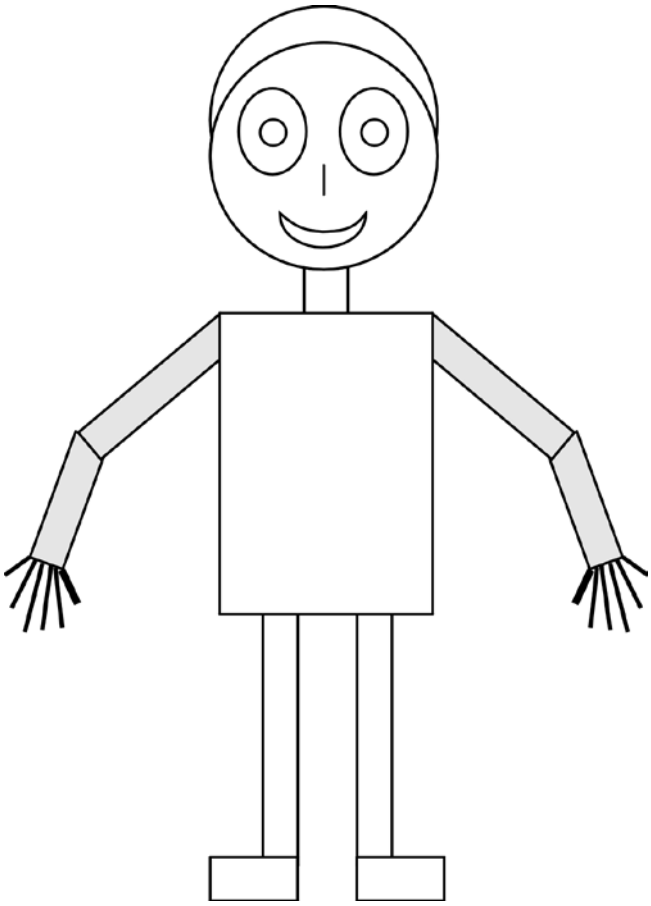
1. Skin regulating temperature on a hot and cold day



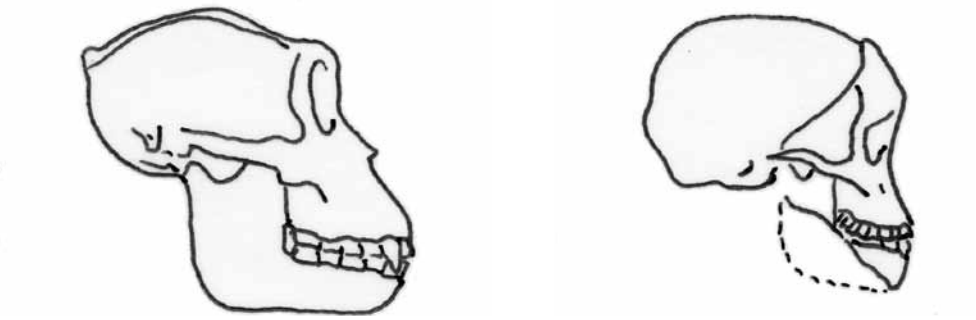


Topic 7: Evolution

1. Characteristics we share with African apes



2. Characteristics that make us different from the African apes



Appendix 2: Exemplar exam paper

The 2014 Life Sciences exams have a new format in line with CAPS. The Department of Basic Education has offered an example of Life Sciences Paper 1 and Paper 2 with marking memoranda.

Use these exam papers and memoranda to help you prepare for your exams:

1. **Answer the questions** in Life Sciences Paper 1. Make sure you take a break before doing the same with Paper 2. Treat them as "real" exams by preparing yourself as if these were real exams, so have the paper, pens, pencils, eraser and other materials that you need. **Time yourself** so you complete each paper within the 2 ½ hours that is allocated to them. This exercise is meant to test your own knowledge – so **don't cheat** yourself by looking up the answers in the memo before you've finished each exam.
2. Use the memoranda to **check whether or not your answers are correct**. Note where you have got answers wrong – these are the sections of the curriculum that you need to do more work on. Go back to your textbooks and to the relevant sections of this study guide, and **spend time learning** the sections for which you got the lowest marks.

basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

LIFE SCIENCES P2

EXEMPLAR 2014

MARKS: 150

TIME: 2½ hours

This question paper consists of 14 pages.

 Please turn over

INSTRUCTIONS AND INFORMATION

Read the following instructions carefully before answering the questions.

1. Answer ALL the questions.
2. Write ALL the answers in the ANSWER BOOK.
3. Start the answers to EACH question at the top of a NEW page.
4. Number the answers correctly according to the numbering system used in this question paper.
5. Present your answers according to the instructions of each question.
6. Do ALL drawings in pencil and label them in blue or black ink.
7. Draw diagrams or flow charts only when asked to do so.
8. The diagrams in this question paper are NOT necessarily drawn to scale.
9. Do NOT use graph paper.
10. You must use a non-programmable calculator, protractor and a compass, where necessary.
11. Write neatly and legibly.

SECTION A

QUESTION 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A to D) next to the question number (1.1.1 to 1.1.10) in the ANSWER BOOK, for example 1.1.11 D.

1.1.1 Which ONE of the following serves as evidence of cultural evolution in early *Homo* species?

A Drawings and carvings on rocks
B Animal remains close to a *Homo* skeleton
C Male and female skeletons in the same area
D More than one *Homo* skeleton in an area

1.1.2 A father has blood type A. He has 4 children with the following blood types:

Child 1 – A
Child 2 – O
Child 3 – AB
Child 4 – B

What is the blood type of the mother of the above children?

A A
B B
C O
D AB

1.1.3 New alleles arise in a sexually reproducing population through ...

A mutations in DNA sequences prior to meiosis.
B random fertilisation of gametes during reproduction.
C random assortment of homologous chromosomes during meiosis.
D exchange of chromatid segments between homologous chromosomes during meiosis.

1.1.4 A tall pea plant was crossed repeatedly with a short pea plant. In each of these crosses, they produced only tall offspring. It is reasonable to conclude that the …

A tall pea plant involved in the cross is homozygous.
B tall pea plant involved in the cross is heterozygous.
C offspring are all heterozygous for height.
D short pea plant involved in the cross is heterozygous.

1.1.5 The table below shows a section of the mitochondrial DNA (mtDNA) sequence for a modern human, a chimpanzee and three hominid species. The letter 'X' in the chimpanzee and the hominid sequences means that the DNA base was the same as that found in the modern human sequence.

ORGANISM	SECTION OF mtDNA SEQUENCE
Modern human	AAT-TCC-CCG-ACT-GCA-ATT-CAC-CTT
Chimpanzee	XXX-XXX-TXA-TTX-XXX-XAC-TGA-AAA
Hominid species 1	GGX-CTT-TTA-TTC-XTC-TCC-GTA-TAG
Hominid species 2	GGX-XGX-XXA-TTC-XTC-CCC-TGT-AAG
Hominid species 3	XTA-XXX-XXA-TTX-ATC-CXC-TGT-TCC

From the data in the table above it is possible to conclude that …

A chimpanzees are more closely related to hominid species 3 than they are to modern humans.
B hominid species 1 is probably the most recent common ancestor of chimpanzees and modern humans.
C modern humans are more closely related to hominid species 2 than to hominid species 3.
D modern humans are more closely related to hominid species 3 than to hominid species 2.

1.1.6 The following data represents a small section of a sequence of nucleic acid bases taken from an animal cell:

A G C U C G U U

From this data it is reasonable to conclude that …

A this portion of nucleic acid will code for a chain of eight amino acids.
B the sequence given will be complementary to the sequence C T C G T G C T T.
C the nucleic acid shown contains the sugar ribose.
D the nucleic acid shown is DNA.

1.1.7 The list below provides information relating to the replication of DNA:

1. Complementary nucleotides bind to each of the two strands.
2. Sugar phosphate bonds form between the nucleotides.
3. The newly formed DNA molecules are identical to each other.
4. After unwinding, the DNA molecule forms two single strands.

The correct order of these events as they occur in DNA replication is …

A 1, 2, 3 and 4.
B 1, 2, 3 and 2.
C 4, 2, 1 and 3.
D 4, 1, 2 and 3.

1.1.8 Which ONE of the following accounts for gametes having a single allele only for a particular characteristic, instead of two?

A The chromosome number is halved during Meiosis II
B Mendel's principle of segregation
C Mendel's principle of independent assortment
D The 'law' of dominance

1.1.9 In multiple alleles …

A more than one gene controls a trait or characteristic.
B there are more than two different alleles for the same gene.
C the different alleles for the same characteristic are at different positions.
D there are only two alleles for a particular gene.

1.1.10 In a situation where a characteristic is expressed more frequently in males than in females in humans, we can conclude that …

A one allele is dominant over the other.
B the alleles for the characteristic are located on the X chromosomes.
C the alleles for the characteristic are located on the autosomes.
D the alleles for the characteristic are located on the Y chromosomes. (10 x 2) **(20)**

1.2 Give the correct biological term for each of the following descriptions. Write only the term next to the question number (1.2.1 to 1.2.6) in the ANSWER BOOK.

1.2.1 An allele that does not influence the phenotype when found in the heterozygous condition

1.2.2 The position of a gene on a chromosome

1.2.3 The physical and functional expression of a gene

1.2.4 Chromosomes that are not responsible for sex determination

1.2.5 The process of finding a desirable gene, isolating it and then moving it into the cells of another organism

1.2.6 The two parts of a chromosome held together by a centromere (6 x 1) **(6)**

1.3 Indicate whether each of the statements in COLUMN I applies to **A only**, **B only**, **both A and B** or **none** of the items in COLUMN II. Write **A only**, **B only**, **both A and B**, or **none** next to the question number (1.3.1 to 1.3.8) in the ANSWER BOOK.

COLUMN I		COLUMN II
1.3.1	Discovered the double helical structure of DNA	A Francis Crick B James Watson
1.3.2	Describes evolution as consisting of long phases of little change alternating with short phases of rapid change	A punctuated equilibrium B Darwinism
1.3.3	Variation within a population in which there is a range of intermediate phenotypes	A discontinuous variation B continuous variation
1.3.4	Evidence for evolution	A mitochondrial DNA B cladogram
1.3.5	Chromosome condition of a cell that has a single set of chromosomes	A diploid B haploid
1.3.6	Two alleles of a gene that are equally dominant	A codominance B complete dominance
1.3.7	The full complement of genes present in an organism	A karyotype B phenotype
1.3.8	Bonds that hold amino acids together in a protein molecule	A hydrogen bonds B peptide bonds

(8 x 2) **(16)**

1.4 In pea plants the allele for round seeds (R) is dominant over the allele for wrinkled seeds (r). The allele for yellow seeds (Y) is dominant over the allele for green seeds (y).

Plant A, heterozygous for both seed shape and seed colour, was crossed with plant B, which had wrinkled, green seeds.

1.4.1 Write down the genotype of:

(a) Plant A (1)

(b) Plant B (1)

1.4.2 Write down ALL the possible genotypes of the gametes of plant A. (2)

1.4.3 State the phenotype of an offspring having the genotype:

(a) rrYy (1)

(b) RrYy (1)

1.4.4 When plant B was crossed with plant C, all the offspring had round yellow seeds.

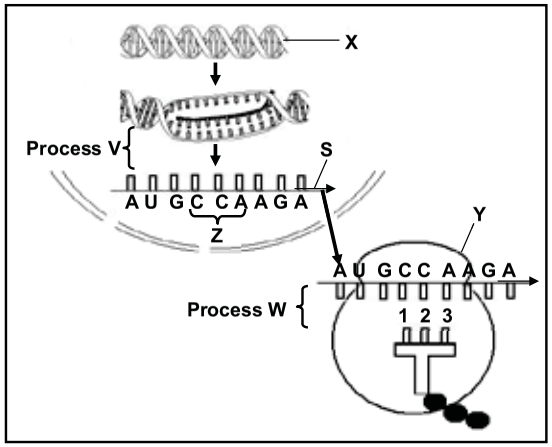
Use this information and write down the genotype of plant C. (2)
(8)

TOTAL SECTION A: 50

SECTION B

QUESTION 2

2.1 The diagram below shows the process of protein synthesis.



2.1.1 Identify the following:

(a) Molecule **X** (1)

(b) Organelle **Y** (1)

2.1.2 Identify the nitrogenous base labelled:

(a) 1 (1)

(b) 3 (1)

2.1.3 Describe the role of DNA during transcription. (3)

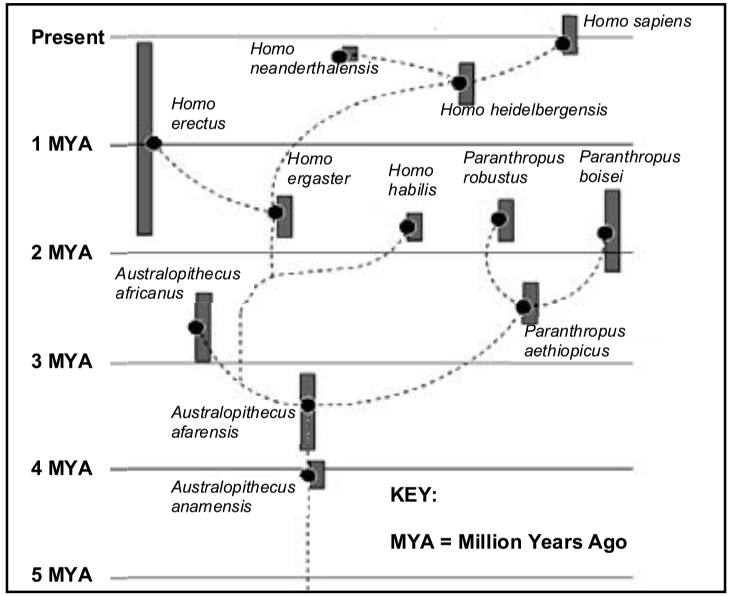
2.1.4 Describe the part of protein synthesis shown as process **W**, which occurs at organelle **Y**. (4)

2.1.5 The table below shows the amino acids that correspond with different DNA codes.

AMINO ACID	DNA CODE
Arginine	TCT
Methionine	TAC
Glycine	GGT

Write down the correct sequence of amino acids coded for by structure **S** in the diagram on the previous page. (3)
(14)

2.2 The phylogenetic tree below shows one interpretation of the origin of humans. The dotted lines indicate the possible evolutionary relationships, and the vertical bars show the period during which the organisms are believed to have existed on earth.



2.2.1 Use the diagram to identify ONE organism that may have competed with *Homo heidelbergensis* for resources. (1)

2.2.2 Identify the common ancestor that gave rise to both *Paranthropus* and *Homo*. (1)

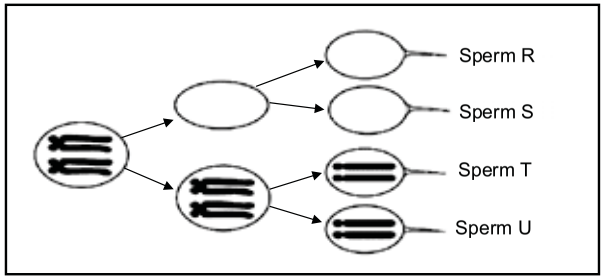
2.2.3 (a) For what period of time did *A. africanus* exist on Earth? Show all working. (3)

(b) Name ONE piece of evidence that could be used to prove that *A. africanus* existed during the time period calculated in QUESTION 2.2.3(a). (1)

2.2.4 (a) Which organism, *H. ergaster* or *H. neanderthalensis*, is more closely related to modern-day humans? (1)

(b) Explain your answer to QUESTION 2.2.4(a) using information in the diagram. (2)
(9)

2.3 The diagram below shows the result of abnormal meiosis, starting with a cell showing chromosome pair 21.



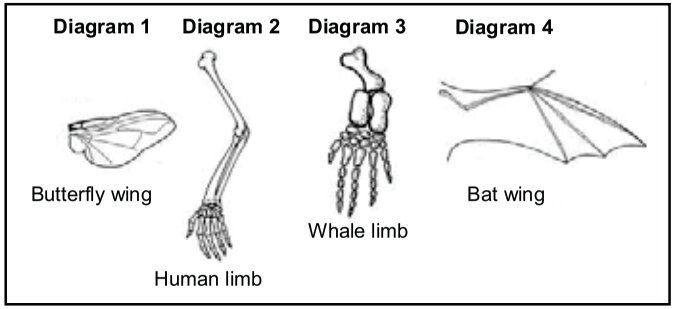
2.3.1 Explain the number of chromosomes present in sperm **R** and sperm **T**. (3)

2.3.2 How many copies of chromosome 21 would you expect in a normal gamete? (1)

2.3.3 What genetic disorder will result if sperm **U** fertilises a normal ovum? (1)

2.3.4 Describe TWO ways in which meiosis contributes to genetic variation. (7)
(12)

2.4 Study the diagrams below showing structures of different organisms.



2.4.1 Which diagram represents a structure that is analogous to the structure in Diagram 4? (1)

2.4.2 Write down the numbers of any TWO diagrams that represent homologous structures. (2)

2.4.3 What information do analogous and homologous structures provide about evolution? (2)
(5)
[40]

QUESTION 3

3.1 Scientists investigated the resistance of mosquitos to DDT.

The following steps were followed:
- They captured a sample of mosquitos from the environment.
- The mosquitos were then exposed to a standard dose of DDT (4% DDT for 1 hour) in the laboratory.
- The number of mosquitos that died was counted.
- Those that survived were left to reproduce.
- A sample was taken from this population every two months and the same procedure was followed for a period of 16 months.

The results are shown in the table below.

TIME (IN MONTHS)	MORTALITY OF MOSQUITOES (%)
0	95
2	87
4	80
6	69
8	60
10	54
12	35
14	27
16	22

3.1.1 Identify the:

(a) Independent variable (1)

(b) Dependent variable (1)

3.1.2 Formulate a hypothesis for this investigation. (3)

3.1.3 Draw a line graph to show how the mortality of mosquitoes changed over the period of the investigation due to the application of DDT. (6)

3.1.4 State TWO factors, other than those mentioned, that should be controlled in this investigation. (2)

3.1.5 State TWO ways in which the scientists could improve the reliability of their results. (2)

3.1.6 Explain, in terms of natural selection, how mosquitoes may develop resistance to DDT. (8)
(23)

3.2 Study the table below, which indicates some of the hominid fossils found in different parts of the world.

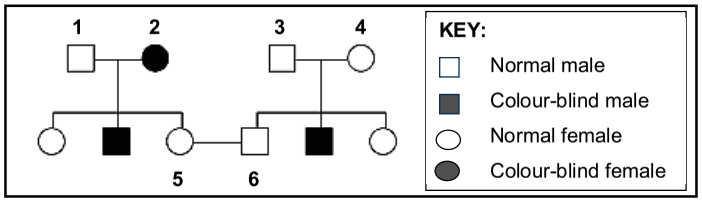
SPECIES	AREA WHERE IT WAS FOUND	PERIOD OF EXISTENCE
Australopithecus afarensis	Eastern Africa	3,4–2,8 mya
Australopithecus africanus	Southern Africa	2,1–2,8 mya
Australopithecus sediba	Southern Africa	2,0–1,9 mya
Homo habilis	Sub-Saharan (Africa)	2,3–1,4 mya
Homo erectus	Africa, Europe, Asia	1,5–0,2 mya
Homo heidelbergensis	Europe, China	0,6–0,35 mya
Homo neanderthalensis	Europe, Western Asia	0,35–0,03 mya
Homo sapiens	Worldwide	0,2 mya–present

[Adapted from *The Evolutionary Road*, Jamie Shreeve, *National Geographic*, July 2010]

3.2.1 Explain why the information in the table supports the 'Out of Africa' hypothesis. (2)

3.2.2 Describe how the analysis of mitochondrial DNA is used to support the 'Out of Africa' hypothesis. (3)
(5)

3.3 The pedigree diagram below shows the inheritance of Daltonism in a family. Daltonism (red-green colour-blindness) is sex-linked. The allele for Daltonism is recessive to the allele for normal colour vision.



3.3.1 Use the symbols X^D, X^d and Y to state the genotype of the following:

(a) Individual **2** (2)

(b) Individual **3** (2)

3.3.2 How many family members not affected by Daltonism are definitely carriers? (2)

3.3.3 Use a genetic cross to determine the possible genotypes and phenotypes of the offspring that may be formed by individuals **5** and **6**. (6)
(12)
[40]

TOTAL SECTION B: 80

SECTION C

QUESTION 4

It is thought that modern humans evolved gradually from ape-like beings over millions of years through speciation.

Describe how a single species can form new species, and explain how the differences in the skulls and other parts of the skeleton of primitive ape-like beings and modern humans support the idea that the general trend in human evolution has been towards bipedalism and a change in diet from raw food to cooked food.

Content: (17)
Synthesis: (3)
(20)

NOTE: NO marks will be awarded for answers in the form of flow charts or diagrams.

TOTAL SECTION C: 20
GRAND TOTAL: 150

basic education

Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

NATIONAL SENIOR CERTIFICATE

GRADE 12

LIFE SCIENCES P2

EXEMPLAR 2014

MEMORANDUM

MARKS: 150

This memorandum consists of 11 pages.

 Please turn over

PRINCIPLES RELATED TO MARKING LIFE SCIENCES

1. **If more information than marks allocated is given**
   Stop marking when maximum marks is reached and put a wavy line and 'max' in the right-hand margin.

2. **If, for example, three reasons are required and five are given**
   Mark the first three irrespective of whether all or some are correct/incorrect.

3. **If whole process is given when only a part of it is required**
   Read all and credit the relevant part.

4. **If comparisons are asked for but descriptions are given**
   Accept if the differences/similarities are clear.

5. **If tabulation is required but paragraphs are given**
   Candidates will lose marks for not tabulating.

6. **If diagrams are given with annotations when descriptions are required**
   Candidates will lose marks.

7. **If flow charts are given instead of descriptions**
   Candidates will lose marks.

8. **If sequence is muddled and links do not make sense**
   Where sequence and links are correct, credit. Where sequence and links are incorrect, do not credit. If sequence and links become correct again, resume credit.

9. **Non-recognised abbreviations**
   Accept if first defined in answer. If not defined, do not credit the unrecognised abbreviation but credit the rest of the answer if correct.

10. **Wrong numbering**
    If answer fits into the correct sequence of questions but the wrong number is given, it is acceptable.

11. **If language used changes the intended meaning**
    Do not accept.

12. **Spelling errors**
    If recognisable, accept the answer, provided it does not mean something else in Life Sciences or if it is out of context.

13. **If common names are given in terminology**
    Accept, provided it was accepted at the national memo discussion meeting.

14. **If only the letter is asked for but only the name is given (and vice versa)**
    Do not credit.

 Please turn over

15. **If units are not given in measurements**
Candidates will lose marks. Memorandum will allocate marks for units separately.

16. **Be sensitive to the sense of an answer, which may be stated in a different way.**

17. **Caption**
All illustrations (diagrams, graphs, tables, etc.) must have a caption.

18. **Code-switching of official languages (terms and concepts)**
A single word or two that appear(s) in any official language other than the learners' assessment language used to the greatest extent in his/her answers should be credited if it is correct. A marker that is proficient in the relevant official language should be consulted. This is applicable to all official languages.

19. **Changes to the memorandum**
No changes must be made to the memoranda without consulting the provincial internal moderator who in turn will consult with the national internal moderator (and the Umalusi moderators where necessary).

20. **Official memoranda**
Only memoranda bearing the signatures of the national internal moderator and the Umalusi moderators and distributed by the National Department of Basic Education via the provinces must be used.

SECTION A

QUESTION 1

1.1	1.1.1	A✓✓		
	1.1.2	B✓✓		
	1.1.3	A✓✓		
	1.1.4	A✓✓		
	1.1.5	D✓✓		
	1.1.6	C✓✓		
	1.1.7	D✓✓		
	1.1.8	B✓✓		
	1.1.9	B✓✓		
	1.1.10	B✓✓		
			(10 x 2)	**(20)**
1.2	1.2.1	Recessive✓		
	1.2.2	Locus✓		
	1.2.3	Phenotype✓		
	1.2.4	Autosomes✓		
	1.2.5	Genetic engineering✓/DNA manipulation/ Biotechnology/DNA recombination		
	1.2.6	Chromatids✓	(6 x 1)	**(6)**
1.3	1.3.1	Both A and B✓✓		
	1.3.2	A only✓✓		
	1.3.3	B only✓✓		
	1.3.4	A only✓✓		
	1.3.5	B only✓✓		
	1.3.6	A only✓✓		
	1.3.7	None✓✓		
	1.3.8	B only✓✓	(8 x 2)	**(16)**
1.4	1.4.1	(a) RrYy✓		(1)
		(b) rryy✓		(1)
	1.4.2	RY, Ry, rY, ry✓✓		(2)
	1.4.3	(a) Wrinkled, yellow✓ seeds		(1)
		(b) Round, yellow✓ seeds		(1)
	1.4.4	RRYY✓✓		(2)
				(8)
				[50]

QUESTION 2

2.1	2.1.1	(a) DNA✓ (b) Ribosome✓	(1) (1)
	2.1.2	(a) G✓ (b) U✓	(1) (1)
	2.1.3	– DNA codes for a particular protein✓ but cannot leave nucleus – One strand of DNA is used as a template✓ – to form mRNA✓	(3)
	2.1.4	– According to the codons on mRNA✓ – tRNA molecules with matching anticodons✓ – bring the required amino acids to the ribosome✓ – This is called translation✓ – The amino acids become attached by peptide bonds✓ – to form the required protein✓ (any 4)	(4)
	2.1.5	Methionine, ✓ Glycine, ✓ Arginine✓ (in the correct order)	(3) **(14)**
2.2	2.2.1	*H. erectus*✓	(1)
	2.2.2	*A. afarensis*✓	(1)
	2.2.3	(a) 3 mya – 2,4✓ mya = 0,6✓ my✓ OR 3 mya – 2,3✓ mya = 0,7✓ my✓	(3)
		(b) Fossils✓	(1)
	2.2.4	(a) *H. neanderthalensis*✓	(1)
		(b) *H. neanderthalensis* and *H. sapiens* share a common✓ ancestor✓ OR Both evolved✓ from *H heidelbergensis*✓	(2) (2) **(9)**

2.3	2.3.1	– The homologous chromosome pair ✓ – does not separate✓/non-disjunction – during anaphase 1✓	(3)
	2.3.2	1✓	(1)
	2.3.3	Down syndrome✓	(1)
	2.3.4	– During crossing over✓ – in Prophase 1✓ – segments of chromatids of homologous chromosomes✓ – are exchanged✓ – leading to each gamete having a mix of genetic material from both parents✓ (any 4)	
		– During Metaphase I✓/II – each pair of homologous chromosomes✓/each chromosome – may line up in different ways✓ on the equator of the spindle – allowing the gametes to have different combinations of maternal and paternal chromosomes ✓ (any 3)	(7) **(12)**
2.4	2.4.1	Diagram 1✓	(1)
	2.4.2	Diagrams 2 & 3✓✓/ 2 & 4/ 3 & 4	(2)
	2.4.3	Analogous structures show that two organisms evolved independently of each other✓ Homologous structures show that two organisms have a common ancestor✓.	(2) **(5)** **[40]**

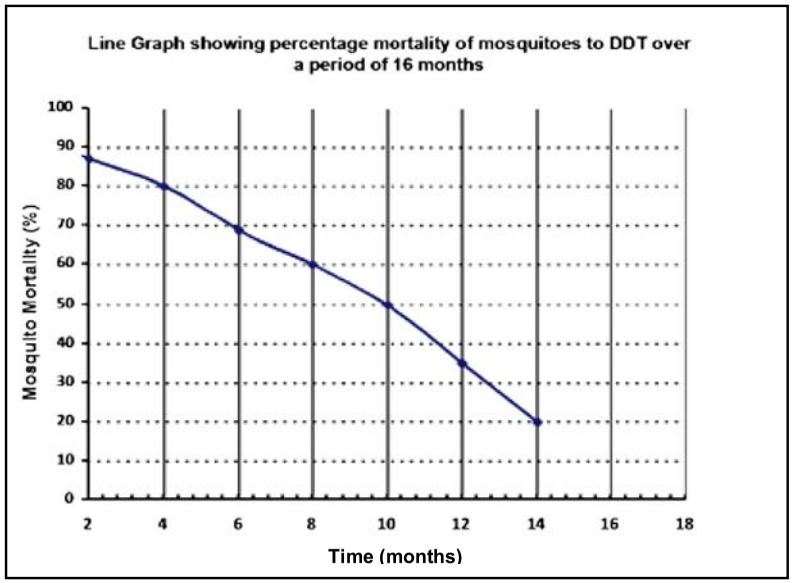
QUESTION 3

3.1 3.1.1 (a) Time ✓ (1)

(b) Mortality of mosquitoes ✓ (1)

3.1.2 Mosquito Mortality due to DDT✓/Resistance of mosquitos to DDT will decrease ✓ over time✓
OR
Mosquito Mortality due to DDT✓/Resistance of mosquitos to DDT will increase ✓ over time✓
OR
Mosquito Mortality due to DDT✓/Resistance of mosquitos to DDT will remain the same ✓ over time✓ (3)

3.1.3



NOTE:

If the wrong type of graph is drawn:
- Marks will be lost for 'correct type of graph'

If axes are transposed:
- Marks will be lost for labelling of X-axis and Y-axis

Mark allocation for the graph

Criterion	Elaboration	Mark
Type of graph	Line graph drawn	1
Caption	Includes both variables: 'Percentage mortality of mosquitoes' and 'Time'	1
X-axis	Appropriate scale AND Correct label and units for X-axis: Time (months)	1
Y-axis	Appropriate scale AND Correct label and units for Y-axis: Mortality of mosquitoes (%)	1
Plotting of points	1–8 points plotted correctly – 1 mark All 9 points plotted correctly – 2 marks	2

(6)

3.1.4
- Same species of mosquito✓
- Identical laboratory conditions for the full period of the investigation ✓
- The same scientist must be used for the full period of the investigation ✓
- Mosquitos should not be hurt for the full period of the investigation ✓

(Mark first TWO only) (any 2) (2)

3.1.5
- Use a larger sample of mosquitoes✓
- Repeat the investigation✓
- Take many samples each time and calculate the average mortality✓

(Mark first TWO only) (any 2) (2)

3.1.6
- More mosquitoes are produced than can survive.✓
- There is genetic variation✓ amongst the mosquitoes.
- Some mosquitoes may be naturally resistant to DDT.✓
- When DDT is applied✓
- those that are resistant survive✓
- and they then reproduce,✓
- passing the allele for resistance to the offspring.✓
- Those that are not resistant, die✓
- and their alleles are lost from the population.✓
- The number of DDT-resistant mosquitoes therefore increases over the generations✓. (any 8) (8)

(23)

3.2 3.2.1 The oldest fossils of human ancestors✓ were only found in Africa✓ (2)

3.2.2
- Mitochondrial DNA is passed down from mother to child✓
- mutations✓ on the mitochondrial DNA
- were traced to an ancestral female that existed in Africa✓ (3)

(5)

3.3 3.3.1 (a) X^dX^d✓ (2)

(b) X^DY✓ (2)

3.3.2 3✓ (2)

3.3.3 **P_1** phenotype Normal female x Normal male ✓
genotype X^DX^d x X^DY ✓

Meiosis

G_1 X^D , X^d x X^D , Y ✓

Fertilisation

X^DX^D, X^DX^d, X^DY, X^dY ✓

F_1 genotype 2 normal females 1 normal male 1 colour-blind male ✓
phenotype

Parents and offspring✓/P_1 & F_1
Meiosis and fertilisation✓ (any 6)

OR

P_1/parent phenotype Grey bodied x grey bodied✓
genotype Gg x Gg ✓

Meiosis

Fertilisation

gametes	X^D	X^d
X^D	X^DX^D	X^DX^d
Y	X^DY	X^dY

1 mark for correct gametes✓
1 mark for correct genotypes✓

F_1 genotype 2 normal females 1 normal male 1 colour-blind male
phenotype

Parents and offspring✓/P_1 & F_1
Meiosis and fertilisation✓ (any 6) (6)
(12)
[40]

TOTAL SECTION B: 80

SECTION C

QUESTION 4

The development of a new species

- If a population splits into two populations✓.
- There is now no gene flow between the two populations. ✓
- Since each population may be exposed to different environmental conditions✓,
- Natural selection occurs independently in each of the two populations✓
- such that the individuals of the two populations become very different from each other✓
- genotypically and phenotypically✓.
- Even if the two populations were to mix again✓,
- they will not be able to reproduce with each other✓, thus becoming different species (any 5) (5)

The development of bipedalism

- The backward position of the foramen magnum on the skull✓,
- the narrow pelvis✓
- and the less-curved spine✓
- indicates that the ape-like beings were quadripedal✓ (any 3)

- The forward position of the foramen magnum on the skull✓,
- the wider pelvis✓
- and the curved spine✓
- indicates that modern humans are bipedal✓ (any 3) (6)

Change in the diet from raw food to cooked food

- The large teeth, especially the canines✓
- as well as the large and long jaws✓
- which makes the skull prognathous✓
- as well as cranial/brow ridges associated with large muscles that operate the jaws✓
- indicate that the ape-like beings ate raw food that required a great amount of processing✓/tearing, biting and chewing. (any 3)

- The smaller teeth, including the canines✓
- as well as the smaller jaw size✓
- which makes the skull less prognathous✓
- as well as the absence of cranial/brow ridges due to the presence of smaller muscles for chewing✓
- indicate that modern humans rely on a diet of cooked food that does not require the same amount of processing✓/tearing, biting and chewing. (any 3) (6)

Content: (17)
Synthesis: (3)
(20)

ASSESSING THE PRESENTATION OF THE ESSAY

Relevance	Logical sequence	Comprehension
Only information regarding development of a new species, the development of bipedalism and change in diet is given (no irrelevant information).	Generally, the development of a new species, the development of bipedalism and change in diet are explained logically.	All three aspects of the question are described correctly.

TOTAL SECTION C: 20
GRAND TOTAL: 150