

STUDY GUIDE

FOR

Understanding Life Sciences

Including Questions and Answers

Grade 12

CAPS

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Education Services

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1

DNA The Code of Life

INTRODUCTION

- There are two types of nucleic acids, DNA and RNA
- DNA (Deoxyribonucleic acid) makes up the genes located on the chromosomes in the nucleus
- RNA (Ribonucleic acid) is formed in the nucleus but functions in the cytoplasm

STRUCTURE OF NUCLEIC ACIDS

- Both DNA and RNA are large molecules
- They are made up of a number of smaller units or monomers called nucleotides
- Each nucleotide is made up of:
 - A nitrogenous base (NB)
 - A sugar portion (S) - deoxyribose in DNA; ribose in RNA
 - A phosphate portion (P)

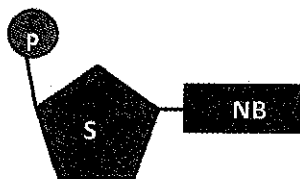


Fig. 1.1 Structure of a single nucleotide

DNA

Location of DNA

- The DNA within the nucleus is called nuclear DNA. Together with proteins, it makes up the chromosomes which in turn go to make up the chromatin network
- Small amounts of DNA are also found outside the nucleus (extra-nuclear DNA) such as within chloroplasts (called chloroplastic DNA) and mitochondria (called mitochondrial DNA or mtDNA).

Structure of DNA

- DNA is double stranded i.e. it consists of two strands of nucleotides joined to each other
- The natural shape of DNA is a double helix
- Each DNA nucleotide contains the sugar, deoxyribose

- There are 2 groups of nitrogenous bases: purines and pyrimidines
- The purines are adenine and guanine whilst the pyrimidines are cytosine and thymine.
- The nitrogen bases are complementary meaning that:
 - Cytosine pairs off with guanine only
 - Adenine pairs off with thymine only
- The two strands of DNA are held together by weak hydrogen bonds
- This structure of DNA is based on the model put forward by Watson and Crick in 1953.

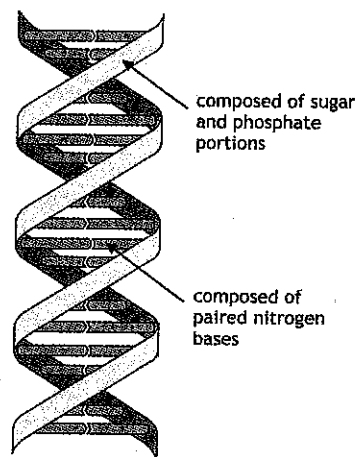


Fig. 1.2 A portion of DNA to show its double helix structure

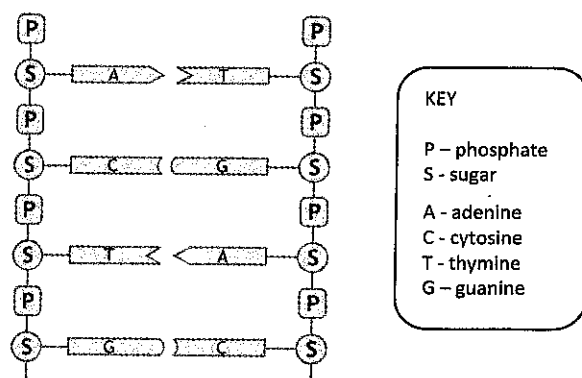


Fig. 1.3 A portion of DNA molecule showing its double stranded structure

Functions of DNA

- DNA codes for the formation of different proteins required in the body
- DNA is responsible for transmitting hereditary characteristics from parents to offspring

RNA

Location of RNA

There are three types of RNA:

- Ribosomal RNA (rRNA) found in the ribosomes in the cytoplasm of the cell
- Messenger RNA (mRNA) which is found in the nucleus of the cell but later moves out of the nucleus and attaches to the ribosome in the cytoplasm
- Transfer RNA (tRNA) found in the cytoplasm of the cell

Structure of RNA

- Ribonucleic Acid (RNA) is similar to DNA except that:
 - It is a single-stranded structure
 - The sugar in it is ribose (not deoxyribose)
 - Thymine is replaced by uracil
 - The bases are not paired

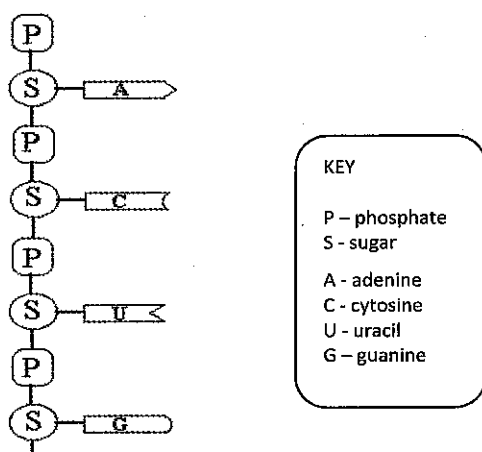


Fig. 1.4 A portion of an RNA molecule showing its single stranded structure

Functions of RNA

- All three types play important roles in protein synthesis

SIMILARITIES BETWEEN DNA AND RNA

- Both contain sugar alternating with phosphate
- Both contain the nitrogenous bases adenine, guanine and cytosine
- Both play a role in protein synthesis

DIFFERENCES BETWEEN DNA AND RNA

DNA	RNA
Found in the nucleus, chloroplast and mitochondria	Found in the nucleus and the cytoplasm
Double stranded molecule	Single stranded molecule
Contains the sugar, deoxyribose	Contains the sugar, ribose
Contains the nitrogenous base, thymine	Contains the nitrogenous base, uracil

DNA REPLICATION

What is DNA replication?

- The process by which DNA makes an identical copy of itself

When does it occur?

- DNA replication occurs just before cell division (mitosis and meiosis). It occurs during interphase

Why does it occur?

- DNA replication is a process by which identical copies of DNA are made so that it could be shared amongst the daughter cells during cell division so that each daughter cell has the same number of chromosomes as the original.
- It allows the daughter cells after mitosis to be identical to each other and to the cell from which they were formed

How does it occur?

DNA replication takes place as follows:

- Double helix DNA **unwinds**¹
- Weak hydrogen bonds between nitrogenous bases break
- and the two DNA strands **unzip**²/separate
- Each original DNA strand serves as a **template**³ to form a new strand
- by attaching to free nucleotides from the nucleoplasm
- to form **complementary strands**⁴ (A to T and C to G)
- Each DNA molecule now consists of 1 original strand and 1 new strand
- The result is **two genetically identical DNA molecules**⁵
- The entire process is controlled by enzymes

NOTE: See 1-5 on the following diagram of DNA Replication

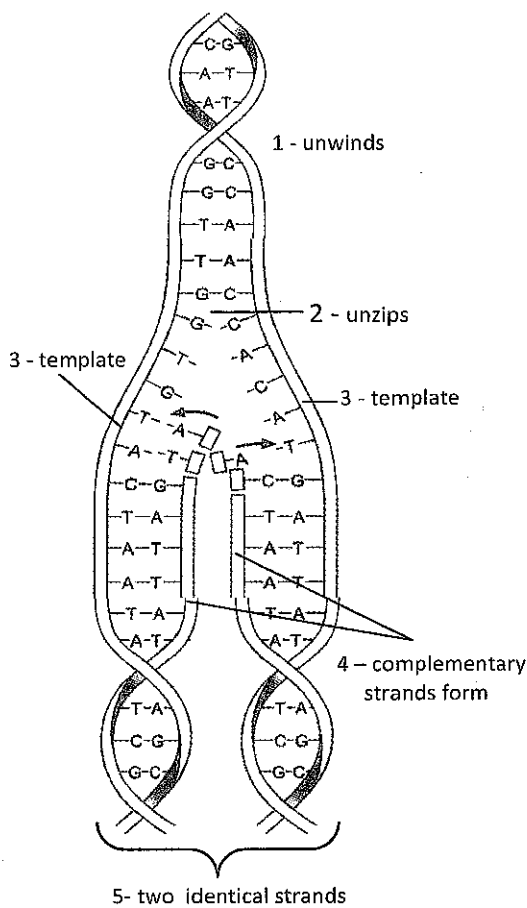


Fig. 1.5 DNA Replication

DNA PROFILE

What is a DNA profile?

- DNA profiles are patterns of black bars left on X-ray film when an extract of DNA is put through a special biotechnical process.
- DNA profiling is a method of identifying an individual by comparing his/her DNA profile with another known DNA profile.

What are the uses of DNA Profiles?

DNA profiles are used for

- The diagnosis of inherited disorders such as cystic fibrosis, haemophilia and sickle cell anaemia
- Identification of criminals in forensic science
- Identification of relatives such as:
 - Establishing whether a particular person is the father of a child or not
 - Tracing siblings (brothers and sisters) who have been separated at birth
 - Identifying people who have died and where their bodies cannot be recognised

Some debates around DNA profiling

DNA profiling is generally accepted as being extremely reliable. However, DNA testing is sometimes controversial because of the following reasons:

- Since only a small piece of DNA is analysed, a DNA profile may not be unique to an individual.
- DNA profiling performed in private laboratories may not follow uniform testing standards and quality controls.
- Since human beings must interpret the test, human error could lead to false results.
- DNA profiling is expensive
- DNA analysis might reveal personal information such as the presence of HIV/AIDS and this could be used against the person because of prejudice against persons with the disease.

PROTEIN SYNTHESIS

Protein synthesis takes place in three stages as follows:

- **Transcription - formation of messenger RNA (mRNA)**
 - DNA double helix unwinds
 - Weak hydrogen bonds of DNA break
 - forming two single strands of DNA
 - One strand acts as a template
 - to form a complementary strand which is mRNA
 - using free RNA nucleotides from the nucleoplasm
 - This process is called transcription
 - Three adjacent bases on mRNA make up a codon
 - which codes for an amino acid
- **Movement of mRNA out of the nucleus**
 - mRNA moves out of the nucleus
 - through the nuclear pore
 - into the cytoplasm
 - where it attaches to the ribosome
- **Translation – using information from mRNA to form a protein**
 - According to the codons of mRNA
 - tRNA molecules with matching/complementary anticodons
 - bring the required amino acids to the ribosome
 - The amino acids link together by peptide bonds
 - to form the required protein
 - The process is called translation

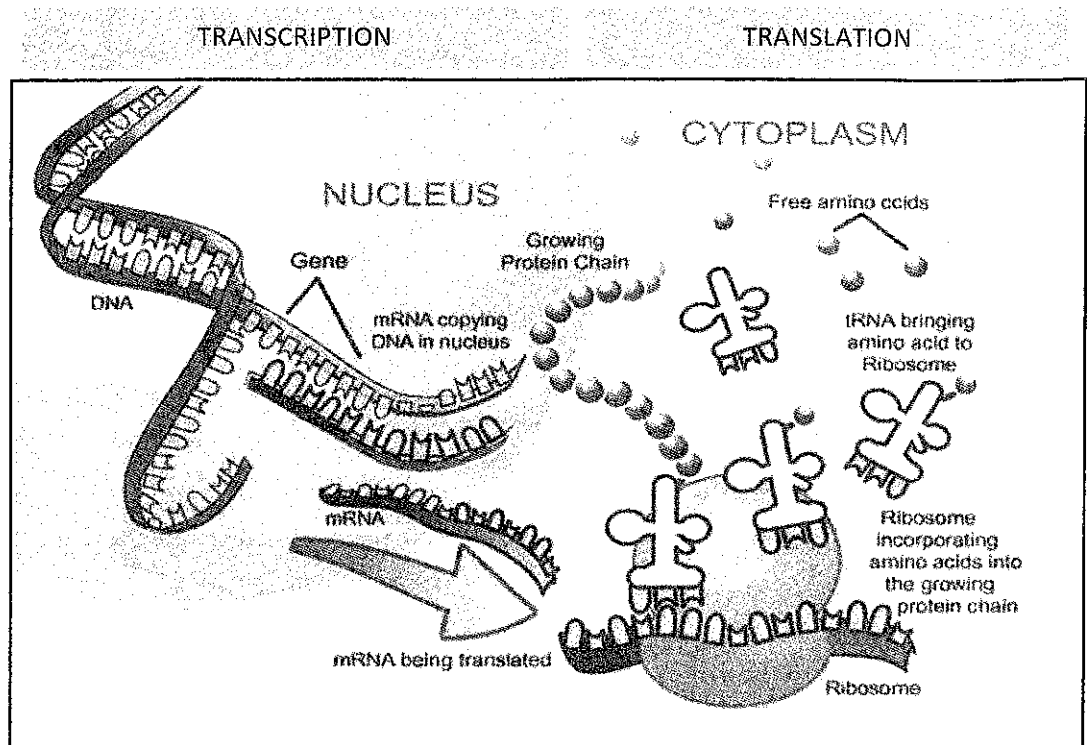


Fig. 1.6 Events in Protein synthesis

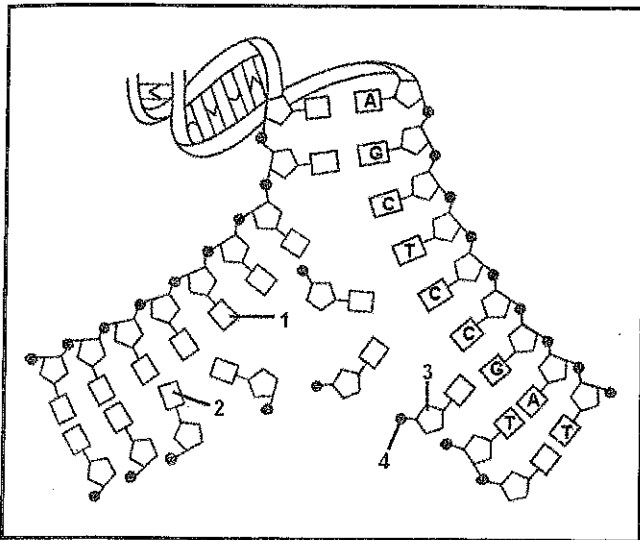
TERMINOLOGY REVIEW

TERM	DESCRIPTION
Anticodon	The triplet of bases on tRNA
Chromatin network	Tangled network of chromosomes located within the nucleus
Codon	The triplet of three consecutive bases on mRNA
Cytosine	The base that pairs off with guanine
DNA	Nucleic acid that is a constituent of chromosomes
DNA Replication	Production of identical copies of DNA
Double helix	Natural shape of a DNA molecule
Extra-nuclear DNA	DNA that only occurs outside the nucleus such as in mitochondria and chloroplasts
Gene	Segment of a chromosome that codes for a particular protein
Hydrogen bonds	Bonds by which base pairs are linked in DNA
Interphase	Phase of the cell cycle during which DNA replication occurs
Messenger RNA	Molecule containing information for protein synthesis in its codons

Non-coding DNA	Sections of DNA that do not carry a code for proteins
Nucleotide	Building blocks consisting of sugar, phosphate and nitrogen base
Nucleus	Site of DNA replication & transcription
Peptide Bond	Bond formed between two amino acids
Ribosome	Site of synthesis of proteins by the combination of amino acids
RNA	Single stranded nucleic acid
Template	Strand of DNA used to form either another strand of DNA or mRNA
Thymine	The base that pairs off with adenine in DNA
Transcription	Transfer of the coded message for protein synthesis from DNA onto mRNA
Transfer RNA	Molecule containing information for protein synthesis in its anti-codons
Translation	Part of protein synthesis from the time amino acids are assembled in a particular sequence

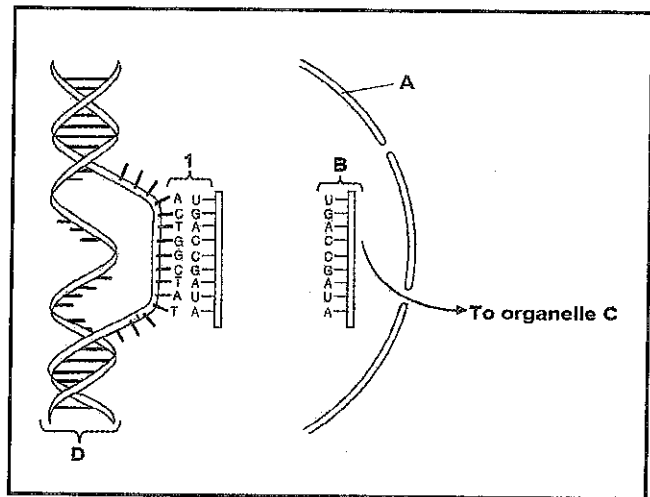
QUESTIONS

1. The diagram below shows part of a DNA molecule in a nucleus just before cell division.



- 2.4 Give TWO reasons why this evidence may not be considered reliable. (2)
- 2.5 Name TWO benefits of DNA profiling other than for solving crimes. (2)

3. Study the diagram below showing a part of the process of protein synthesis.

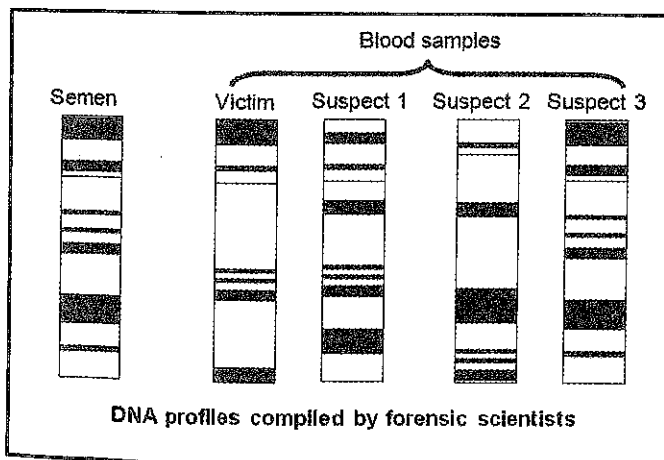


- 1.1 Identify the parts labelled: (1)
- 1.1.1 3 (1)
- 1.1.2 4 (1)
- 1.2 Identify the nitrogenous bases labelled: (1)
- 1.2.1 1 (1)
- 1.2.2 2 (1)
- 1.3 Explain why the diagram above represents replication and not transcription. (2)

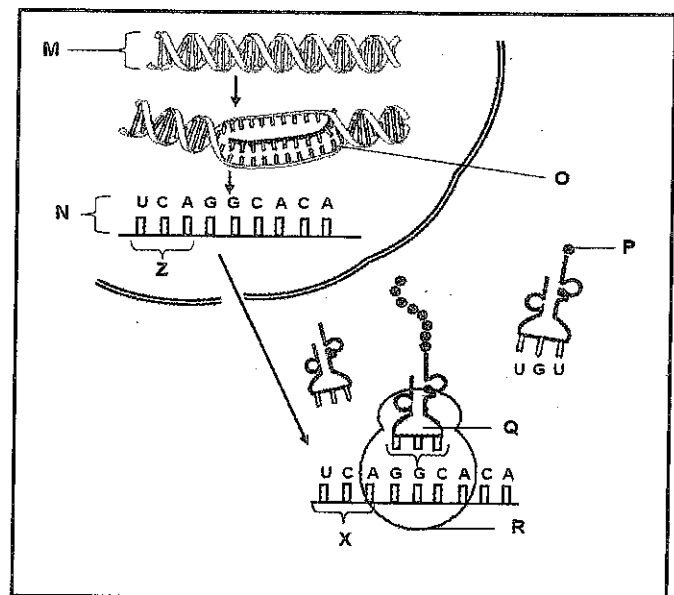
- 3.1 Provide labels for structures A, B and D respectively. (3)
- 3.2 State ONE function of molecule D. (1)
- 3.3 Which part of protein synthesis takes place at 1? (1)
- 3.4 Name the type of proteins that control the process named in QUESTION 3.3. (1)
- 3.5 Identify organelle C. (1)
- 3.6 Name and describe the part of protein synthesis that takes place at organelle C. (6)

2. Study the diagram below which shows the following DNA profiles/genetic fingerprints:

- Blood of a raped female victim
- Blood of three suspects
- Semen found on the female victim



4. The following diagrams represent the process of protein synthesis.



- 2.1 Which suspect was most likely the rapist? (1)
- 2.2 Explain your answer to QUESTION 2.1. (2)
- 2.3 Give ONE reason why this evidence may be considered reliable. (1)

DNA – The Code of Life

- 4.1 Identify compound M and organelle R. (2)
- 4.2 Write down the sequence of the first three nitrogenous bases on the DNA strand that led to the formation of Z. (2)
- 4.3 Name the part/stage of protein synthesis that is illustrated in O. (1)
- 4.4 The table below shows the base triplets of DNA and the amino acid it codes for.

Base triplet of DNA	Amino acid coded for
AGT	Serine
CCG	Glycine
TGT	Threonine
GTA	Histidine
CAA	Valine
TCC	Arginine
ACA	Cysteine

With reference to the diagram in QUESTION 4 and the table above:

- 4.4.1 Name the amino acid labelled P. (2)
- 4.4.2 State the base sequence of the molecule labelled Q. (2)
- 4.4.3 What name is given to the triplet of tRNA bases that code for each amino acid? (1)
- 4.4.4 Describe how the composition of the protein molecule changes if the base sequence at X was UGU instead of UCA. (2)

ANSWERS

- 1.
- 1.1 1.1.1 deoxyribose✓ sugar (1)
1.1.2 phosphate✓ group (1)
- 1.2 1.2.1 Guanine✓ (1)
1.2.2 Guanine✓ (1)
- 1.3 - The formed complementary strand✓ contains thymine✓/ not uracil **OR**
- Both strands of DNA molecule✓ are being used as a template✓ (2)
- 2.
- 2.1 3✓ (1)
- 2.2 The DNA profile of the semen✓ found on the female victim matches the DNA profile of the blood of suspect 3✓ (2)
- 2.3 Everybody, except for identical siblings, has a unique DNA profile✓ (1)
- 2.4 - Require a large length of DNA to get accurate profile✓
- Deliberate swapping of specimens in the laboratory✓ any (2)

- 2.5 - Determine genetic disorders✓
- Paternity tests✓
- Determine identity of dead persons✓
- Research into variation in populations✓
- Tracking individuals in population e.g. cycads in South Africa✓ any (2)

- 3.
- 3.1 A – Nuclear membrane✓
B – mRNA/RNA✓
D – DNA✓ (3)
- 3.2 - Carrying hereditary characteristics from parents to their offspring✓
- Controls the synthesis of proteins✓ any (1)

3.3 Transcription✓ (1)

3.4 Enzymes✓ (1)

3.5 Ribosome✓ (1)

- 3.6 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 the codon of the mRNA✓
- so that the amino acids are placed in the correct sequence✓
- adjacent amino acids are linked ✓
- by a peptide bond
- to form a protein ✓ any (6)

- 4.
- 4.1 M - DNA✓
R - Ribosome✓ (2)
- 4.2 AGT✓✓ (2)
- 4.3 Transcription✓ (1)
- 4.4 4.4.1 Threonine✓✓ (2)
4.4.2 CCG✓✓ (2)
4.4.3 Anticodon✓ (1)
4.4.4 The amino acid attached to it would be cysteine✓
instead of serine✓ leading to the formation of a different protein (2)

2

Meiosis

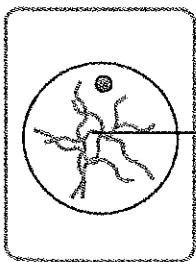
INTRODUCTION

- Meiosis is the division of one cell into four cells each of which has half the chromosome number as the parent cell. Furthermore, each of the four cells is genetically different from each other.
- Meiosis usually occurs during gametogenesis, a process during which gametes are formed.
- In plants, meiosis occurs in the anther to produce pollen grains and in the ovary to produce the ovule.
- In humans, meiosis occurs in the testes to produce sperms and in the ovary to produce an ovum.
- In some lower organisms e.g. bread mould, meiosis occurs after fertilisation.

PROCESS OF MEIOSIS

- According to the cell cycle, meiosis follows Interphase.
- Meiosis can be divided into two parts, Meiosis I and Meiosis II.
- In Meiosis I, a single diploid cell forms two haploid cells i.e. the chromosome number is halved.
- In Meiosis II, each of the haploid cells from Meiosis I forms 2 haploid cells, similar in many respects to mitosis.

Interphase

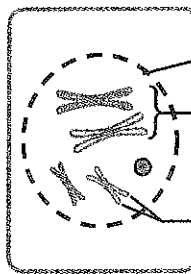


chromatin network (DNA replicates and doubles itself)

- DNA replication takes place to double the amount of genetic material.
- As a result of DNA replication, the single stranded chromosomes become double stranded i.e. made up of two chromatids joined by a centromere.

Meiosis I

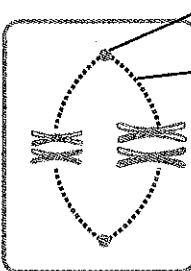
Prophase I



- nuclear membrane starts to disappear
- a pair of homologous chromosomes each with two chromatids (bivalent)
- a chromosome with two chromatids

- The chromatin network unwinds to form distinct chromosomes.
- Each chromosome is made up of two identical chromatids (due to DNA replication in Interphase I) joined by a centromere.
- Crossing-over takes place between chromatids of homologous chromosomes leading to the exchange of genetic material.

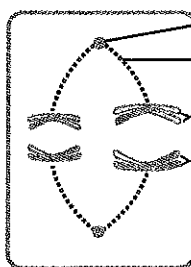
Metaphase I



- centriole (formed by splitting of the centrosome)
- spindle thread forms between centrioles
- chromosomes arranged randomly at the equator in homologous pairs

- The chromosomes become arranged randomly along the equator in homologous pairs
- attached to the spindle threads formed by the centrioles.

Anaphase I

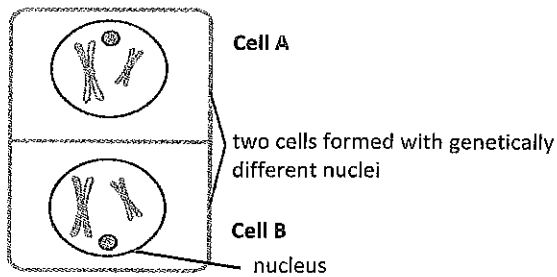


- centriole
- spindle thread
- whole chromosome pulled to one pole
- the other whole chromosome goes to the other pole

- Spindle threads contract.
- The two chromosomes of each homologous pair (each with two chromatids) are pulled to the opposite poles.

Meiosis

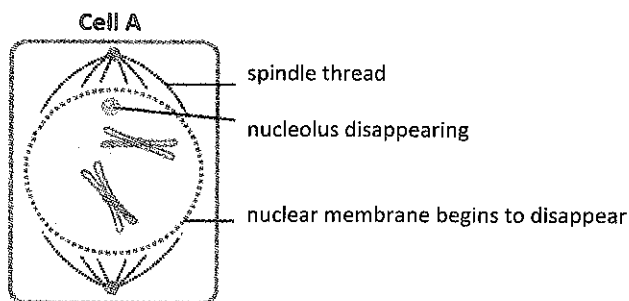
Telophase I



- Two groups of chromosomes appear forming a nucleus at each pole with half the number of chromosomes as the original cell
- The cytoplasm divides to form two new cells.
- The two new cells (A and B) are also genetically different because of crossing-over.

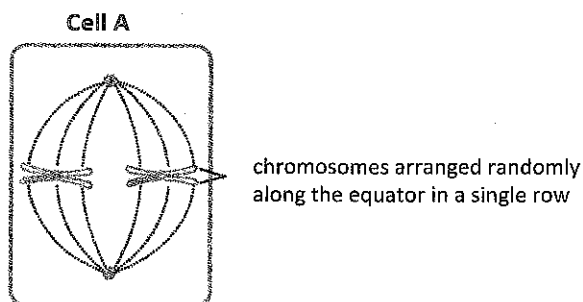
Meiosis II

Prophase II



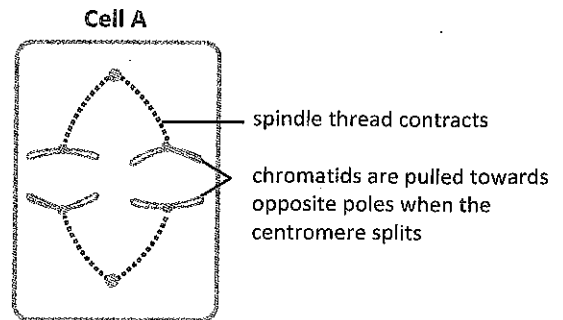
- In cell A (and the same applies to cell B) each chromosome is visible as two chromatids.
- Centrosome splits into centrioles which move to opposite poles.

Metaphase II



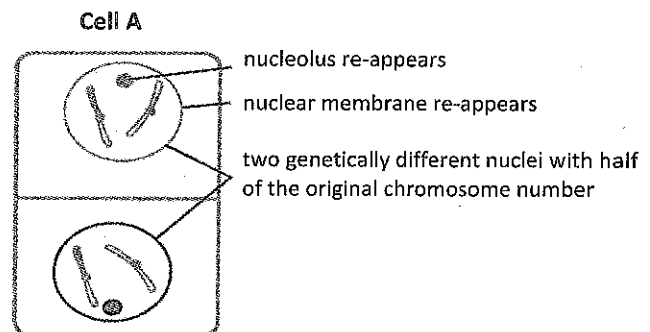
- The chromosomes become arranged singly and randomly along the equator attached to the spindle threads.

Anaphase II



- Spindle threads contract
- The chromosomes split into two single chromatids
- The chromatids are pulled towards opposite poles

Telophase II



- Two groups of chromosomes occur - one at each end of the cell forming two new nuclei.
- The cytoplasm of cell A divides to form two new cells.
- In the same way cell B also divides to form two new cells.
- In total there are now four new cells, each with half the number of chromosomes we originally started with in the first division.
- The four cells are genetically different.

SIGNIFICANCE OF MEIOSIS

- Leads to the formation of haploid gametes in some organisms and haploid spores in some other organisms
- The halving effect of meiosis overcomes the doubling effect of fertilisation, thus maintaining a constant chromosome number from one generation to the next.
- Crossing over during prophase I and random arrangement of chromosomes during metaphase I and II introduces genetic variation.

MITOSIS AND MEIOSIS

Similarities

In both mitosis and meiosis:

- DNA replication takes place
- The nucleus divides
- The cytoplasm divides
- New cells are formed

Differences

Mitosis	Meiosis
Usually occurs to form more somatic cells	Usually occurs to form sex cells/gametes
One nuclear division	Two nuclear divisions
Two cells formed have the same number of chromosomes as the parent cell	Four cells formed have half the number of chromosomes as the parent cell
Two cells formed are genetically identical to each other and to the parent	Four cells formed are genetically different from each other and from the parent
During prophase the chromosomes are not in pairs	During prophase I the chromosomes come together in homologous pairs
No crossing-over	Crossing-over takes place during first prophase I
During metaphase the chromosome splits and chromatids are pulled towards opposite poles	During metaphase I, whole chromosomes are pulled towards opposite poles. The chromosome does not split

MEIOSIS I AND MEIOSIS II

Differences

Meiosis I	Meiosis II
Chromosomes double stranded in all phases	Chromosomes single stranded in all phases
Crossing-over takes place in Prophase 1	No crossing-over
Chromosomes arranged along the equator in homologous pairs in Metaphase 1	Chromosomes arranged along the equator singly in Metaphase 2
Whole chromosomes are pulled to opposite poles in Anaphase 1	Chromatids are pulled to opposite poles in Anaphase 2
Chromosome number is halved during meiosis I	Chromosome number does not change during meiosis II
Results in two cells	Results in four cells

ABNORMAL MEIOSIS

Introduction

- Sometimes, the following mistakes may occur during the process of meiosis:
 - During Anaphase 1, one or more homologous pairs of chromosomes may not separate.
 - During Anaphase 2, the sister chromatids of one or more chromosomes may not separate.
- This is referred to as non-disjunction and may lead to aneuploidy or polyploidy.
 - In aneuploidy gametes forming from meiosis may have one extra chromosome or one less chromosome
 - In polyploidy gametes resulting from meiosis may have no chromosomes or an extra set of chromosomes.
- Such an abnormal gamete in each case may fuse with a normal gamete or another abnormal gamete, leading to different genetic disorders.

Down syndrome

- Down syndrome is the result of an extra chromosome number 21. Down syndrome is also called trisomy 21.
- In meiosis 1, the chromosome pair 21 may not separate or,
- in meiosis II, the chromatids of chromosome 21 may not separate.
- Some gametes will therefore have an extra copy (2 copies) of chromosome number 21
- If a gamete with 2 copies of chromosome 21 fuses with a normal gamete with 1 copy of chromosome 21,
- the resulting zygote will have 3 copies of chromosome number 21 (47 chromosomes instead of 46) resulting in Down syndrome.
- Individuals with Down syndrome are characterised by mental retardation, hearing loss, heart defects, decreased muscle tone, upwardly slanting eyes, a small mouth and nose, abnormal ear shape and a depressed nasal bridge.
- There is no cure for Down syndrome. Only the symptoms are treated.
- To detect the occurrence of Down syndrome in unborn babies, foetal cells are removed from the uterus of the pregnant mother by amniocentesis and analysed.

- The karyotype resulting from such an analysis is then examined to determine if there is an abnormal number of chromosomes

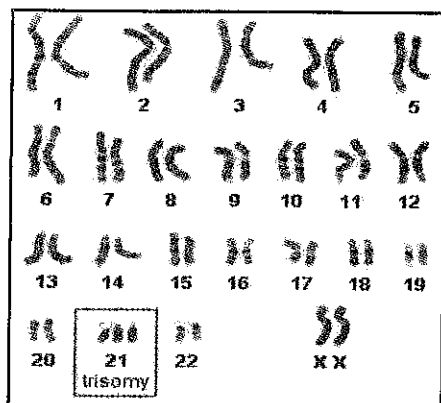


Fig. 2.1 Karyotype of a person with Down syndrome

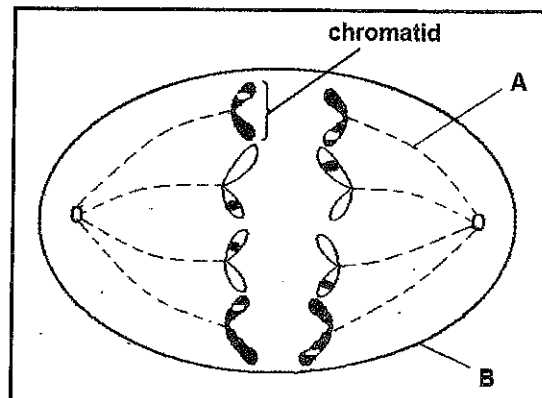
TERMINOLOGY REVIEW

TERM	DESCRIPTION
Anaphase I	Phase in meiosis in which chromosomes are pulled apart
Anaphase II	Phase in meiosis in which chromatids are pulled apart
Aneuploidy	The presence of an extra chromosome or absence of one chromosome in gametes due to non-disjunction
Bivalent	A pair of homologous chromosomes involved in crossing over
Centrioles	Structures that form spindle threads during meiosis
Centrosome	Structure that splits to form two centrioles in animal cells during meiosis
Chiasma	Point of overlap of chromatids during crossing over
Chromatids	The two strands that make up a chromosome
Crossing over	The exchange of genetic materials between chromatids of homologous chromosomes
Diploid	Chromosome condition describing the presence of two sets of chromosomes in each cell
DNA replication	Process by which a single stranded chromosome becomes double stranded
Down syndrome	Genetic disorder caused by the presence of an extra copy of chromosome 21
Haploid	Chromosome condition describing the presence of a single set of chromosomes in each cell

Homologous	Chromosomes that are identical in shape and appearance that code for the same set of characteristics
Interphase	Phase during which DNA replication takes place
Karyotype	The number and type of chromosomes possessed by an individual
Meiosis	The type of cell division that results in halving of the chromosome number.
Meiosis	Cell division producing daughter cells that are dissimilar
Metaphase I	Phase in meiosis in which chromosomes line up at the equator in pairs
Metaphase II	Phase in meiosis in which chromosomes are arranged singly at the equator
Mitosis	Cell division producing identical cells
Non-disjunction	Non separation of chromosomes or chromatids during meiosis
Polyploidy	The presence of an extra set of chromosomes or the absence of chromosomes in gametes due to non-disjunction
Prophase I	Phase in meiosis in which crossing-over occurs
Spindle threads	Structures to which chromosomes are attached during Metaphase I and Metaphase II
Telophase I	Phase in meiosis in which two cells are formed having half the chromosome complement as the original
Telophase II	Phase in meiosis in which four cells are formed having half the chromosome complement as the original cell

QUESTIONS

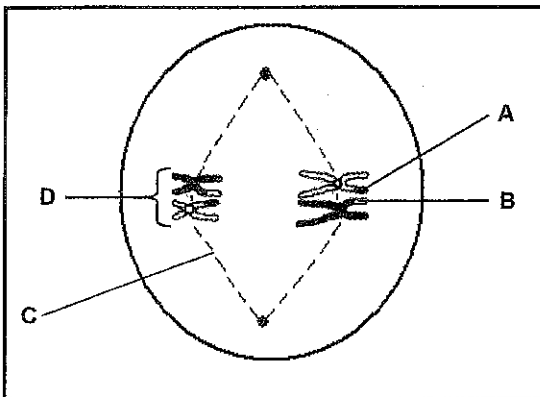
- The diagram below represents an animal cell in a phase of meiosis.



Meiosis

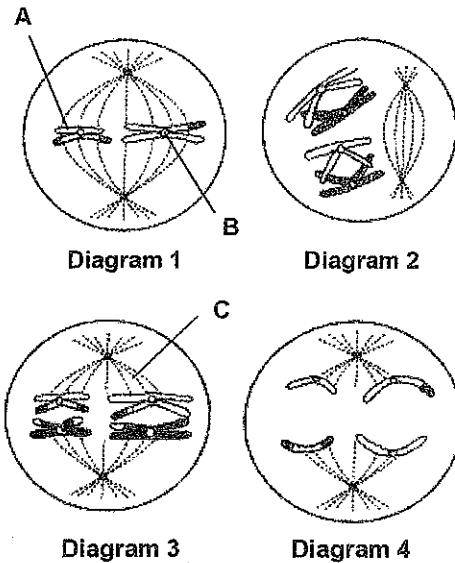
- 1.1 State which phase of meiosis is represented in the diagram above. (1)
- 1.2 Give a reason for your answer to QUESTION 1.1. (2)
- 1.3 Identify parts A and B. (2)
- 1.4 How many chromosomes: (2)
 - 1.4.1 Were present in the parent cell before it underwent meiosis (1)
 - 1.4.2 Will be present in each cell at the end of the meiotic division (1)
- 1.5 State ONE place in the body of a human female where meiosis would take place. (1)
- 1.6 Could the cell represented in the diagram be that of a human? (1)
- 1.7 Explain your answer to QUESTION 1.6. (2)
- 1.8 Give TWO reasons why meiosis is biologically important. (2)

2. The diagram below represents an animal cell in a phase of meiosis.



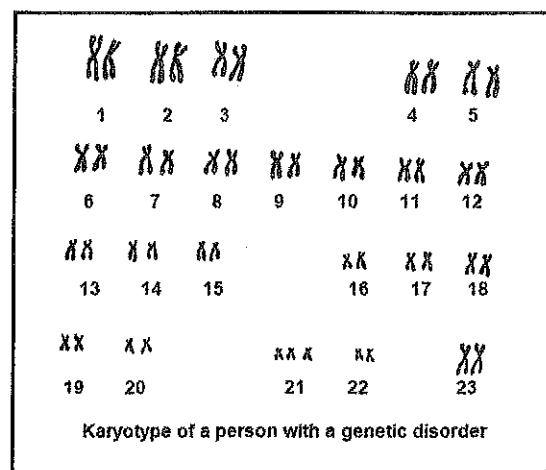
- 2.1 Label C and D. (2)
- 2.2 2.2.1 Identify the phase represented in the diagram above. (1)
- 2.2.2 Give a reason for your answer to QUESTION 2.2.1. (2)
- 2.3 Name the process which resulted in parts A and B being different from each other. (1)
- 2.4 Describe how the process referred to in QUESTION 2.3 occurs. (3)
- 2.5 State the importance of the process named in QUESTION 2.3. (1)
- 2.6 2.6.1 How many cells will be formed at the end of the first division of the cell drawn in the diagram above? (1)
- 2.6.2 How many chromosomes will each daughter cell have when the cell, drawn in the diagram above, has completed meiosis? (1)

3. Study the following diagrams representing different phases of meiosis.



- 3.1 Provide labels for structures A, B and C. (3)
- 3.2 Which phase is represented by: (1)
 - 3.2.1 Diagram 1? (1)
 - 3.2.2 Diagram 2? (1)
- 3.3 Write down the numbers of the diagrams to show the correct sequence in which the phases occur. (2)
- 3.4 Tabulate THREE differences between the first and second stages of meiosis. (7)
- 3.5 Name and explain TWO processes/mechanisms that ensure that the gametes produced at the end of meiosis are genetically different from each other. (4)

4. Study the karyotype of a human below and answer the questions based on it.



- 4.1 Is this karyotype that of a male or a female? (1)
 4.2 Give a reason for your answer to QUESTION 4.1. (1)
 4.3 Name the genetic disorder that the individual with this karyotype has. (1)
 4.4 Give a reason for your answer to QUESTION 4.3. (2)
 4.5 Explain how abnormal meiosis may lead to the genetic disorder named in QUESTION 4.3 (6)

ANSWERS

1.
 1.1 Anaphase II✓ (1)
 1.2 Chromatids✓ are pulled towards the poles✓ (2)
 1.3 A Spindle fibre✓ (2)
 B Cell membrane✓ (2)
 1.4 1.4.1 8✓ (1)
 1.4.2 4✓ (1)
 1.5 Ovary✓ (1)
 1.6 No✓ (1)
 1.7 Humans would have 23✓ chromosomes/46 chromatids in this phase. In this diagram only 4 chromosomes✓/8 chromatids are shown (2)
 1.8 - Halving of chromosome number which overcomes the doubling effect of fertilisation✓
 - Promotes/contributes to genetic variation✓
 - Formation of gametes/cells containing one allele of a gene pair✓ any (2)
 2.
 2.1 C – spindle threads✓/spindle fibres
 D – homologous chromosomes✓ (2)
 2.2 2.2.1 Metaphase 1✓ (1)
 2.2.2 Chromosomes are aligned at the equator✓ in homologous pairs✓ (2)
 2.3 Crossing over✓ (1)
 2.4 - Homologous chromosomes line up ✓ at the equator
 - Chromatids from homologous chromosomes overlap✓
 - Chromatid segments are exchanged at the chiasmata✓ (3)
 2.5 Promotes genetic variation✓ in the gametes/offspring will be different from the parents (1)
 2.6 2.6.1 2✓ (1)
 2.6.2 2✓ (1)

3.
 3.1 A - Chromatid✓
 B - Centromere✓
 C - Spindle fibre✓ (3)
 3.2 (a) Metaphase 2✓ (1)
 (b) Prophase I✓ (1)
 3.3 Diagram 2, Diagram 3, Diagram 1, Diagram 4✓✓ (2)
 3.4
- | Meiosis I | Meiosis II |
|--|---|
| Crossing over takes place✓ | No crossing over takes place✓ |
| In metaphase the chromosomes align at the equator in homologous pairs✓ | In metaphase chromosomes align singly✓ at the equator |
| Reduction division✓ | No reduction division✓ |
| During anaphase whole chromosomes✓ move towards the poles | During anaphase chromatids✓ move towards the pole |
- any 3 x 2 + 1 table (7)
 3.5 Crossing over✓
 Pieces of chromatids/groups of genes are exchanged✓ between homologous chromosomes (2)
 Random✓/independent assortment of chromosomes
 Maternal and paternal chromosomes assort themselves randomly/independently on either side of the equator✓ during metaphase (2)
 4.
 4.1 Female✓ (1)
 4.2 Has two X chromosomes✓ (1)
 4.3 Down Syndrome✓ (1)
 4.4 Carries 3✓ copies of chromosome number 21✓ (2)
 4.5 - Due to non-disjunction✓
 - in meiosis 1, the chromosome pair 21 may not separate✓ or,
 - in meiosis II, the chromatids of chromosome 21 may not separate✓.
 - Some gametes will therefore have an extra copy✓ (2 copies) of chromosome number 21
 - If a gamete with 2 copies of chromosome 21 fuses with a normal gamete with 1 copy of chromosome 21✓,
 - the resulting zygote will have 3 copies of chromosome number 21✓ (47 chromosomes instead of 46) resulting in Down syndrome. any (6)

3

Reproduction in Vertebrates

INTRODUCTION

Different groups in the animal kingdom have different strategies to maximize reproductive success in different environments.

EXTERNAL AND INTERNAL FERTILISATION

External Fertilisation

- During external fertilisation, the sperm cell fertilises the egg cell outside the body of the female.
- Water is always required for external fertilisation for two reasons:
 - It prevents the eggs from drying out
 - It must be present to allow the sperms to swim towards the eggs
- Frogs, starfish and trout are examples of animals that undergo external fertilisation.
- The disadvantage of external fertilisation is that a large number of sperm may not reach the egg cells. To compensate for this, organisms with external fertilisation produce a large number of sperm to ensure that at least some do reach the egg cells.

Internal Fertilisation

- During internal fertilisation, the male deposits its sperm cells inside the reproductive organs of the female and fertilisation occurs inside the female's reproductive organs.
- Internal fertilisation is an adaptation that allows terrestrial animals to reproduce in a dry environment.
- Birds and mammals are examples of animals that undergo internal fertilisation.
- Because internal fertilisation is more certain than external fertilisation, organisms with internal fertilisation produce a smaller quantity of sperm.

OVIPARY, OVOVIVIPARY AND VIVIPARY

Ovipary

- This refers to a method of reproduction in which eggs are laid and development of these eggs takes place outside the mother's body.

These eggs may have been fertilised internally before being laid or they may be fertilised after they are laid. Each egg eventually hatches into a young animal.

- Many vertebrates (e.g. frogs) reproduce in this way.
- The disadvantage of ovipary is that the eggs may be preyed upon by predators. The chances of this happening are reduced if the eggs are protected by the parents.

Vivipary

- This refers to a method of reproduction in which the young develop inside the uterus of the mother after the eggs are fertilised internally, receiving nutrients from the mother's blood through a placenta. When they are released outside the body (born), the young are active.
- Mammals are viviparous.
- The advantages of vivipary are as follows:
 - Since fertilisation is internal there are greater chances of offspring being produced
 - The young are already well developed when born. Unlike eggs which are laid in ovipary and which can be eaten more easily by predators, offspring from vivipary are less prone to this, and especially so if parental care is also provided.

Ovovivipary

- This refers to a method of reproduction in which young develop from eggs that are fertilised internally and retained within the mother's body after fertilisation but obtain their nutrients from the egg yolk and not from the mother. The young hatch inside the mother's reproductive system and are born soon afterwards.
- Many fish and reptiles reproduce in this way.
- Because of internal fertilisation there is a greater chance of offspring being produced. As in vivipary, the young are already well developed when born. They are less prone to being eaten by predators compared to the eggs in ovipary.

AMNIOTIC EGG

- The amniotic egg is characteristic of reptiles and birds.
- The amniotic egg of birds, most reptiles and some mammals is covered by a shell.

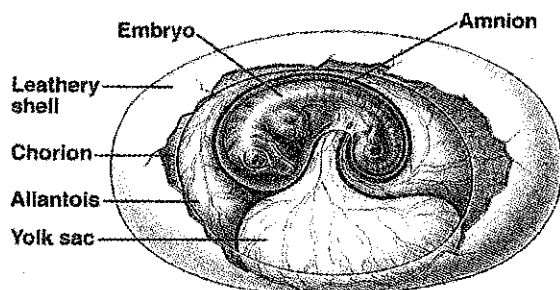


Fig. 3.1 An Amniotic Egg

- The amniotic egg contains four membranes, called extra-embryonic membranes ('extra' means outside), because they are not part of the embryo itself. These four membranes are:
 - The Amnion: It encloses an amniotic cavity containing amniotic fluid which cushions the embryo against mechanical shock.
 - The Chorion: It allows oxygen which enters through the shell to pass through to the embryo, and carbon dioxide to pass from the embryo through the shell to the air outside.
 - The Allantois: It stores waste produced by the embryo. It also functions in gaseous exchange, just like the chorion.
 - The Yolk Sac: The yolk sac contains yolk which serves as food for the embryo.
- The shells of the eggs of birds and reptiles reduce dehydration. This allows birds and reptiles to occupy a wider range of terrestrial habitats than amphibians. Most mammals do not have an egg shell. Their embryos are adapted to avoid dehydration by developing within the mother.

PRECOCIAL AND ALTRICIAL DEVELOPMENT

Two different methods of development of their young have evolved among birds. These are precocial development and altricial development. The method of development that evolved in each bird species depended on the availability of food and the presence/absence of predators in the original environment.

Precocial Development

- The original environment of birds capable of precocial development probably had many predators. The environment probably also had lots of food available. The females of precocial development species collected and ate this food to produce eggs with lots of energy. This provided more time and more energy for greater development within the egg.
- As a result, the young of birds (called nestlings or hatchlings) capable of precocial development are quite well-developed when they hatch and show the following characteristics:
 - Eyes are open when they hatch
 - Bodies are covered with soft feathers called downs
 - Able to move about soon after hatching
 - Able to feed themselves
 - Independent of their parents
- From the above, we can see why precocial young are able to leave their nest soon after hatching in search of their own food. They are capable of avoiding predation to a small extent.

Altricial Development

- The original environment of birds capable of altricial development probably did not have many predators. The environment probably also had little food available. Therefore, females of altricial development species produced eggs with not as much energy as those of precocial development species. This meant less energy for development within the egg.
- As a result, the young of birds capable of altricial development are poorly-developed when they hatch and show the following characteristics:
 - Eyes are closed when they hatch
 - Bodies do not have down feathers
 - Unable to move about soon after hatching
 - Unable to feed themselves
 - Dependent on their parents
- From the above we can see why altricial young stay in their nests until they are better developed and able to fly, walk or swim. This puts pressure on the parents to hide and protect the nests. Otherwise, the entire brood of nestlings can be wiped out by predators.
- About 60% of all bird species show altricial development. They include all the perching birds such as finches, canaries, crows, swallows, mockingbirds, warblers and mynahs.

PARENTAL CARE

'Parental care' or 'parental investment' refers to the ways in which parents increase the chances of the offspring surviving. Parental care may take place in the following ways:

- In the building of nests and burrows. Many invertebrates and vertebrates prepare burrows or nests for breeding purposes.
- In some species e.g. most frogs and fishes, the eggs are laid on the substrate with little or no care. A few lizards and snakes guard the eggs after they are laid, and pythons incubate their eggs for a while.
- In some animals e.g. certain species of sharks, the fertilised eggs are retained inside the female's body and are only released when the eggs are about to hatch i.e. they are ovoviviparous.
- All mammals, on the other hand, are viviparous, retaining, providing food and protecting them until they are born.
- In the provision of food for the unborn/unhatched young. For example, in scarab beetles, both parents collect food and make them into small balls which are left in the burrows, before the eggs hatch.
- In providing young with food after hatching/birth. For example, in some crabs and birds, young are fed on food similar to those of adults. Most altricial nestlings are fed on young insects although the adults feed mainly on grains.
- In protecting the young. In some invertebrates, larvae take shelter beneath one parent or cling to some part of the parent's body. In this way, young are protected from predators or parasites.
- In providing social assistance to mature offspring. For example, in hyenas and ground squirrels, young mature females stay close to their mothers. This allows the mothers to teach their young how to interact with others within the group.
- The offering of parental care increases the chances of survival of the offspring.

TERMINOLOGY REVIEW

TERM	DESCRIPTION
Allantois	Structure in a developing embryo used in gas exchange; non functional in humans
Altricial development	Production of offspring that are born helpless, unable to move or feed by themselves
Amnion	Inner membrane of the embryo containing a fluid that acts as a shock absorber
Amniotic egg	An egg containing four extra-embryonic membranes
Chorion	Outer membrane of the embryo that plays a role in gas exchange
External fertilisation	Fertilisation of the egg cell by a sperm cell outside the body of a female
Internal Fertilisation	Fertilisation of the egg cell by a sperm cell inside the female reproductive system
Ovipary	A method of reproduction involving the laying of eggs which then hatch outside the body of the female
Ovovivipary	A method of reproduction involving the hatching of eggs in the female reproductive system
Precocial development	Production of offspring that are independent, can feed and move by themselves
Vivipary	Young are born alive after a period of being protected and nourished by the body of the mother
Yolk sac	Structure in amniotic eggs that provides nutrition to the embryo

QUESTIONS

1. 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. There are four possible answers. Choose only one option to answer by writing **A only**, **B only**, **Both A and B** or **None** next to the question number.

COLUMN I		COLUMN II	
1.1	Eggs incubated in nests	A	Ovipary
		B	Ovovivipary
1.2	Young arise from hatching inside the mothers body	A	Ovipary
		B	Vivipary
1.3	Gestation period required	A	Ovipary
		B	Vivipary
1.4	Eggs incubated in the female body	A	Ovipary
		B	Ovovivipary

Reproduction in Vertebrates

1.5	Offspring are born small and helpless	A	Altricial development
		B	Precocial development
1.6	Offspring can feed by themselves	A	Altricial development
		B	Precocial development
1.7	Functions in gas exchange	A	Chorion
		B	Allantois
1.8	Serves as a source of nutrition	A	Amnion
		B	Yolk sac
1.9	Leads to wastage of a large number of sperm	A	Internal fertilisation
		B	External fertilisation

2. Explain the challenge that external fertilisation poses and how have organisms with external fertilisation overcome this challenge? (4)
3. List TWO advantages of internal fertilisation. (2)
4. Explain the advantage of ovovivipary as opposed to ovipary. (4)
5. Explain the advantage of vivipary as opposed to ovovivipary. (4)
6. Explain why the allantois and yolk sac are non-functional in humans. (2)
7. Explain why precocial development is normally associated with environmental conditions of high food availability and high incidence of predators. (4)
8. Tabulate 3 differences in the characteristics of offspring arising from precocial development as opposed to altricial development. (7)

ANSWERS

1.
 - 1.1 A only✓✓
 - 1.2 None✓✓
 - 1.3 B only✓✓
 - 1.4 B only✓✓
 - 1.5 A only✓✓
 - 1.6 B only✓✓
 - 1.7 Both A and B✓✓
 - 1.8 B only✓✓
 - 1.9 B only✓✓
 (18)
2. A large number of sperm is wasted✓ in external fertilisation since many may not reach the egg or may be destroyed✓. Organisms produce a large number of sperms and eggs✓ to ensure that some get fertilised✓. (4)
3.
 - The chances of fertilisation are greater✓
 - It allows for fertilisation even in dry habitats✓
 (2)

4. The chances of producing offspring are greater✓ in ovovivipary since the eggs are protected✓ within the mother while developing. The young that arise are also better developed to cope in the environment✓.
In ovipary many eggs laid may be eaten by predators✓. The young that arise are not well developed✓ and therefore have smaller chances of surviving✓. any 2x2 (4)
5. The level of development of the young✓ in ovovivipary is dependent on the limited supply of food✓ in the egg.
In vivipary, more food is available✓ to the young through the uterus wall of the mother and therefore the young are more developed before birth✓. (4)
6. In humans, the functions of gas exchange and nutrition✓ are carried out by the placenta✓. (2)
7. The high food availability allows the females to feed well and produce eggs with a large quantity of nutrition✓. This allows for longer development of the young✓ before hatching allowing the young to be more independent✓ and capable of avoiding predators✓. (4)

Precocial development	Altricial development
□ Eyes are open when they hatch✓	□ Eyes are closed when they hatch✓
□ Bodies are covered with soft feathers called downs✓	□ Bodies do not have down feathers✓
□ Able to move about soon after hatching✓	□ Unable to move about soon after hatching✓
□ Able to feed themselves✓	□ Unable to feed themselves✓
□ Independent of their parents✓	□ Dependent on their parents✓

any 3x2 + 1 for table (7)

4

Human
Reproduction

INTRODUCTION

- (4) During sexual reproduction in humans a haploid male gamete with 23 chromosomes fuses with a haploid female gamete also with 23 chromosomes to form a single diploid cell called the zygote with 46 chromosomes/23 pairs of chromosomes.
- This zygote undergoes mitosis several times to produce an embryo.
- (4) The cells of the embryo become differentiated to form our various body parts.

(2) MALE REPRODUCTIVE SYSTEM

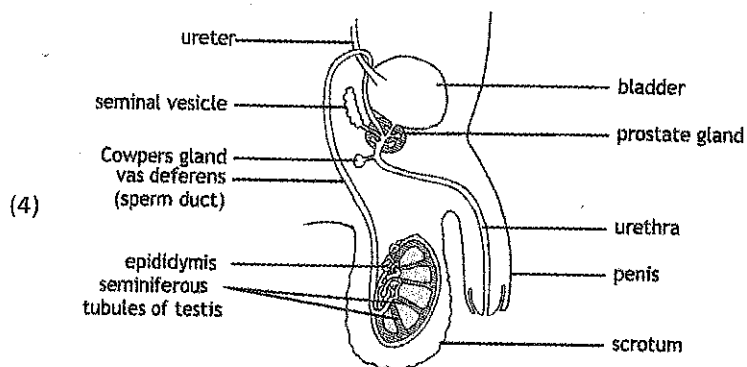


Fig. 4.1 The Male Reproductive System (side view)

- (7) The **testes** are the male sex organs.
 - The **seminiferous tubules** of the testes produce spermatozoa
 - The **Sertoli cells** of the testes serve as nutrients for the developing sperm cells/spermatozoa.
 - The **cells of Leydig** secrete the male sex hormone called testosterone.
 - During puberty, **testosterone** is responsible for the development of male characteristics such as the growth of hair on the face, armpits and pubic areas, lowering of the voice and the development of the muscles which gives males their characteristic shape such as broad shoulders.
- The **epididymis** stores sperms temporarily and later passes these sperms into the vas deferens.
- The **vas deferens** carries the spermatozoa from the epididymis into the ejaculatory duct.
- Contraction of the muscular walls of the

ejaculatory duct forces its contents (called semen) through the urethra.

- The **urethra** is a common tube for the passage of urine and semen.
- The Accessory Glands (**seminal vesicles**, the **prostate gland** and **Cowper's glands**) secrete a fluid which promotes movement of the spermatozoa and which provides nutrition to the spermatozoa
- The **penis** is responsible for transferring spermatozoa from the male to the female.

FEMALE REPRODUCTIVE SYSTEM

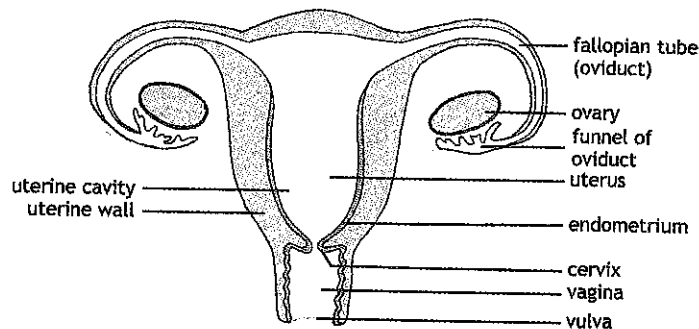


Fig. 4.2 The Female Reproductive System (front view)

- The **ovaries** are the female sex organs.
 - The **ovary** produces ova within follicles.
 - The follicles secrete the female sex hormones **oestrogen** and **progesterone**.
 - During puberty the female sex hormones are responsible for the development of female characteristics such as increase in size of the breasts, the development of pubic hair, hair in the armpits and menstruation.
- The **Fallopian tubes** convey ova from the ovaries to the uterus. It is also the site of fertilisation.
- The **uterus** serves for attachment of the embryo if fertilisation takes place. The lining of the uterus, the **endometrium**, is richly supplied with blood vessels.
- The **vagina** leads from the uterus to the outside by means of the external opening, the vulva. During copulation the penis is placed into the vagina where it releases its spermatozoa.

GAMETOGENESIS

Gametogenesis refers to the process by which gametes are produced from the germinal epithelium of the sex organs (testes and ovaries) through meiosis.

Spermatogenesis

Spermatogenesis refers to the process by which spermatozoa are produced from the germinal epithelium of the testis. It happens as follows:

- Cells of the germinal epithelium lining the seminiferous tubules undergo meiosis
- Each cell that undergoes meiosis produces four haploid spermatids
- Each spermatid matures to form a spermatozoan



Fig. 4.3 A spermatozoan

Each spermatozoan is made up of a head, a middle-piece and a long tail.

- The **head** is made up of mainly the nucleus which contains the 22 autosomes and either the X or Y chromosome. In the front of the head is the **acrosome** which contains enzymes that help in penetrating the ovum.
- The **middle piece** contains numerous **mitochondria** to provide energy for locomotion. The mitochondria contain mitochondrial DNA (mtDNA).
- The long **tail** enables the spermatozoan to swim.

Oogenesis

Oogenesis refers to the process by which ova are produced from the germinal epithelium of the ovaries. It happens as follows:

- The germinal epithelium in the ovary undergoes mitosis
- to form numerous follicles.
- One cell inside a follicle enlarges and undergoes meiosis.
- Of the four cells that are formed, only one survives to form a mature ovum.

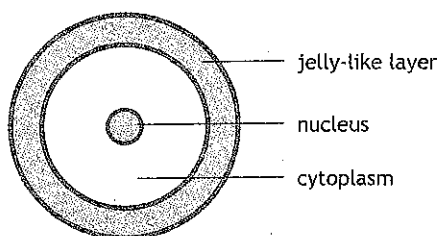


Fig. 4.4 An ovum

MENSTRUAL CYCLE

Introduction

Human females who have reached puberty go through a reproductive cycle called the menstrual cycle. The menstrual cycle refers to the change that occurs in the ovary and uterus of a female over a period of about 28 days, for the purposes of fertilisation. There are two separate cycles that make up the menstrual cycle: the ovarian cycle and the uterine cycle.

The Ovarian Cycle and Ovulation

The ovarian cycle describes what happens inside the ovary as the ovum develops inside the Graafian follicle, which then releases the ovum to become a corpus luteum.

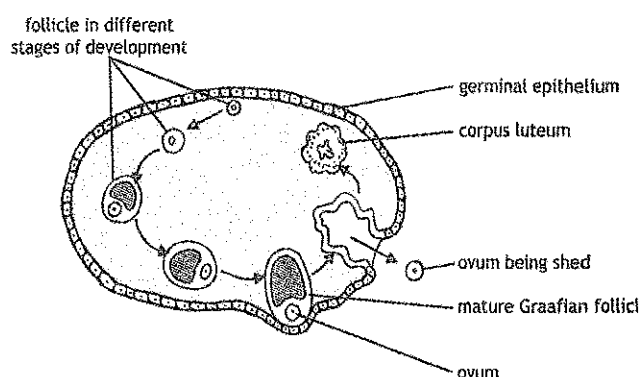


Fig. 4.5 A section through the ovary, showing the ovarian cycle

- The follicle stimulating hormone (FSH) is produced by the hypophysis/pituitary gland.
- FSH stimulates the development of the Graafian follicle containing a mature ovum.
- The Graafian follicle produces a hormone oestrogen which starts the preparation of the uterus for attachment of the fertilised ovum.
- Approximately every 4 weeks (28 days), the Graafian follicle ruptures (breaks open) to release an ovum. This is called ovulation.
- The ovum is collected by the funnels of the Fallopian tube.
- The luteinising hormone (LH), also produced by the pituitary gland/hypophysis, helps convert the ruptured follicle into a structure called a corpus luteum.
- The corpus luteum secretes the hormone progesterone which maintains pregnancy.
- If fertilisation does not take place, the corpus luteum degenerates and progesterone production drops.

- The unfertilized ovum passes down the Fallopian tube, into the uterus and leaves the body through a process known as menstruation.

The Uterine Cycle and Menstruation

The uterine cycle describes the changes that take place in the wall of the uterus as it gradually thickens, becomes enriched with blood vessels up until the endometrium wall tears away; accompanied by the loss of blood.

- The Graafian follicle produces a hormone oestrogen which starts the preparation of the uterus for attachment of the fertilised ovum by making the endometrium:
 - Thicker
 - More vascular (increased blood supply)
 - More glandular
- This helps the uterus to prepare for for attachment of the fertilised ovum in the event of fertilisation.
- After the ovum is released through ovulation, the corpus luteum produces the hormone progesterone which continues the preparation of the uterus, just in case fertilisation takes place.
- If the ovum is fertilised by a sperm cell, the corpus luteum continues secreting progesterone which makes certain that the embryo remains attached to the uterine wall i.e. it ensures that pregnancy is maintained.
- If the ovum is not fertilised, the corpus luteum is destroyed. Progesterone secretion drops and menstruation occurs.
- During menstruation, the endometrium lining of the uterus comes off as the menstrual period. This is accompanied by the loss of blood.
- The menstrual period usually lasts for about 4 to 5 days.
- Menstruation takes place about 14 days after ovulation.
- The next ovum is then released about 14 days after menstruation.

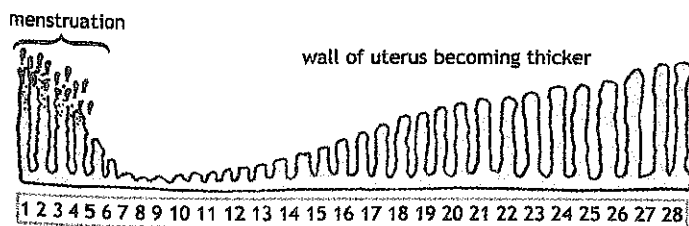


Fig. 4.6 Changes in the wall of the uterus over a 28-day period (uterine cycle)

FERTILISATION AND DEVELOPMENT OF ZYGOTE TO BLASTOCYST

- During sexual intercourse or copulation the penis is placed inside the vagina and the spermatozoa are released.
- The spermatozoa swim up the uterus and into the Fallopian tube.
- If an ovum is present in the Fallopian tube at this time, the nucleus of one spermatozoan may penetrate and fertilise the ovum, resulting in a diploid zygote.
- Since the spermatozoan has 23 single chromosomes and the ovum has 23 single chromosomes, the zygote has 23 pairs of chromosomes (it is diploid i.e. it has 46 chromosomes occurring as 23 pairs).
- Since the sperm cell came from the male parent and the ovum from the female parent, the zygote contains genetic material from both parents.
- As the zygote passes down the Fallopian tube into the uterus it divides by mitosis to form a hollow ball of cells called the blastocyst.

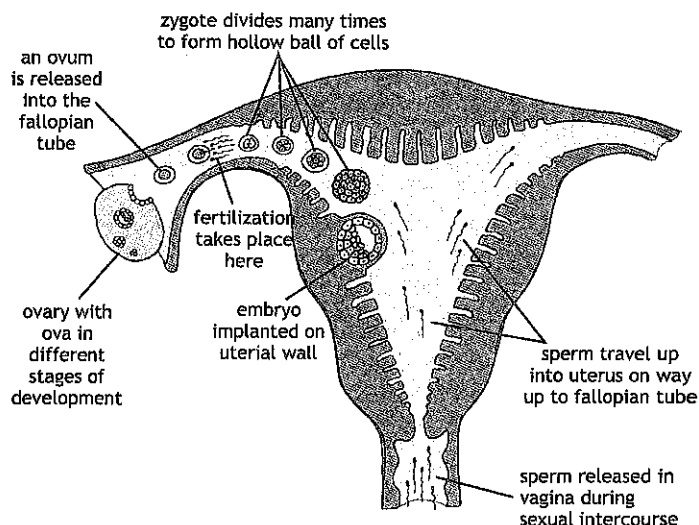


Fig. 4.7 Fertilisation and Implantation

DEVELOPMENT INTO AN EMBRYO

- By the time it reaches the uterus, the blastocyst develops into an embryo.
- The embryo becomes attached to the endometrium wall of the uterus. This is referred to as implantation.
- The endometrium was already thickened with a rich supply of blood vessels by the hormone oestrogen secreted by the Graafian follicle.

- Now that fertilization has taken place, the corpus luteum (which was the Graafian follicle) secretes the hormone progesterone which makes certain that the embryo remains attached to the uterine wall.

IMPLANTATION AND DEVELOPMENT

- Soon after the blastocyst attaches itself to the endometrium wall of the uterus, it develops two extra-embryonic membranes around itself.
- These membranes are:
 - The chorion on the outside, which forms the chorionic villi
 - An amnion, on the inside, with its cavity, the amniotic cavity, filled with amniotic fluid
- The amniotic fluid has the following functions:
 - Acts as shock absorber, protecting the foetus against mechanical injury
 - Prevents dehydration of the embryo
 - Keeps the foetus within a small temperature range
 - Allows relatively free foetal movement for growth and development
- The chorionic villi together with the uterine tissue in which the villi are embedded makes up the placenta.
- The umbilical cord attaches the embryo to the placenta.
- The placenta has the following functions:
 - Serves for attachment of the embryo to the mother.
 - Allows for diffusion of dissolved food from the mother to the foetus.
 - Allows for diffusion of oxygen from the mother to the foetus, and for the diffusion of carbon dioxide from the foetus to the mother.
 - Allows for diffusion of nitrogenous excretory wastes from the foetus to the mother.
 - After about the twelfth week of pregnancy it secretes progesterone which maintains pregnancy.
- The umbilical cord attaches the foetus to the placenta. It contains the umbilical artery and umbilical vein.
 - The umbilical artery carries deoxygenated blood with nitrogenous wastes from the embryo to the placenta.
 - The umbilical vein carries oxygenated blood with dissolved food from the placenta to the foetus.

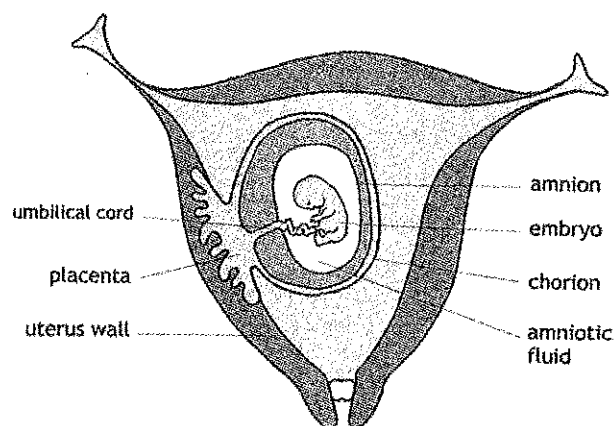


Fig. 4.8 The foetus with its extra-embryonic membranes

GESTATION

- The period during which the embryo develops within the uterus of the mother up to the time the baby is born is referred to as pregnancy. It is also called the gestation period.
- During this period, the embryo increases in shape and size as it grows.
- By 12 weeks it looks clearly like a human baby and is now called a foetus.

CONTRACEPTION

Contraceptives are used by humans to prevent pregnancy. There are different methods that can be used to do this. The table lists some contraceptive methods and how they affect human reproduction.

Method	Effect on Human Reproduction
Condom	Acts as a barrier, stops sperm getting into the vagina.
Loop/IUD	It prevents fertilised ova/embryos from becoming attached to the uterine wall.
Female condom (Femidom)	Acts as a barrier, stops sperm getting into the uterus/Fallopian tubes.
Diaphragm	Acts as a barrier as it covers the cervical opening and prevents sperm from entering the uterus.
Contraceptive pill	Contains artificially produced hormones which prevents the production of ova/ovulation.
Spermicides	Contain a chemical substance that kills sperm and it also acts as a barrier, which prevents sperm from entering through the cervix.
Male sterilisation (vasectomy)	The sperm ducts are cut and tied. Semen without sperm is produced

Method	Effect on Human Reproduction
Contraceptive injections	Contain progesterone/combination of oestrogen and progesterone which stops ovulation. It works for 2 to 3 months.
Female Sterilisation (tubal ligation)	The Fallopian tubes are cut and tied to prevent the fusion of sperm and ovum.
Withdrawal	The penis is taken out of the vagina before ejaculation but is not a safe method because many sperms can be released before ejaculation.
Rhythm	Sexual intercourse is avoided three to four days before and after ovulation. This is between days 10 and 18 of the menstrual cycle.

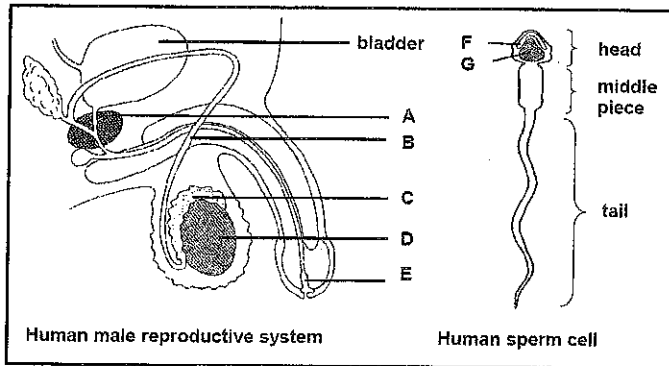
TERMINOLOGY REVIEW

TERM	DESCRIPTION
Acrosome	Structure in the sperm cell that contains enzymes used to penetrate the ovum
Amniotic fluid	The liquid that surrounds the human embryo
Blastocyst	A hollow ball of cells into which the fertilised ovum develops
Cells of Leydig	Specialised cells found between the seminiferous tubules that produce the hormone testosterone
Chorion	The membrane that forms finger-like projections which grow into the uterine wall
Endometrium	The lining of the uterus which is richly supplied with blood vessels
Epididymis	Coiled tubular structure outside the testis that stores sperms.
Fallopian tube	The part of the female reproductive system in which fertilisation takes place
Foetus	The name given to the embryo after it reaches 12 weeks
Follicle stimulating hormone/FSH	The hormone produced by the pituitary gland which controls growth of the Graafian follicle
Gametogenesis	The formation of gametes by meiosis.
Germinal epithelium	Layer within the ovary that is responsible for formation of ova through meiosis
Implantation	The process by which the embryo becomes attached to the uterine wall

Gestation	Another name for the period of pregnancy
LH/Luteinising hormone	The hormone which converts the ruptured follicle into a corpus luteum
Meiosis	Type of cell division by which sperms are produced
Menstrual Cycle	The 28-day reproductive cycle in females involving changes in the ovary and uterus
Menstruation	Tearing away of the endometrium lining of the uterine wall, accompanied by the loss of blood
Mitosis	The cell division by which the zygote becomes multicellular
Oestrogen	The hormone which starts the preparation of the lining of the uterus for attachment of the fertilised ovum
Oogenesis	Production of ova by meiosis
Ovulation	Process by which an ovum is released from the ovary in humans
Pituitary gland/Hypophysis	Gland in the brain that produces FSH and LH
Placenta	Combination of embryonic and maternal tissue responsible for gas exchange, nutrition and excretion
Progesterone	Hormone that maintains pregnancy
Puberty	The stage when sexual maturity is reached in males and females
Sertoli cells	Specialised cells inside the seminiferous tubules which play a role in nutrition
Spermatogenesis	Production of spermatozoa by meiosis
Testosterone	Hormone responsible for secondary sexual characteristics in males
Umbilical Cord	A hollow, rope-like tube which attaches the embryo to the placenta
Umbilical artery	The blood vessel that carries nitrogenous waste from the foetus to the placenta
Umbilical vein	The blood vessel that carries oxygenated blood from the placenta to the foetus

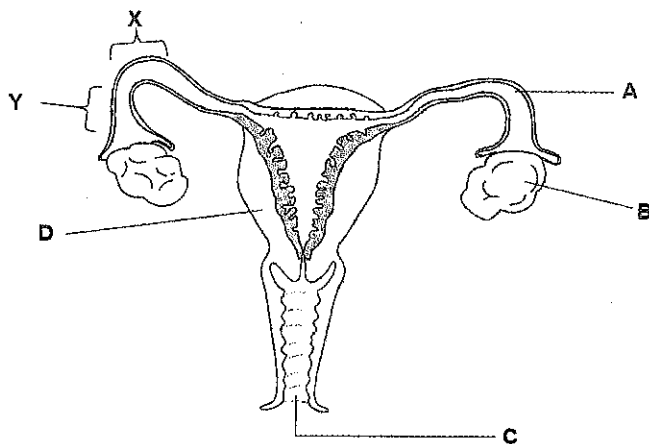
QUESTIONS

1. Study the diagrams below and answer the questions that follow.



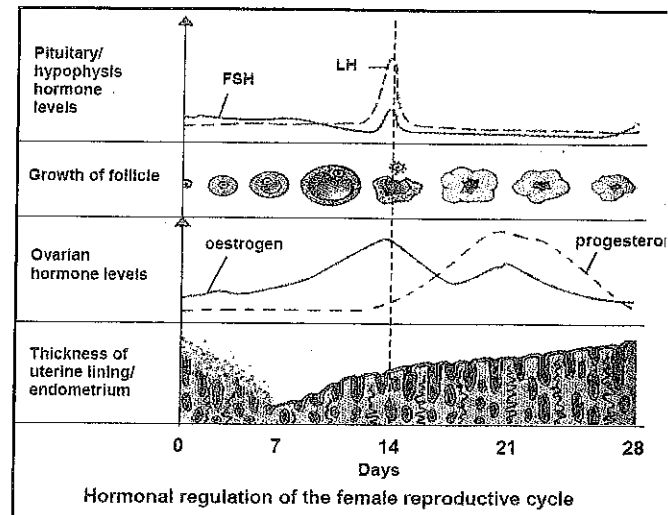
- 1.1 Provide labels for A, B, E and G. (4)
- 1.2 State ONE function each of C and F, respectively. (2)
- 1.3 State the LETTER and NAME of the part where sperm are produced. (2)
- 1.4 Explain why it is necessary for part D to 'hang outside' the body of the male. (2)
- 1.5 Name the following: (2)
 - 1.5.1 The cells that secrete a male sex hormone (1)
 - 1.5.2 The hormone that stimulates the development of secondary sexual characteristics in males (1)
- 1.6 During a vasectomy, part B is surgically cut.
 - 1.6.1 Explain how this procedure will act as a method of contraception. (2)
 - 1.6.2 Will it be possible for a man who is HIV positive to pass the HI virus to another person after he undergoes a vasectomy? (1)
 - 1.6.3 Explain your answer to QUESTION 1.6.2. (2)

2. The diagram below represents the female reproductive system.



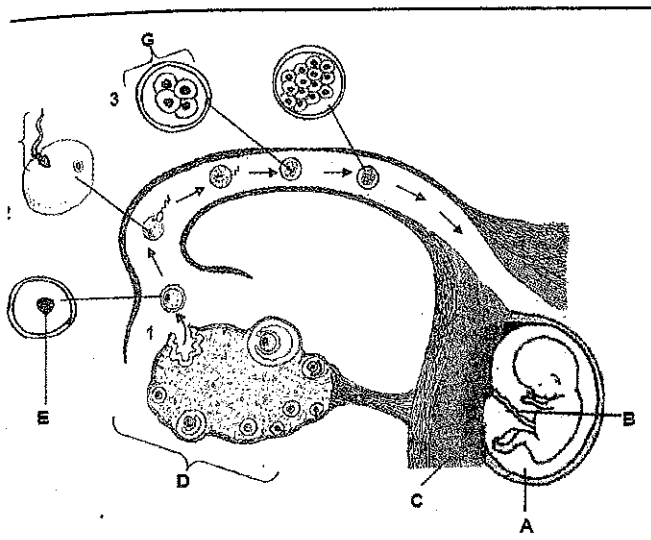
- 2.1 Provide labels for structures A, B and C. (3)
- 2.2 State THREE functions of D. (3)
- 2.3 Fertilisation usually takes place at Y. Why will a blockage at X:
 - 2.3.1 Prevent fertilisation at Y (1)
 - 2.3.2 Not necessarily lead to infertility (2)

3. Study the graph below which shows the menstrual cycle and the influence of the different hormones or it.



- 3.1 On which day does ovulation take place? (1)
- 3.2 Between which days does menstruation take place? (1)
- 3.3 State any ONE function of luteinising hormone (LH). (1)
- 3.4 Describe the changes in the level of LH shown in the graph. (3)
- 3.5 Describe the relationship between the level of oestrogen and the endometrium from day 7 to day 14. (2)
- 3.6 Explain why it is necessary for the level of progesterone in the blood to increase after ovulation. (2)
- 3.7 Did fertilisation take place in the 28-day cycle illustrated in the graph? (1)
- 3.8 Explain your answer to QUESTION 3.7. (2)

4. The diagram below shows part of the female reproductive system. Structures B to G and processes 1, 2 and 3, occurring in the Fallopian tube and uterus, are magnified.



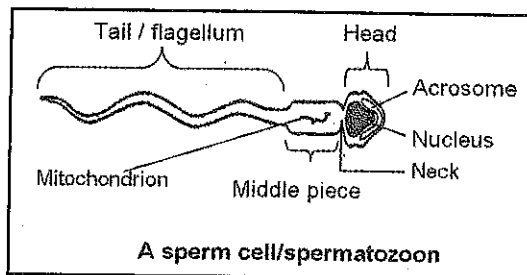
- 4.1 Label C and D. (2)
 4.2 State which processes are taking place at 1, 2 and 3, respectively. (3)
 4.3 State how many chromosomes are present in the following structures: (3)
 4.3.1 E (1)
 4.3.2 Each cell of structure G (1)
 4.4 Draw an enlarged labelled diagram of structure F to show its details. (5)
 4.5 State TWO functions of fluid A. (2)
 4.6 Structure B transports substances to and from the foetus. (1)
 4.6.1 Name ONE useful substance transported to the foetus. (1)
 4.6.2 Name ONE waste product transported from the foetus. (1)

ANSWERS

1.
 1.1 A - prostate gland✓
 B - vas deferens / sperm duct✓
 E - urethra✓
 G - nucleus✓ (4)
 1.2 C Stores sperms temporarily✓/sperms mature here (2)
 F Contain enzymes to break down the cell membrane of the egg cell✓ (2)
 1.3 D✓ testis ✓/seminiferous tubules (2)
 1.4 To keep the testes at a temperature that is (about 3 °C) lower than body temperature✓
 A lower temperature is necessary for the production of healthy sperm✓ (2)
 1.5 1.5.1 Cells of Leydig✓ (1)
 1.5.2 Testosterone✓ (1)

- 1.6 1.6.1 Severing of the vas deferens✓
 Will not allow sperms to pass to urethra and into the female✓ and hence no fertilisation results✓ any (2)
 1.6.2 Yes✓ (1)
 1.6.3 HI virus is carried in body fluids✓
 Can infect a person through open wounds✓/blood transfusion/sexual intercourse
 Therefore vasectomy does not stop the transmission of HIV (2)
 2.
 2.1 A - Fallopian tube✓
 B - Ovary✓
 C - Vagina✓ (3)
 2.2 - Encloses✓ and protects✓ the developing embryo/foetus
 - Forms part of the placenta✓
 - Which provides for the nutrition✓/gaseous exchange/excretion of the embryo
 - Allows for implantation✓/attachment of the embryo
 - Contracts during labour for child birth✓ (3)
 2.3 2.3.1 The sperms will be prevented from reaching the ovum✓ (1)
 2.3.2 The egg produced in the other ovary✓ can still be fertilised✓ in the other Fallopian tube (2)
 3.
 3.1 Accept day 14 or day 15✓ (1)
 3.2 Days 0 - 7✓ (1)
 3.3 - Causes the follicle to burst open✓/stimulates ovulation (1)
 3.4 - Stimulates the formation of the corpus luteum✓
 - LH levels remain low up to day 12/13 ✓
 - Then it increases sharply up to day 14✓
 - After which it decreases and remains low✓ (3)
 3.5 As the oestrogen level increases ✓ the thickness of the endometrium also increases✓ (2)
 3.6 Maintain the increase in the thickness of the endometrium✓ (2)
 for greater chance of implantation✓
 3.7 No✓ (1)
 3.8 The progesterone level✓ has dropped✓/not maintained/corpus luteum has started to degenerate (2)

- 4.
- 4.1 C - Endometrium✓
D - Ovary✓ (2)
- 4.2 1 - Ovulation✓
2 - Fertilisation✓
3 - Mitosis✓ (3)
- 4.3 (a) 23✓ (1)
(b) 46✓/23 pairs (1)
- 4.4



(5)

- 4.5 Shock absorber✓/prevents physical or mechanical damage
Protects the foetus from drying out✓
Insulates the foetus against temperature fluctuations✓
Allows foetal movement for growth and development✓ any (2)
- 4.6 4.6.1 Oxygen✓
Dissolved food✓ (examples e.g. glucose, amino acids, water)
Antibodies✓ any (1)
- 4.6.2 Metabolic waste✓
Carbon dioxide✓
Nitrogenous waste
Water ✓ any (1)

5

GENETICS

INTRODUCTION

Genetics refers to the study of heredity and the variations that occur in the transmission of hereditary characteristics. In other words, in genetics we study the similarities and differences between related individuals.

GENETICS TERMINOLOGY

Chromosomes

A pair of chromosomes that are identical in shape and size, where one is of maternal origin and the other of paternal origin, is referred to as a homologous pair of chromosomes.

Genes

A particular length of DNA at a particular location (locus) on the chromosome that influences a particular characteristic is called a gene.

Alleles

Alternative forms of a gene found at the same locus, and providing different expressions of a characteristic, are called alleles.

Phenotype

The external appearance of an organism is referred to as its phenotype.

Genotype

The genetic composition of the individual or the combination of alleles for a particular characteristic is known as its genotype. It can thus be said that the genotype determines the phenotype.

Dominant

A dominant allele is one that influences the phenotype of an individual whether in a homozygous or heterozygous condition. It masks the effect of the recessive allele.

Recessive

A recessive allele is one that influences the phenotype of an individual only when in a homozygous condition. In the heterozygous condition, its effect is masked by the dominant allele.

Complete Dominance

In complete dominance, one allele is dominant over the other allele. The other allele is said to be recessive.

When a dominant allele and a recessive allele together make up the genotype of an individual, then the dominant allele determines the phenotype. The effect of the recessive allele is masked.

Homozygous

When an individual has two copies of the same allele for a particular characteristic, the individual is said to be homozygous (pure-breeding/true breeding) for that characteristic.

Heterozygous

When an individual has two contrasting or different alleles for a characteristic, the individual is said to be heterozygous (hybrid).

Monohybrid cross

A monohybrid cross refers to reproduction (also called a cross) between two individuals involving the inheritance of only one characteristic or trait.

Dihybrid cross

A dihybrid cross refers to reproduction (also called a cross) between two individuals involving the inheritance of two characteristics or traits.

Incomplete Dominance

When no one allele is dominant over the other, we cannot refer to either allele as being recessive or dominant. When in combination with each other, the alleles produce a new, third phenotype which is intermediate to the other two phenotypes.

Codominance

When both alleles are equally dominant, both alleles will influence the phenotype when they occur together. They produce a third, new phenotype which is a combination of the other two phenotypes.

Multiple Alleles

Multiple alleles refer to the presence of more than two alleles of the same gene all found at the same locus (position) on a chromosome.

Sex-linked alleles

These are alleles for body characteristics that are located on the sex chromosomes. They lead to characteristics which occur more frequently in one sex than the other.

Haemophilia

Haemophilia is a sex-linked characteristic in which the blood of an individual does not clot easily due to the absence of clotting factors. It occurs more frequently in males than in females.

Colour blindness

Colour-blindness is a sex-linked characteristic usually characterised by an ability of a person to distinguish between red and green. It occurs more frequently in males than in females.

Mutations

A mutation refers to a sudden change to the structure of a gene or a chromosome, altering the genotype of an individual, thus leading to altered characteristics.

Genetic Engineering

Genetic engineering, also called genetic modification, is the deliberate modification of the characteristics of an organism by manipulating its genetic material, using biotechnology.

Biotechnology

Biotechnology is the use of biological processes, organisms, or systems to manufacture products intended to improve the quality of human life.

Stem Cells

Stem cells are undifferentiated cells that have the potential to differentiate to form any tissue or organ in the body.

Mitochondrial DNA

DNA which is contained in mitochondria and passed from mother to child through the ovum.

Cloning

This refers to the production of genetically identical offspring using biotechnology.

DNA profile

Unique pattern formed by the DNA fragments of an individual.

Genetic Lineage

A lineage or a pedigree refers to a line of descent that links the existence of individuals or groups of individuals to their recent or distant ancestors. When genetic information is used to do this, it is referred to as a genetic lineage.

MONOHYBRID CROSS OF COMPLETE DOMINANCE

One allele is dominant over the other allele. The other allele is said to be recessive. When a dominant allele and a recessive allele together make up the genotype of an individual, then the dominant allele determines the phenotype.

To represent the alleles for a cross of complete dominance involving for example, flower colour (red or white):

- A letter is usually chosen according to the dominant allele.
- The upper case form of this letter will represent the dominant allele for red flower colour; **R**
- The lower case form of the letter will represent the recessive allele for white flower colour; **r**.

Consider the following genetics problem:

The allele for red flower colour is dominant over the allele for white flower colour. A homozygous red flowering plant is crossed with a homozygous white-flowering plant. Determine the possible phenotypes and genotypes of the offspring.

The solution to the above genetics problem can be represented as follows:

Key	Colour:	R- red	x	r - white
P₁	<i>phenotype</i>	red	x	white
	<i>genotype</i>	RR	x	rr
<i>meiosis</i>				
G₁		R	x	r
<i>fusion</i>				
F₁	<i>genotype</i>			Rr
	<i>phenotype</i>			red

Now consider the following genetics problem:

A heterozygous red flowering plant is crossed with a white-flowering plant. Determine the possible phenotypes and genotypes of the offspring.

From the statement we can conclude the following:

- The cross is monohybrid since it involves only one characteristic
- The characteristic is flower colour
- The phenotypes of the parents are red and white flowers respectively

- Since a heterozygous genotype involves one dominant allele and one recessive allele, the phenotype is determined by the dominant allele.
- Since the phenotype of the heterozygous parent is red flowers in this case, we now know that the allele for red flower colour is dominant
- From the above we now know that the allele for white flower colour is recessive

The solution to the above genetics problem can be represented as follows:

Key	Colour:	R- red		r - white
P₁	phenotype	red	x	white
	genotype	Rr	x	rr
meiosis				
G₁		R, r	x	r
fusion				
F₁	genotype	Rr		rr
	phenotype	1 red :		1 white

Using the Punnet square method, the same solution can be represented as follows:

Key	Colour:	R - red		r - white
P₁	phenotype	red	x	white
	genotype	Rr	x	rr
meiosis				
G₁		R	r	
fusion				
F₁	phenotype	2 red		2 white

MONOHYBRID CROSS OF INCOMPLETE DOMINANCE

No one allele is dominant over the other. We therefore cannot refer to alleles as being recessive or dominant. When in combination with each other, the alleles produce a new, third phenotype.

To represent the alleles for example, flower colour (red or white), since no one allele is dominant over the other:

- TWO letters are chosen, one for each allele.
- For example, in flower colour the allele for red flower colour will be upper case, **R**.
- The allele for white flower colour will be **W**.

Now consider the following genetics problem:

*In an **incomplete dominance** cross, a homozygous red flowering plant is crossed with a homozygous white-flowering plant. Determine the possible phenotypes and genotypes of the offspring.*

The solution to the above genetics problem can be represented as follows:

Key	Colour:	R- red		W - white
P₁	phenotype	red	x	white
	genotype	RR	x	WW
meiosis				
G₁		R	x	W
fusion				
F₁	genotype	RW		
	phenotype	ALL pink		

MONOHYBRID CROSS OF CODOMINANCE

Both alleles are equally dominant. When in combination with each other, both alleles will influence the phenotype.

To represent the alleles for example flower colour (red or white), since both alleles are equally dominant:

- TWO letters are chosen, one for each allele.
- For example, in flower colour the allele for red flower colour will be upper case, **R**.
- The allele for white flower colour will be **W**.

Now consider the following genetics problem:

*In a **codominance** cross, a homozygous red flowering plant is crossed with a homozygous white-flowering plant. Determine the possible phenotypes and genotypes of the offspring.*

The solution to the above genetics problem can be represented as follows:

Key	Colour:	R- red		W- white
P_1	phenotype	red	x	white
	genotype	RR	x	WW
meiosis				
G_1		R	x	W
fusion				
F_1	genotype			RW
	phenotype	Equal distribution of red and white		

THE INHERITANCE OF BLOOD TYPE

- Among humans there are four blood types: blood type A, blood type B, blood type AB and blood type O. These are regarded as the phenotypes.
- In the human population there are three alleles controlling these four blood types viz. alleles I^A , I^B and i .
- An individual can only have two of these three alleles making up his/her genotype.
- The i allele is recessive to the I^A and I^B alleles. The alleles I^A and I^B are co-dominant to each other.
- The table below illustrates the possible allele combinations (genotypes) and the blood groups (phenotypes).

GENE COMBINATION (Genotype)	BLOOD TYPE (Phenotype)	REASON
$I^A I^B$	AB	I^A and I^B are co-dominant
$(I^A I^A), (I^A i)$	A	I^A is dominant over i
$(I^B I^B), (I^B i)$	B	I^B is dominant over i
(ii)	O	Two recessive alleles present

Now consider the following genetics problem:

A man homozygous for blood type A married a woman heterozygous for blood type B. Determine the possible genotypes and the phenotypes of the offspring.

The solution to the above genetics problem can be represented as follows:

P_1	phenotype	A	x	B
	genotype	$I^A I^A$	x	$I^B i$
meiosis				
G_1		I^A	x	I^B, i
fusion				
F_1	genotype	$I^A I^B$; $I^A i$		
	phenotype	AB ; A		

THE INHERITANCE OF SEX

- Each species has its own characteristic number, shape and size of chromosomes in each somatic cell. This is called its karyotype.
- Every somatic cell of the human body has 23 pairs of chromosomes. Of these, 22 pairs are called autosomes and the remaining pair is called the sex chromosomes/gonosomes.
- The sex chromosomes are of two types: X and Y. Females have two X chromosomes (+ 22 pairs of autosomes). Males have X and Y chromosomes (+ 22 pairs of autosomes).
- Since the shape and size of the 23rd pair of chromosomes is different in males and females, the karyotype of the human male is different from that of the human female.
- The egg cells of females will contain only one X chromosome (+ 22 single autosomes) because they have been produced by meiosis.
- The sperm cells of males on the other hand have either an X chromosome (+ 22 single autosomes) or a Y chromosome (+ 22 single autosomes) because they have been produced by meiosis.
- If an X sperm cell fertilizes an ovum (which can only have an X chromosome) the zygote has an XX combination which is a female.
- If a Y sperm cell fertilizes an ovum (X), the zygote has an XY combination which is a male.
- Since X and Y sperm cells are produced in equal numbers, there is a 50:50 chance of the offspring being male or female. This can be represented as a genetic cross as shown below.

Key	Male: XY	Female: XX		
P ₂	phenotype	male	x	female
	genotype	XY	x	XX
meiosis				
G ₂		X, Y	x	X
fusion				
F ₂	genotype	XX ; XY		
	phenotype	1 female : 1 male 50% : 50%		

THE INHERITANCE OF SEX-LINKED CHARACTERISTICS

- The genes for most bodily characteristics are located on the 22 pairs of autosomes.
- In addition to determining sex, the sex chromosomes/gonosomes also contain genes for certain bodily characteristics.
- Since the genes for these characteristics are located on the sex chromosomes, we call them sex-linked characteristics.
- The X and Y chromosomes are not identical. In some cases, if an allele for a particular characteristic is on the X chromosome, there is no allele for the same characteristic on the Y chromosome (since the Y chromosome is smaller in size).
- If the allele on the X chromosome in a male is a recessive one, then the recessive characteristic will automatically show up in the individual because there is no allele/ no dominant allele on the Y chromosome to mask or hide the effective of the recessive allele.
- Haemophilia and colour blindness are two genetic disorders which are examples of sex-linked characteristics.

Haemophilia

- The blood of people who have haemophilia does not clot easily because of the absence of clotting factors.
- Haemophilia affects mostly males.
- We say that it is a recessive condition since it is caused by a recessive allele found on the X-chromosome. Therefore, if we show the allele for normal blood (the dominant allele) by 'H' then the allele for haemophilia would be 'h', since it is a recessive condition.

- Let us now examine how inheritance patterns change when sex-linked characteristics are involved. Let us consider a cross between a normal male and a female with haemophilia as shown below.

Now consider the following genetics problem:

A normal male marries a female with haemophilia. Determine the possible genotypes and phenotypes of their children.

The solution to the above genetics problem can be represented as follows:

Key	Normal blood: H	Haemophilia: h		
P ₁	phenotype	Normal male	x	Haemophiliac female
	genotype	X ^H Y	x	X ^h X ^h
meiosis				
G ₁		X ^H , Y	x	X ^h
fusion				
F ₁	genotype	X ^H X ^h ; X ^h Y		
	phenotype	normal female ; haemophiliac male 50% 50%		

Colour blindness

- Various types of colour-blindness exist.
- The most common type is red-green colour blindness, where the person cannot distinguish between red and green.
- Red-green colour blindness is caused by a recessive allele.
- Red-green colour blindness is inherited in exactly the same way as haemophilia, with more males being affected than females.

DIHYBRID CROSS

A **dihybrid** cross refers to a cross between two individuals involving the inheritance of **two** characteristics or traits. For example, what would happen if we cross a plant with yellow, round seeds with another plant that has green, wrinkled seeds? Notice that this involves two characteristics: **colour of seeds and shape of seeds**.

Let us now look at some of the experiments conducted by Mendel involving two characteristics.

Mendel's Experiments

Mendel crossed pure breeding plants having seeds that were round and yellow with pure breeding plants having seeds that were wrinkled and green. He found that all the F_1 offspring had seeds that were round and yellow. We can summarise this as follows:

Parents: round, yellow seeds x wrinkled, green seeds

Offspring: All round, yellow seeds

When Mendel crossed the F_1 offspring, he found the F_2 generation produced the following seed types in the phenotypic ratio 9:3:3:1

- 9 round, yellow seeds
 - 3 wrinkled, yellow seeds
 - 3 round, green seeds
 - 1 wrinkled, green
- } new combinations

Note that, in addition to the phenotypes of the grand-parents (round, yellow and wrinkled, green), two new phenotypic conditions appeared in the F_2 generation. These are the 3 wrinkled, yellow seeds and the 3 round, green seeds.

Mendel's Law of Independent Assortment

From this work Mendel developed another law – the *Law of Independent Assortment* which states that:

- The various 'factors' controlling the different characteristics (seed shape, seed colour, plant height, flower colour) are separate entities, not influencing each other in any way, and sorting themselves out independently during gamete formation.
- This explained the appearance of new phenotypic combinations in the F_1 cross that were different from that of the parents.

Explanation of Mendel's Dihybrid Cross in Terms of Genes and Alleles

- Each characteristic is controlled by a single gene consisting of two alleles.
 - The gene for seed colour consists of two alleles (Y for yellow colour which is dominant and y for green colour which is recessive)
 - The gene for seed shape consists of two alleles (R for round seeds which is dominant and r for wrinkled seeds which is recessive)
- The plant which is homozygous for both round and yellow seeds has the genotype RRYy.

Understanding Life Sciences

- The plant which is homozygous for both wrinkled and green seeds has the genotype rryy.
- Notice that each plant has two alleles for each characteristic. As a result of meiosis during gamete formation, the gametes from each parent will have only one allele for each characteristic (due to the halving effect of meiosis).
 - The gametes from the plant with round and yellow seeds (RRYY) will have the genotype RY.
 - The gametes from the plant with wrinkled and green seeds (rryy) will have the genotype ry.
- During fertilisation the gamete with RY genotype from one parent combines with the ry gamete from the other parent resulting in a zygote (which develops into an offspring) with the genotype RrYy.
- The seeds of the offspring are round and yellow since the allele for round seeds, R dominates or masks the allele for wrinkled seeds, r. Similarly the allele for yellow seeds, Y dominates or masks the allele for green seeds, y.
- Diagrammatically this dihybrid cross leading to the F_1 is shown below.

Key	Shape:	R - round	r - wrinkled
	Colour:	Y - yellow	y - green
P₁	phenotype	Round, yellow	x Wrinkled, green
	genotype	RRYY	x rryy
meiosis			
G₁		RY	x ry
fusion			
F₁	genotype		RrYy
	phenotype	ALL Round, yellow seeds	

- When these F_1 offspring are crossed with each other, then each parent having the genotype RrYy, can form four types of gametes. Because of Mendel's principle of independent assortment, the alleles could go in any combination into each gamete during anaphase of meiosis. The following four combinations are possible: RY, Ry, rY, ry.
- The following figure shows the genotypes and phenotypes resulting from a fusion of these gamete types.

Key		Shape:	R- round	r – wrinkled	Colour:	Y - yellow	y - green
P₂		<i>phenotype</i>	Round, yellow	x		Round, yellow	
		<i>genotype</i>	RrYy	x		RrYy	
Meiosis		RY	Ry	rY	ry		
G₂		RRYY	RRYy	RrYY	RrYy		
	RY	Round, yellow	Round, yellow	Round, yellow	Round, yellow		
Fusion		RRYy	RRyy	RrYy	Rryy		
	Ry	Round, yellow	Round, green	Round, yellow	Round, green		
F₂		RrYY	RrYy	rrYY	rrYy		
	rY	Round, yellow	Round, yellow	wrinkled, yellow	wrinkled, yellow		
	ry	Round, yellow	Round, green	wrinkled, yellow	wrinkled, green		

MUTATIONS

- A mutation refers to a sudden change to the structure of a gene or a chromosome
- Mutations occur suddenly and randomly and may be caused by many environmental agents such as X-rays, cosmic rays, ultra-violet radiation and certain chemicals.
- Since mutations generally affect a single or a few base pairs in just a single gene, we often refer to them as **gene mutations** to distinguish them from larger chromosomal changes (called **chromosomal mutations** or chromosomal aberrations) that sometimes take place.

Gene Mutations

A gene mutation refers to a change in the structure of a gene as a result of a change in the DNA sequence. Gene mutations therefore involve individual genes. There are two types of gene mutations: point mutations and frame-shift mutations.

Point Mutations

- In a point mutation, there is a change in a single base pair in the DNA molecule at just one point (i.e. a single base pair is replaced by another base pair). This is sometimes referred to as a base substitution.
- This could lead to altered characteristics.
- Sickle-cell anaemia is an example of a genetic disorder caused by a point mutation.

Frame-shift Mutations

- A single base pair may be inserted or deleted from the DNA molecule.

- From the point of addition or deletion onwards the DNA will be different from the original DNA.
- This could lead to altered characteristics.
- Albinism is an example of a genetic disorder caused by a frameshift mutation.

Chromosomal Aberrations/ Chromosomal Mutations

Chromosomal aberrations refer to changes in the normal structure or number of chromosomes. For example, parts of chromosomes may be broken off and lost during mitosis or meiosis. Often, chromosomes break and then rejoin incorrectly. Sometimes, the parts join backwards or even to the wrong chromosome.

Many chromosomal mutations result from the failure of chromosomes to separate properly during meiosis I. Normally one chromosome from each homologous pair moves to each pole of the cell. Sometimes, however, both chromosomes move to the same pole of the cell. This failure to separate is called non-disjunction.

Effects of Mutations

- Mutations may be harmful or harmless to the organism in which it occurs.
- Harmful mutations** are normally referred to as **lethal mutations**: the mutated organism dies and the harmful characteristics are not passed on to the next generation.
- Harmless mutations** may be of two types:
 - Neutral mutations**: They have no effect on the structure or functioning of the organism which possesses them.

- **Advantageous mutations:** Besides being harmless, a few mutations may be advantageous to the organism and they are passed on from parent to offspring. Sometimes, the advantageous mutant gene wipes out all the other alleles controlling the same characteristics within the population. We refer to these as *fixed mutations*.

GENETIC DISORDERS CAUSED BY MUTATIONS

Gene mutations or chromosomal aberrations/mutations cause a change in the genetic code. The genetic code is used to direct the manufacture of certain proteins needed in the body to perform certain structural and functional roles.

As a result of mutations, the required protein may not form, or an altered form of the required protein may be made. This can lead to various genetic disorders. Down syndrome, albinism, haemophilia and sick-cell anaemia are examples of some human genetic disorders caused by mutations.

Down Syndrome

95% of Down syndrome children are born with an extra copy of chromosome number 21. Since there are 3 copies of chromosome number 21 instead of 2, Down syndrome is also called Trisomy 21.

Sickle cell anaemia

- Sickle cell anaemia is caused by a mutant allele on chromosome number 11.
- Sickle cell anaemia causes the red blood corpuscles to become sickle shaped.
- The sickle-shaped cells block the small blood vessels.

Haemophilia

- Normally, when the skin tears and blood vessels burst open, the blood platelets produce a clotting agent which causes the blood to clot.
- In a person suffering from haemophilia, the blood does not clot well because the clotting agent is not produced.

Albinism

- Albinism refers to a group of genetic disorders all of which are characterised by a lack of the pigment melanin.
- The most common type of albinism is oculo-

cutaneous albinism which affects the eyes and skin.

MUTATIONS, NATURAL SELECTION AND EVOLUTION

- In addition to meiosis and chance fertilisation mutations contribute to variation.
- Mutations thus result in new, altered genotypes leading to new phenotypes.
- Only those individuals that have characteristics that are advantageous to enable it to compete successfully for resources in the environment and protect it from other organisms in the environment are able to survive.
- Charles Darwin called this Natural Selection implying that Nature selected only those that were best adapted to the environment to live and reproduce.
- As natural selection occurs from generation to generation, there is a continual, gradual change in populations leading to speciation (the evolution of new species).

GENETIC MODIFICATION

Genetic modification is the deliberate modification of the characteristics of an organism by manipulating its genetic material, using biotechnology.

- If the DNA of *E.coli* (bacteria) is recombined with a small portion of human DNA that is responsible for producing the hormone insulin, then the bacteria can be tricked into producing human insulin.
- In a similar way it is possible to enable a plant, for example, to become very resistant to disease or to produce a very high yield of a particular food type. The foods produced by such methods are called genetically modified foods, sometimes simply called GMF.

Arguments for genetic modification

- It will allow for the production of medication and other resources more cheaply.
- Pest resistant and drought resistant plants can be produced.
- Crop yield can be increased thereby increasing food security.
- The shelf life of fruit and vegetable can be increased thus decreasing wastage.

d Arguments against genetic modification

- Initially it is an expensive process – this money could be used for other immediate needs.
- We are interfering with nature as we are trying to play God.
- It may have potential health impacts.
- We are unsure of long term effects of using GMOs.

STEM-CELL RESEARCH

Sources of stem cells

- In the embryo stage, all cells are identical and are undifferentiated. Each of these undifferentiated cells has the potential to differentiate to form any tissue or organ in the body. These are called embryonic stem cells.
- Blood from the umbilical cord and placenta (known as cord blood or placenta blood) is one of the richest sources of stem cells that can ever be collected.
- The use of stem cells from cord blood is becoming more popular than the use of embryonic stem cells, since it does not involve the destruction of embryos to obtain the stem cells.

Uses of stems cells

Since stem cells have the potential to form any tissue or organ in the body, they can be used to replace diseased or damaged cells. For example, if the beta cells of the islets of Langerhans have been damaged, stem cells can be used to form new beta cells. These beta cells will then produce insulin normally and the diabetic patient can be cured.

It can also be used for treatment of many diseases such as diabetes, leukaemia, Alzheimer's disease, osteoporosis and sickle cell anaemia.

Not everyone agrees with the ethics of stem cell research.

- Those in favour generally argue that embryos are only tiny amounts of undifferentiated tissue. Since excess embryos produced for invitro fertilisation are destroyed anyway, it is acceptable for them to be used to help others. They argue that the use of stem cells from cord blood or from the eight-cell stage embryo is not immoral since it does not lead to destruction of the embryos.

- Those against, believe that a new life begins as soon as the sperm cell fertilises an egg cell. Therefore, they argue that when we use human embryos for research purposes we are actually using humans. They say that the use of embryos and their destruction after use in stem cell research is immoral. For some, the use of stem cells from cord blood or the eight-cell embryo stage is also unacceptable, arguing that we should not try to "play God".

CLONING

Cloning is the production of an individual which is genetically identical to the one from which it was produced, using biotechnology. Cloning of mammals such as rabbits, guinea pigs, cows, sheep and even humans is based on the following:

- When a haploid sperm fuses with a haploid egg, a diploid zygote forms which then develops into an embryo, eventually forming a new organism.
- If the egg is not fertilised within a certain period of time, it does not develop further; it is discarded from the body.

Scientists decided that the body is able to somehow 'tell' whether the ovum has been fertilised or not, by detecting whether it has the diploid number of chromosomes or not. They put forward the hypothesis that we should be able to 'cheat' the body into believing that the egg is fertilised by 'giving' the ovum the diploid number of chromosomes. They believed that the ovum will then act like a zygote would normally do.

They then went about testing whether their hypothesis was correct or not. This was the procedure they followed:

- They removed an ovum from a rabbit by surgery. Let us call this rabbit A.
- They then removed the nucleus of this ovum.
- They then removed an actively dividing somatic cell from another rabbit of the same species. Let us call this rabbit B.
- They carefully took out the nucleus from a cell of rabbit B.
- The nucleus of rabbit B was inserted into the ovum of rabbit A.
- The ovum, now with a diploid number of chromosomes, was put back into rabbit A.

This ovum behaved just like a fertilised egg. It became attached to the 'womb' and developed into a new individual. In other words, their investigation proved that their hypothesis was correct. We say that the results supported the hypothesis.

Remember that since the nucleus came from rabbit B, the new individual is therefore a **clone** of rabbit B.

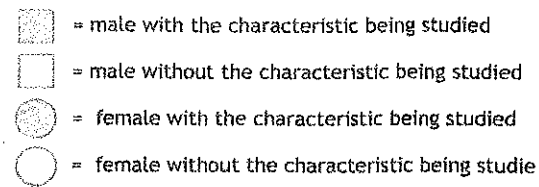
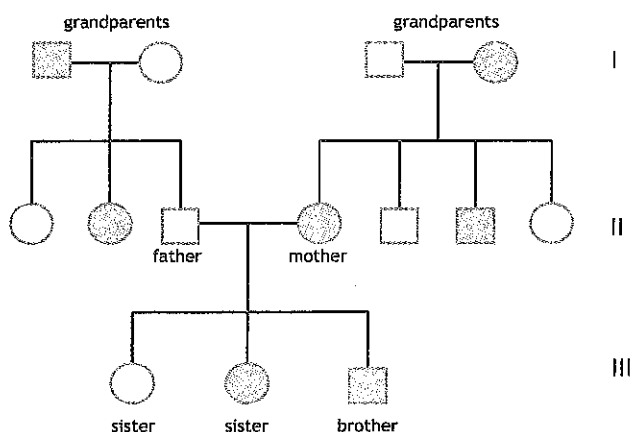
TRACING GENETIC LINEAGE USING PEDIGREE DIAGRAMS

A **lineage** or a **pedigree** refers to a line of descent that links the existence of individuals or groups of individuals to their recent or distant ancestors. When genetic information is used to do this, it is referred to as a **genetic lineage**.

Especially in tracing our own human ancestors, we use **pedigree diagrams** as a representation of a person's ancestors, including parents, grandparents, great-grandparents and beyond. It is a record of our pedigree or lineage.

Pedigrees are used by scientists to learn how different characteristics or traits are inherited from parents to offspring. Pedigree diagrams are also used in genetics to determine the probability of offspring in a family having a particular genetic disorder. Pedigree diagrams can help show if a genetic trait is dominant or recessive, passed on through the men in the family or independent of gender.

There are specific symbols used in genetic pedigree diagrams. Carefully study the example of a pedigree diagram provided to understand how it is constructed and how to interpret it in order to gain information about the inheritance of different characteristics.



In the pedigree diagram above:

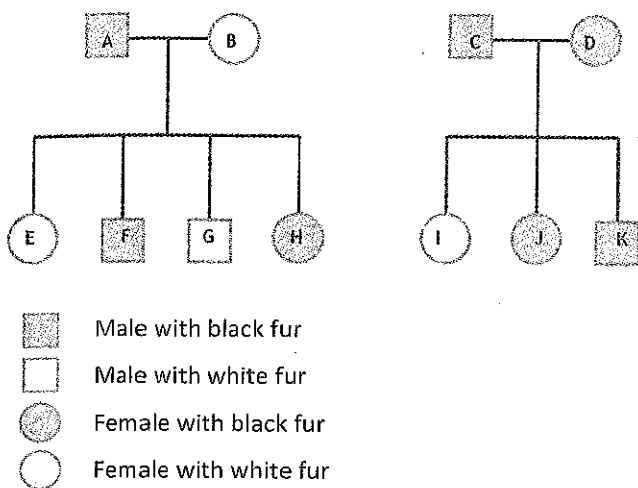
- A square represents a male and a circle represents a female.
- The horizontal lines joining a square and a circle show mating between a male and female (shows a set of parents).
- The vertical lines show the offspring of each group of parents.
- All the squares and circles in any one line are from the same generation. The generations are marked I, II and III.
- The squares and circles are either shaded or unshaded depending on the characteristics of the various individuals. A key is used to denote this.

Remember the following **steps** when interpreting pedigree diagrams:

1. Study the key and opening statement/s providing clues about phenotypes, and dominant and recessive characteristics.
2. Using information from the key, write down the phenotypes of all the individuals below each square or circle.
3. Fill in the genotype of all the individuals with the recessive condition - it has to have 2 recessive alleles (two lower case letters e.g. ff).
4. If the individuals showed the dominant characteristic fill in the first letter of the genotype which has to represent the dominant allele (a capital letter e.g. F).
5. For every individual in the diagram that has the recessive condition, it means that two recessive alleles were inherited, one from each of the parents. It also means that any offspring the individual has will inherit at least one recessive allele. Work backwards/forwards and fill in on the recessive allele for each parent/offspring.
6. Any other individual showing the dominant characteristic will now be homozygous dominant (FF) or heterozygous dominant (Ff).

Let us now use these steps to interpret the pedigree diagram that follows.

The diagram below shows the pedigree of two rabbit families. The allele for black fur is dominant over the allele for white fur. Determine the genotype of each of the rabbits labelled A to K.



Step 1

We are studying the inheritance of fur colour. Black fur is the dominant condition, white is recessive. This helps us form a key to determine the genotypes: **B** represents the allele for black colour; **b** represents the allele for white fur colour.

Step 2

From the key provided in the statement of the problem we can conclude that there are 6 females: 3 with black fur and 3 with white fur. There are 5 males: 4 with black fur and one with white fur.

Step 3

Since white fur is the recessive condition (white fur), individuals B, E, G and I will have the genotype **bb**.

Step 4

The first allele for individuals A, C, D, F, H, J and K will be **B** since they show the dominant condition (black fur).

Step 5

Both families had offspring with the recessive condition. Parents A, B, C and D must therefore have had at least one recessive allele in their genotype. The genotype of A, C and D is therefore **Bb**.

Offspring F and H have one parent with the recessive condition and will therefore inherit one recessive allele. Their genotypes are therefore now also **Bb**.

Based on the genotypes of parents C and D, we can only state that individuals J and K could be either **BB** or **Bb**.

Using the steps (1-5) we have been able to determine the phenotypes and genotypes of all individuals in the pedigree.

TERMINOLOGY REVIEW

TERM	DESCRIPTION
Albinism	Genetic disorder characterised by the non-production of the pigment melanin
Alleles	Alternative forms of a gene found at the same locus
Chromatin network	Tangled network of chromosomes located within the nucleus
Cloning	The production of genetically identical offspring, using biotechnology
Codominance	Cross involving alleles of a gene that are equally dominant, leading to a third phenotype which is a combination of the other two phenotypes
Complete dominance	Cross involving characteristics controlled by dominant and recessive alleles
Dihybrid	A cross involving two characteristics
DNA	Nucleic acid that is a constituent of chromosomes
DNA profile	Unique pattern formed by the DNA fragments of an individual.
Dominant	Allele that influences the phenotype whether in the homozygous or heterozygous combination
Down syndrome	Disorder caused by the presence of an extra copy of chromosome number 21
Frameshift mutation	A gene mutation caused by the addition or deletion of a base pair
Gene	Segment of a chromosome that codes for a particular protein
Genetic modification	Manipulation of the genotype of organisms to produce desirable characteristics
Genotype	The alleles of a gene that an individual possesses for a particular characteristic
Haemophilia	Sex-linked disorder characterised by the absence of clotting factors
Heterozygous	Individual with two different alleles for a particular characteristic found at the same locus
Homozygous	Individual with two copies of the same allele for a particular characteristic
Incomplete dominance	Cross involving alleles that are neither dominant or recessive, leading to an intermediate phenotype
Independent assortment	The movement of alleles for a characteristic into different gametes independently of the alleles for other characteristics
Monohybrid	A cross involving a single characteristic

TERM	DESCRIPTION
Multiple alleles	More than two alleles at the same locus influence a single characteristic
Mutation	Sudden change in the structure of a gene
Pedigree diagram	A representation that traces the transmission of a characteristic over many generations of a family
Phenotype	The external appearance of an organism
Point mutation	A gene mutation caused by the substitution of a base pair
Recessive	Allele that influences the phenotype only when in the homozygous combination but not in the heterozygous condition
Sex-linked characteristics	Characteristics controlled by alleles of a gene that are located on the sex chromosomes
Sickle-cell anaemia	Disorder caused by a point mutation leading to abnormally shaped red blood cells
Stem cells	Undifferentiated cells that can form any other cell type in an organism

QUESTIONS

1. Learners want to investigate eye colour in fruit flies (*Drosophila melanogaster*). Fruit flies can have red (R) eyes or white (r) eyes. Red eye colour is dominant and white eye colour is recessive.

Male fruit flies, homozygous for red eye colour, were bred with female fruit flies, homozygous for white eye colour.

Show how the possible phenotypes and the genotypes of the F₁ generation for eye colour may be obtained.

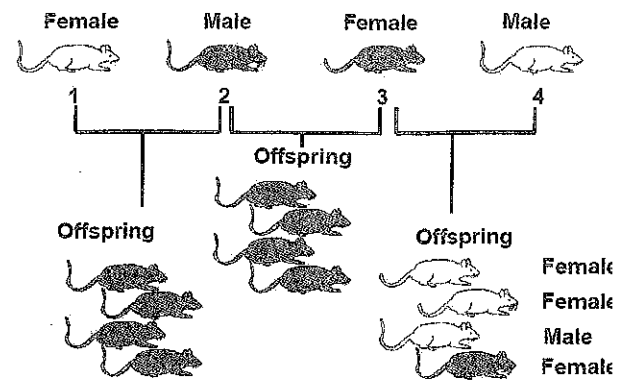
(6)

2. In humans, the allele for blue (b) eyes is recessive to the allele for brown (B) eyes. A man, heterozygous for brown eyes, marries a woman with blue eyes. Show how the possible genotypes, phenotypes and ratio of individuals with brown and blue eyes in the F₁-generation, may be obtained.

(6)

3. Study the diagrams below that show some breeding experiments on mice. A single pair of alleles showing complete dominance controls coat colour (white or grey) in these mice.

(6)



- 3.1 Which sex chromosomes would be present in the gametes of parent mouse 2 and mouse 3, respectively? (2)
- 3.2 If mice 3 and 4 had a second set of offspring, what is the percentage chance that the first mouse born would be female? (1)
- 3.3 Which of the parent mice (1, 2, 3 or 4) is likely to be homozygous dominant for coat colour? (1)
- 3.4 State why mouse 3 can only be heterozygous for coat colour. (2)

4. In rabbits the dominant allele (B) produces black fur and the recessive allele (b) produces white fur. Study the table below showing the genotypes of four rabbits.

Rabbit	1	2	3	4
Genotype	BB	Bb	Bb	bb

- 4.1 What are the phenotypes for rabbits 2 and 4 respectively? (2)
- 4.2 State the genotypic ratio that is shown in the table above. (1)
- 4.3 If rabbits 1 and 4 were mated together and had 12 offspring, how many of these would you expect to be black? (1)
- 4.4 Rabbit 2 was allowed to breed with rabbit 3. Use a genetic cross to show the possible phenotypes and genotypes of the F₁ generation for fur colour. (6)

5. In an experiment to show co-dominance, cows with white fur (W) were crossed with bulls with red fur (R). All the offspring of the F₁-generation have roan fur (RW). A roan fur consists of patches of white and patches of red fur. Roan cows and roan bulls were crossed and the results are given below.

Genetics

Genotype	RR	RW	WW
Number of offspring	120	240	120

TRAIT	NUMBER OF LEARNERS	
	DOMINANT	RECESSIVE
Earlobe	70	130
Tongue	24	176
Little finger	15	185

- 5.1 Give the ratio of the different phenotypes shown in the above table. (2)
 - 5.2 Use the information in the table above to draw a pie-chart showing the proportions of the different genotypes. (7)
 - 5.3 Explain why the cows and bulls with genotype RW have roan fur and not only red or only white fur. (3)
6. Study the table below which shows the relationship between the age of a mother and the risk of having a Down syndrome baby.

Age of mother (years)	Risk of Down's syndrome baby (per 10 000 births)
25	8
35	25
45	200

- 6.1 State the relationship between the mother's age and the chance of having a baby with Down syndrome. (2)
 - 6.2 By how many times does the risk of having a baby with Down syndrome increase between 35 and 45 years of age? (1)
 - 6.3 How many chromosomes are present in a cell of the body of a baby with Down syndrome? (1)
 - 6.4 Explain why a person with Down syndrome has an abnormal number of chromosomes. (4)
7. A group of learners investigated the frequency of dominant and recessive traits in their school. Their hypothesis was:

There will be more learners with dominant traits than learners with recessive traits.

The traits below were investigated in 200 learners:

DOMINANT TRAIT	RECESSIVE TRAIT
Unattached earlobe	Attached earlobe
Rolled tongue	Unrolled tongue
Bent little finger	Straight little finger

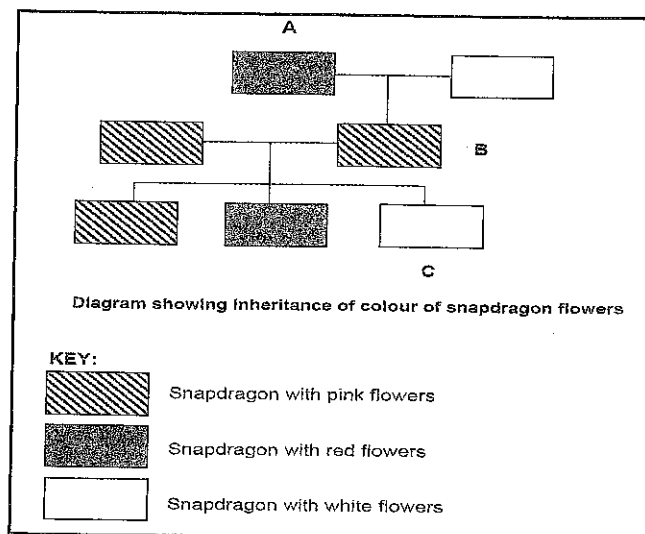
The results below were obtained during the investigation.

- 7.1 Show the results for each trait above as bar graphs on the same system of axes. (7)
- 7.2 Explain why age need NOT be controlled in this investigation. (2)
- 7.3 State ONE way in which the learners ensured reliable results. (1)
- 7.4 State any TWO planning steps that the learners had to consider before conducting the investigation. (2)
- 7.5 Will the learners accept or reject their hypothesis? (1)
- 7.6 Explain your answer to QUESTION 7.5. (2)

8. Study the diagram below which shows three generations of snapdragon plants and answer the questions which follow.

Use the following symbols for the contrasting alleles:

W – for white flowers
R – for red flowers



- 8.1 State the kind of dominance shown in the diagram above. (1)
- 8.2 Use the symbols R and W and write down the genotypes of each of the following snapdragon plants:
 - 8.2.1 A (2)
 - 8.2.2 B (2)
 - 8.2.3 C (2)

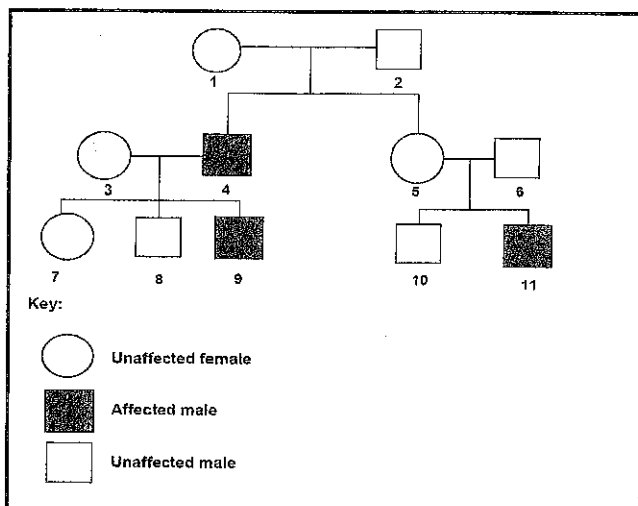
9. A rare form of rickets in humans is caused by a sex-linked dominant allele (R), which is carried on the X-chromosome. An affected female, whose father was unaffected, married an unaffected male.

- 9.1 Determine the possible genotypes and phenotypes of their offspring by representing a genetic cross. (6)
- 9.2 What is the percentage chance that they will have a child who is an unaffected male? (2)
- 9.3 Explain why this disorder does NOT affect males only. (2)
- 9.4 This genetic disorder is caused by a gene mutation in which the DNA triplet CAG is altered to TAG.
- 9.4.1 Name this type of mutation. (1)
- 9.4.2 Describe how the type of mutation mentioned in QUESTION 9.4.1 would affect the structure of the protein it codes for. (2)
- 9.5 Give TWO reasons why this couple should undergo genetic counselling before having children. (2)

10. Haemophilia is a sex-linked disease caused by the presence of a recessive allele (X^h). A normal father and heterozygous mother have children.

- 10.1 Represent a genetic cross to determine the possible genotypes and phenotypes of the children of the parents mentioned in QUESTION 10. (6)
- 10.2 What are the chances of the parents having a child that will be a haemophiliac male? (2)
- 10.3 Explain why the father is not a carrier for haemophilia. (2)

11. The pedigree diagram below traces the inheritance of haemophilia in a family.



- 11.1 How many family members not affected by haemophilia are carriers? (1)
- 11.2 Explain why this disorder affects mostly males in this family. (1)
- 11.3 Use the possible alleles X^H , X^h and Y to determine the genotype of the following:

- 11.3.1 Individual 1 (1)
- 11.3.2 Individual 4 (1)

- 11.4 What are the chances of individual 10 and his wife, who is a carrier (not shown in the pedigree), having a child who is a boy and who is affected? (1)
- 11.5 Give TWO reasons why individual 9 and his partner should undergo genetic counselling before starting a family. (2)

12. Show by means of a genetic cross how it is possible for a man, heterozygous for blood type A and a woman, heterozygous for blood type B to produce a child with any one of the four blood types. (1)

13. In certain plants, the allele for tallness (T) dominates over that for shortness (t). The allele for red flowers (R) dominates over the allele for white flowers (r).

Using the Punnet square method, represent a genetic cross to show the genotypes and phenotypes of the offspring resulting from the following parents:

Parent 1: Homozygous for tallness and heterozygous for red flowers

Parent 2: Heterozygous for both tallness and red flowers (1)

14. Using genetically modified organisms as a source of food, is supported by some people and rejected by others.

Explain SIX advantages of using genetically modified organisms as a source of food. (12)

15. Clones are a group of genetically identical organisms.

Explain THREE advantages and THREE disadvantages of cloning. (12)

ANSWERS

1.

Key	Eye Colour:	Red – R		White - r
P ₁	phenotype	red eyed	x	white eyed
	genotype	RR	x	rr
meiosis	G ₁	R	x	r
fusion	F ₁ genotype	Rr		
	phenotype	ALL Red eyed		

2.

Key	Eye Colour:	Brown – B		Blue - b
P ₁	phenotype	brown eyed	x	blue eyed
	genotype	Bb	x	bb
meiosis	G ₁	B, b	x	b
fusion	F ₁ genotype	Bb ; bb		
	phenotype	1 brown eyed : 1 blue eyed		

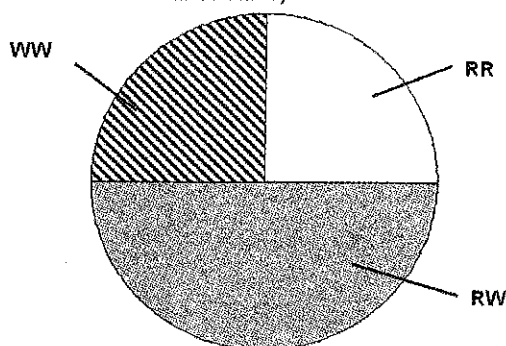
- 3.
- 3.1 Mouse 2 - XY✓
Mouse 3 - XX✓ (2)
- 3.2 50%✓ (1)
- 3.3 Mouse 2✓ (1)
- 3.4 A cross between mouse 3 and mouse 4✓ produced offspring with white✓/recessive coat colour and white colour will only show up if both parents have at least one recessive gene✓ (2)

- 4.
- 4.1 2 - Black✓
4 - White✓ (2)
- 4.2 1BB: 2Bb: 1bb✓ (1)
- 4.3 12✓ (1)
- 4.4 (6)

Key	Fur Colour:	Black – B		White - b
P ₁	phenotype	black fur	x	black fur
	genotype	Bb	x	Bb
meiosis	G ₁	B, b	x	B, b
fusion	F ₁ genotype	BB ; Bb ; Bb ; bb		
	phenotype	3 black fur : 1 white fur		

- 5.
- 5.1 1 : 2 : 1✓✓ (2)
- 5.2 (7)

The proportions of different genotypes (for coat colour of cattle)

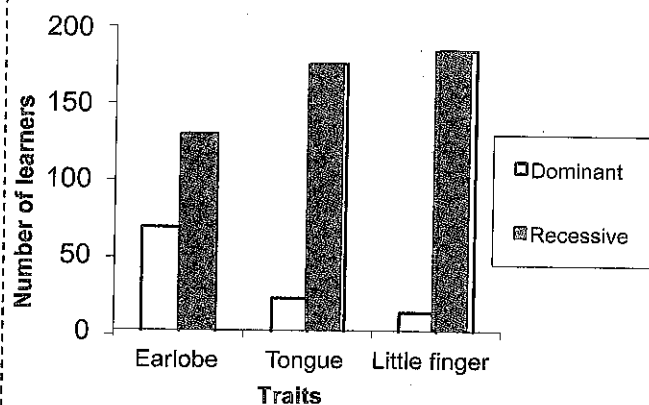


Correct type of graph	1
Caption	1
Correct proportions of slices	1 mark for general proportion (at a glance) 1 mark for accurate proportion in pie chart
Label / key for each slice	3 marks (1 mark for each correct label) Labels RR and WW can be interchanged

- 5.3 Both alleles✓ for fur colour are equally dominant✓ co-dominant and therefore both are expressed in the phenotype✓ (3)
- 6.
- 6.1 As age of mother increases✓ chances of having a Down syndrome baby increases✓ (2)
- 6.2 8✓ (1)
- 6.3 47✓ (1)
- 6.4 During meiosis I the chromosome pair 21 does not separate ✓
Could also occur during meiosis II✓
Failure of chromatids to separate ✓
Called non-disjunction✓
One gamete will have an extra chromosome✓
If this gamete fuses with a normal gamete with 23 chromosomes✓ the resulting zygote will have 47 chromosomes✓ any (4)

7.
7.1

The frequency of three different traits in a learner population



Rubric for the mark allocation of the graph

Correct type of graph	1
Caption for graph	1
Correct label for X-axis and appropriate width of bars	1
Graphs labelled/key provided for 2 graphs	1
Correct label for Y-axis and appropriate scale for Y-axis	1
Drawing of bars	1 – 1 to 5 bars plotted correctly 2 – All 6 bars plotted correctly

(7)

7.2 These traits are inherited✓ and not influenced by age✓ (2)

7.3 Had a large sample size✓ (1)

7.4

- Get permission from the principal/authorities to conduct the investigation✓
- Decide on the appropriate time/day to conduct the investigation✓
- Decide on the sample size✓
- Decide on sample selection✓
- Investigators to learn how to recognise/identify each trait✓
- Decide how to record results of the investigation✓

any (2)

7.5 Rejected✓ (1)

7.6 More learners✓ displayed the recessive traits compared to the dominant traits✓ (2)

8.

8.1 Incomplete✓ dominance (1)

8.2 8.2.1 RR✓✓ (2)

8.2.2 RW ✓✓ (2)

8.2.3 WW✓✓ (2)

9.

9.1 (6)

Key	Rickets:	Affected – R	Unaffected – r
P_1	phenotype	Affected female	x Unaffected male
	genotype	$X^R X^r$	x $X^r Y$ ✓
meiosis	G_1	X^R, X^r	x X^r, Y ✓
fusion	F_1	genotype	$X^R X^r, X^R Y, X^r X^r$ & $X^r Y$ ✓
	phenotype	1 affected daughter, 1 affected son, 1 unaffected daughter & 1 unaffected son ✓	

9.2 25✓✓ % (2)

9.3 It is caused by a dominant✓ allele carried on the X-chromosome, which both males and females have✓ (2)

9.4 9.4.1 Point✓ mutation (1)

9.4.2 A different amino acid would be coded for✓ resulting in a different protein✓ (2)

9.5

- To determine the chances of having a child with the disorder✓
- Help them evaluate whether they would cope with such a child✓
- Help them make an informed decision on whether to have children ✓

any (2)

10.

10.1 (6)

Key	Rickets:	Normal – H	Haemophiliac – h
P_1	phenotype	Normal male	x Normal female
	genotype	$X^H Y$	x $X^H X^h$ ✓
meiosis	G_1	$X^H ; Y$	x $X^H ; X^h$ ✓
fusion	F_1	genotype	$X^H X^H, X^H X^h, X^H Y, X^h Y$ ✓
	phenotype	2 normal daughters, 1 normal son, 1 son with haemophilia✓	

0.2 25% ✓ chance / 1 ✓ out of 4 ✓ / ¼ ✓ (2)

0.3 The male has the XY chromosome/only one X chromosome ✓
The Y chromosome does not have the allele for this trait ✓ (2)

1. 4 ✓ (1)

1.1 The allele for the trait is carried on the X-chromosome ✓
1.2 Y chromosome does not carry the allele for the trait ✓
Male only has one X chromosome ✓
A male needs only one recessive allele ✓ to be haemophiliac
Whereas for a female to be haemophiliac both alleles must be recessive ✓ any (3)

11.3.1 $X^H X^h$ ✓ ✓ (2)

11.3.2 $X^h Y$ ✓ ✓ (2)

25% ✓ ✓ (2)

- 0.5 - To determine if the wife is a carrier ✓
- To determine the chances of having a child with haemophilia ✓
- Help them evaluate whether they would cope with such a child ✓
- Help them make an informed decision about whether to have children ✓ any (2)

(6)

Alleles:	I^A	;	I^B	;	i
phenotype	Blood type A	x	Blood type B		
genotype	$I^A i$	x	$I^B i$		
meiosis					
gametes	I^A ; i	x	I^B ; i		
fusion					
genotype	$I^A I^B$; $I^A i$; $I^B i$; ii				
phenotype	AB	A	B	O	

13. (6)

Key	Height:	T- tall	t - short
	Flower Colour:	R - red	r - white
P₂	phenotype	Tall, red flowers	x Tall, red flowers
	genotype	TTRr	x TtRr
Meiosis		TR	Tr
G₂	TR	TTRR Tall, red	TTRr Tall, red
Fusion	Tr	TTRr Tall, red	TTrr Tall, white
F₂	tR	TtRR Tall, red	TtRr Tall, red
	tr	TtRr Tall, red	Ttrr Tall, white
Phenotypic ratio: 6 tall, red flowers ; 2 tall, white flowers			

14. - Increased yield of food ✓ to prevent starvation ✓
- Increased nutrient ✓ content of food to improve human health ✓
- Produce oil with less saturated fat ✓ / lower caffeine level to improve human health ✓
- Increased shelf life ✓ of plant products reducing food spoilage ✓ / minimising waste
- Control pests ✓ by inserting genes instead of using chemicals thus reducing harm to the environment ✓
- Produce crops resistant to disease ✓ / pests / drought, thus increasing their yield / decreasing production costs ✓
- Cheaper ✓ to produce hence lowering the cost of food ✓
- Selecting genes that delay ripening ✓ of fruits to meet the demand locally and internationally ✓
- Enhance the taste ✓ of food for increased marketability ✓ any (6 x 2)

(12)

15. Advantages of cloning
- Producing individuals with desired traits ✓ to eliminate unwanted characteristics ✓
- Better yield ✓ to increase the amount of food ✓ for a large population
- Resistant to diseases ✓ to save on the use of pesticides and herbicides ✓

- Organisms produced in a shorter time✓to increase yield✓
 - Saving endangered species✓without the need for mating partners✓
 - Producing body parts✓reducing rejection of transplanted parts✓
 - Produce offspring✓ for organisms that are infertile and cannot have their own offspring✓
 - Reproduction✓ is not seasonally dependent✓
- any 3 x 2

Disadvantages of cloning

- Objection✓/religious beliefs to interfering with God's/Supreme Being's creation✓
 - Reducing the gene pool ✓by reducing variation✓
 - Cloned organisms may have developmental/morphological problems✓ and not survive long✓
 - Costly process✓ not all farmers/people/government's can afford it✓
 - May generate more experimental waste✓causing ethical✓ issues around disposal of waste
 - May lead to killing of clones✓ to obtain spare body parts✓
- any 3 x 2 (12)

6

Human Nervous System
and Sense Organs

INTRODUCTION

Humans use two systems to respond to the environment viz. the nervous system with its sense receptors and the endocrine system.

THE NEED FOR A NERVOUS SYSTEM

It detects changes in the environment thus allowing the body to react to these changes.

It enables co-ordination of the various activities of the body. In the next topic, you will come across another system (the endocrine system) which also assists in co-ordination.

NERVOUS TISSUE

Nerves are composed of nerve fibres. The nerve fibres in turn are made up of specialized nerve cells called neurons. There are three types of neurons as follows:

Sensory neurons which carry impulses from the receptors (nerve endings or sense organs) to the central nervous system (brain and spinal cord)

Motor neurons which carry impulses from the central nervous system to the effectors (muscles or glands)

Connector neurons/interneurons carry impulses inside the central nervous system from a sensory neuron to a motor neuron

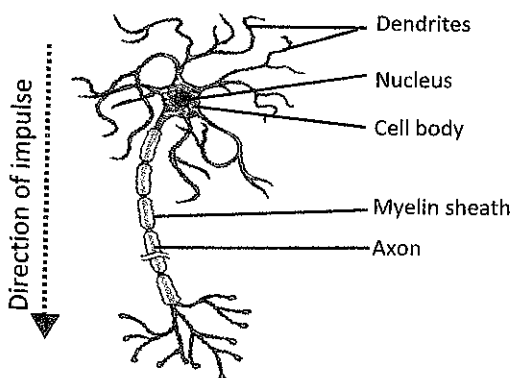


Fig. 6.1 A Motor Neuron

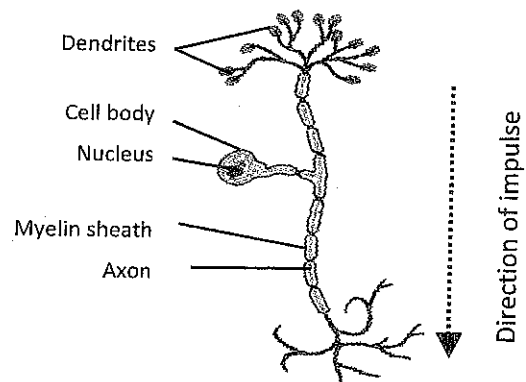


Fig. 6.2 A Sensory Neuron

All neurons consist of a cell body with its dendrites and an axon. A nerve impulse always travels from the dendrites to the cell body to the axon.

- The axon is covered by two membranes viz. a myelin sheath and a neurilemma.
- The myelin sheath provides electrical insulation and helps to speed up the transmission of impulses.

When neurons carry nerve impulses, more than one neuron is involved.

- The neurons are lined up in such a way that the axon terminals of one neuron lie next to the dendrites of another.
- The neurons are not directly connected to each other. There is a microscopic gap or synapse between the axon terminals of one neuron and the dendrite of another.
- Nerve impulses are carried along the neuron by electrical impulses but communication across the synapse is by means of chemicals called neurotransmitters.
- Such communication is referred to as a synaptic contact.

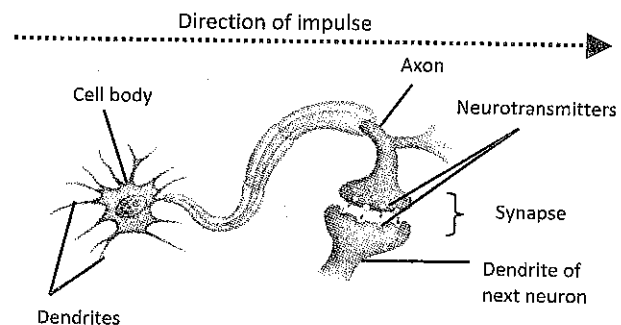


Fig. 6.3 A Synapse

PARTS OF THE NERVOUS SYSTEM

- The nervous system is composed of the central nervous system and peripheral nervous system.
- The **central nervous system** includes the brain and spinal cord.
- The **peripheral nervous system** is made up of all the nerves outside the central nervous system. It may be further sub-divided into the somatic nervous system and the autonomic nervous system.
- The **somatic nervous system** includes all parts of the nervous system that enable the body to react to changes in the external environment.
- The **autonomic nervous system** includes those parts of the nervous system that control the internal environment. It controls such actions as sweating, and the heart and breathing rates.
- Most parts of the nervous system function together to bring about co-ordination and homeostasis.

CENTRAL NERVOUS SYSTEM

BRAIN

- The brain is protected by the cranium in which it lies and by a system of three membranes called the meninges.
- Within the brain are hollow cavities called ventricles filled with cerebrospinal fluid.
- The brain gives rise to twelve pairs of nerves referred to as cranial nerves.

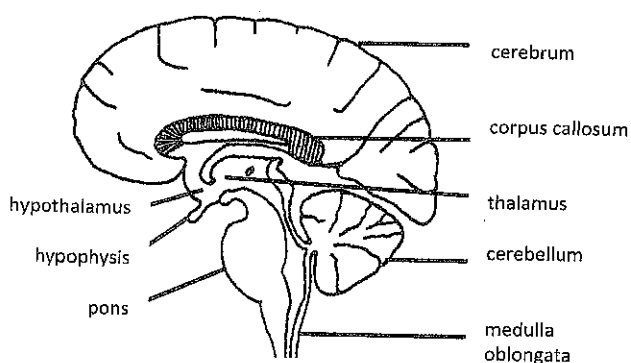


Fig. 6.4 L.S. Section through the brain

- The cerebrum is the largest part of the brain. The two hemispheres of the cerebrum are connected together by bundles of nerve fibres, the largest of which is the **corpus callosum**. Below the corpus callosum is the thalamus. Below the thalamus is the hypothalamus.
- The functions of the **cerebrum** are as follows:
 - It controls all voluntary actions
 - It receives and interprets all sensations viz sight, hearing, smell, taste and touch
 - It controls all the higher thought processes such as memory, judgment and reasoning
- The **hypothalamus** which is a separate part of the brain is responsible for the control of:
 - Body temperature
 - Blood pressure
 - Sleep
 - Appetite
 - Thirst
 - Emotions
- The **cerebellum** is responsible for the following functions:
 - Co-ordination of voluntary movements e.g. Walking and running
 - Maintaining muscles tone, balance and equilibrium
- The brain stem is made up of the mid-brain, the pons Varolli and the medulla oblongata. The medulla oblongata continues as the spinal cord.
- The main functions of the **medulla oblongata** are as follows:
 - It contains the reflex centres responsible for breathing, regulation of the heart beat, dilation and constriction of blood vessels, salivation and swallowing i.e. it is responsible for all the involuntary actions.
 - It conducts impulses from the spinal cord to the higher parts of the brain, and vice versa.
 - Impulses cross-over from one side to the other as they pass through the medulla so that nerves from the left side of the brain control the right side of the body and vice versa.

SPINAL CORD

- The spinal cord is located in the vertebral canal and protected by the vertebrae.
- It is surrounded and protected by the meninges.
- It is continuous with the medulla oblongata of the brain.
- Spinal nerves arise from the spinal cord
- Sensory neurons enter the dorsal root of the spinal nerves. They bring impulses from the receptor to the spinal cord. Since the sensory neuron has the cell body centrally situated, the dorsal root has a swelling called the dorsal root ganglion to accommodate all the cell bodies of the sensory neurons.
- Connector neurons are situated in the spinal cord between the sensory and motor neurons. They transmit impulses from the sensory neurons to the motor neurons.
- Motor neurons leave the spinal cord through the ventral root of the spinal nerves. They take impulses from the spinal cord to the effector organ (muscle or gland).

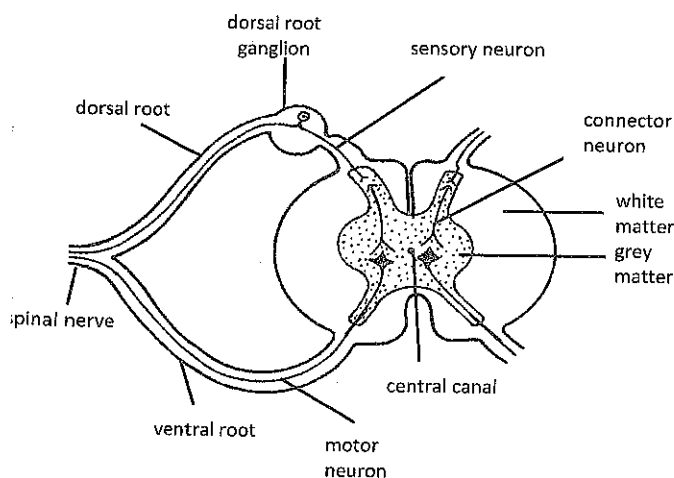


Fig 6.5 T/S Spinal Cord

Functions of spinal cord

- It conducts impulses between the brain and the receptors and effectors
- It serves as a centre for reflex actions

REFLEX ACTION AND REFLEX ARC

- A **reflex action** may be defined as a rapid, automatic (involuntary) response to a stimulus received by an organ or other receptor.
- The **reflex arc** is the functional unit of the nervous system. It is the path taken by an impulse in bringing about a response to a stimulus during a reflex action.

First study the diagram that follows showing the components of a reflex arc. Thereafter we will see how these various components work together during a reflex action.

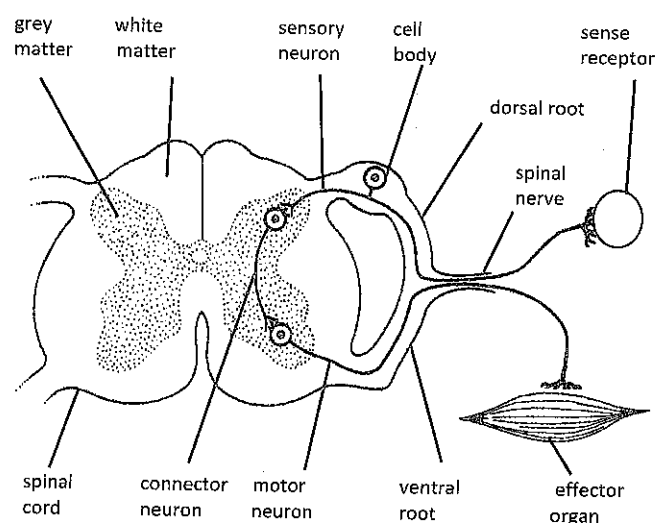


Fig 6.6 Components of a Reflex Arc

You will notice that the reflex arc involves:

- The spinal cord
- The spinal nerves with three types of neurons
- A **receptor** (located in the sense organs) which picks up changes in the environment
- An **effector** (muscle or gland) which responds to the changes.

Let us now look at how the reflex arc works during a reflex action. We will use the example of the response that occurs when your finger is placed over a burning candle, as an example of a reflex action. The numbering for each step in the process corresponds to the numbering in the diagram that follows thereafter.

- Step 1** Heat receptors in the skin of your fingers receive the heat stimulus and convert it to a nerve impulse.
- Step 2** The sensory neuron conducts the nerve impulse through the dorsal root of the spinal nerve into the spinal cord.
- Step 3** In the spinal cord the sensory neuron makes synaptic contact with a connector neuron which in turn makes synaptic contact with a motor neuron.
- Step 4** The impulses are conducted by the motor neuron out of the spinal cord towards the muscles of your hand which act as effectors.
- Step 5** The muscles contract to pull your hand away from the hot surface.

An impulse is also sent from the connector neuron in the spinal cord to the brain. This makes it possible for you to experience the pain and become aware that you had placed your hand on a hot surface.

Now use the diagram below to review the same steps of the reflex action just described without looking at the information for each step.

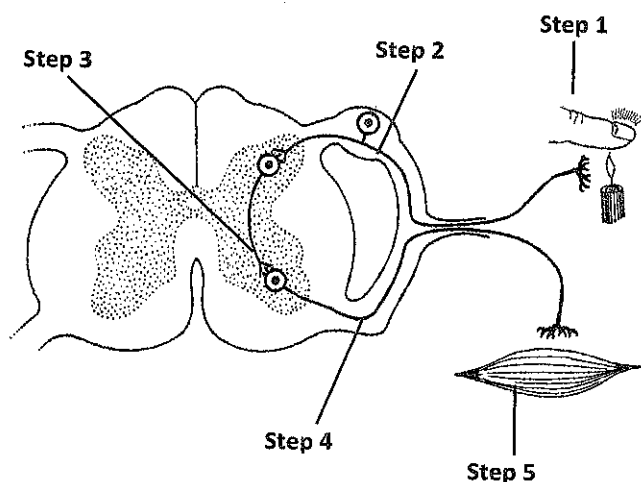


Fig 6.7 Steps in a Reflex Action

PERIPHERAL NERVOUS SYSTEM

The peripheral nervous system is made up of all the nerves outside the central nervous system. It is divided into the **somatic nervous system** and the **autonomic nervous system**.

The **somatic nervous system (SNS)** includes all parts of the nervous system that enable the body to react to changes to the external environment. It is made up of free nerve endings, sense organs, sensory

nerves, motor nerves and effectors (muscles and glands).

The **autonomic nervous system** is made up of centres in the brain and spinal cord, nerve cells and smooth muscles, glands and internal organs as well as sympathetic and parasympathetic nerves running to these muscles, glands and internal organs.

These nerves function antagonistically. For example the **sympathetic nerves** of the heart increase the heart rate while the **parasympathetic nerves** slow down the heart rate.

The main function of the autonomic nervous system is to control the sub-conscious activities of the body (e.g. heartbeat, peristalsis, dilation of blood vessels). In this way, it helps to restore **homeostasis**.

DISORDERS OF THE CENTRAL NERVOUS SYSTEM

Alzheimer's disease

- This disease occurs when the nerve tissue within the brain of a person appears to waste away/become destroyed.
- Although it usually occurs in older persons, it is not brought about by the normal ageing process. It can strike people in their 40's and 50's as well.
- The main symptom of Alzheimer's disease is memory loss and confusion. Alzheimer's patients forget even the most basic things such as tying shoe laces, how to do household chores and how to drive.
- No drug has been found as yet for the successful treatment of this disease.

Multiple sclerosis

- Sometimes the body's own immune system attacks and destroys the myelin sheath covering the neurons, causing a disorder called multiple sclerosis.
- Persons suffering from multiple sclerosis have physical as well as mental disabilities.
- The cause of multiple sclerosis is unknown. Genetics, infections and environmental factors all seem to play a part in causing the illness.
- There is no known cure for multiple sclerosis. Medical treatment tries to slow the rate at which the illness progresses.

INJURIES TO THE CENTRAL NERVOUS SYSTEM

- Injuries to the central nervous system may be caused by a direct blow to the brain or spinal cord, or by a stroke which reduces blood flow to one or more parts of the brain.
- The effect of injuries to the central nervous system depends on which part of the brain is damaged.
 - If the medulla oblongata is damaged, breathing, salivation and swallowing will be affected.
 - If the back of the cerebrum is injured, then vision will be poor.
 - If the cerebellum is damaged, balance and equilibrium as well as the co-ordination of voluntary movements will be affected.
 - If the spinal cord is injured, then impulses from the brain to and from different parts of the body will be affected.

EFFECT OF DRUGS ON THE CENTRAL NERVOUS SYSTEM

- Impulses are transmitted through a neuron and then across a synapse to another neuron by neurotransmitters.
- The use of drugs may either stimulate or inhibit the action of these neurotransmitters.
- For this reason drugs may have stimulant or depressant effects on the user.
- Some common effects of drugs include memory loss, paranoia, anxiety and confusion.

SENSE ORGANS AND SENSE RECEPTORS

There are receptors present in different sense organs of the body that are sensitive to different stimuli such as light, sound, taste, pressure, pain, temperature, heat and cold.

When stimulated, these receptors will convert the stimuli into impulses and transmit them to the brain where the impulse is interpreted. This then allows the body to react to the stimuli in appropriate ways. Below is a list of receptors located in the different sense organs:

- Receptors for temperature, pressure and pain (in the skin)

- Receptors for taste (the taste buds on the tongue)
- Receptors for smell (the olfactory organ, in the nose)
- Receptors for sound (organ of Corti in the cochlea of the ear)
- Receptors for balance (in the sacculus and utricle and semi-circular canals of the ear)
- Receptors for light (photoreceptors in the eye)

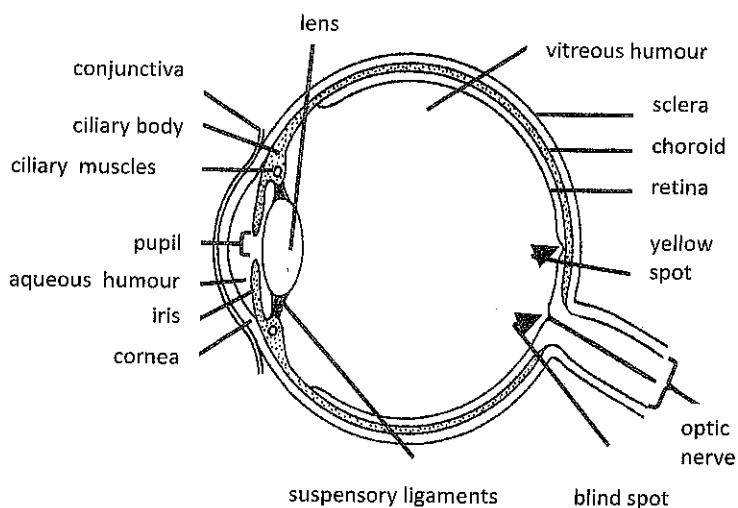
THE EYE

Protection

The eyeball is protected in the following ways:

- It lies in a bony cavity in the skull called the orbit
- Fat and connective tissue between the eyeball and bone of the socket protect the eye
- The exposed part of the eye is protected by a thin membrane, the conjunctiva
- The front of the eye is protected by the upper and lower eyelids
- The eyelids have eyelashes which prevent foreign particles such as dust and insects from entering the eye
- Tears secreted by the lachrymal glands keep the conjunctiva moist, remove dust particles and destroy bacteria

Structure of the eye



The wall of the eyeball consists of three layers viz. the sclera, choroid and retina.

The **sclera** is a tough, non-elastic, opaque outer covering. In front, the opaque sclera becomes specialised as a transparent disc called the **cornea**, which is a part of the sclera. The sclera has the following functions:

- The sclera protects the inner structures
- The sclera maintains the round shape of the eye
- The cornea permits light to enter the eye
- The cornea refracts light rays so as to focus them on the retina

The **choroid** is the middle layer, which contains blood vessels and a brown pigment. The choroid is continuous with the **ciliary body** and the **iris**. The ciliary body contains the **ciliary muscles**. The iris may be coloured blue, green, or brown etc. and gives the eye its colour. The opening in the centre of the iris is the **pupil**.

The **choroid** has the following functions:

- The pigment within the choroid prevents reflection of light within the eye by absorbing light rays.
- Suspensory ligaments arising from the ciliary body hold the lens in position.
- The ciliary muscles help to alter the shape of the lens for near and distant vision.
- The iris has radial and circular muscles, which control the size of the pupil.
- The pupil is able to control the amount of light entering the eye.

The **retina** is the innermost layer of the eye. It is made up of two types of light receptor cells viz. **rods** and **cones**. The nerve fibres from the rods and cones leave the eye as the **optic nerve**, which carries impulses to the brain. The **yellow spot**, a small depression in the centre of the retina, has a very high concentration of cones without rods. It is the centre of the clearest vision. The **blind spot**, the area of the retina from which the optic nerve arises, contains no rods and cones and is therefore not sensitive to light.

The **retina** has the following functions:

- The retina is the light sensitive area of the eye. Images are formed on the retina
- The rods are responsible for vision in dim light while the cones are responsible for bright light vision and colour vision

The **inside of the eye** contains the lens, the aqueous humour and the vitreous humour.

The **lens** is an elastic, transparent, biconvex structure situated behind the iris. It is held in position by the suspensory ligaments. The lens has two main functions as follows:

- The lens refracts light rays entering so as to focus them on the retina
- The shape of the lens can be altered for near and distant vision

The **aqueous humour** is the liquid that fills the space between the cornea and the lens. It has the following functions:

- It maintains the shape of the cornea
- It supplies the lens and cornea with food and oxygen
- It plays a minor role in the refraction of light

The **vitreous humour** is the jelly-like substances that fill the space behind the lens. It has the following functions:

- It maintains the shape of the eyeball
- It plays a minor role in the refraction of light

Functioning of the eye

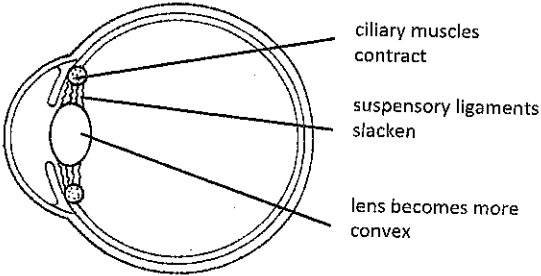
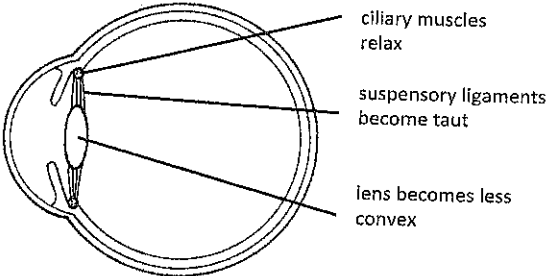
- Light reflected from objects passes through the cornea, aqueous humour, pupil, lens and vitreous humour and falls on the retina where an image is formed.
- The rods and cones pick up the stimulus and convert it to a nerve impulse.
- These impulses are conveyed to the optic nerve which transmits the impulse to the cerebrum of the brain. Here the impulse is interpreted.
- The eye is able to adjust to the distance of the object from the eye (accommodation) as well as to the light intensity (pupillary mechanism).

Binocular vision

Binocular vision is vision in which both eyes are used together. One of the advantages of binocular vision is that it gives a wider field of view. Since each eye forms an image, the two images are combined to form a three dimensional (stereoscopic) presentation of that object.

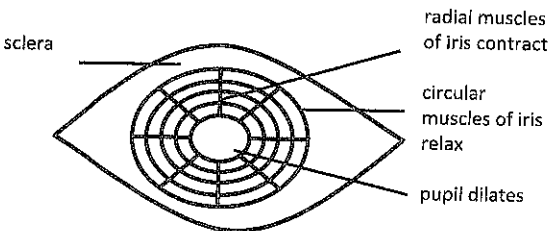
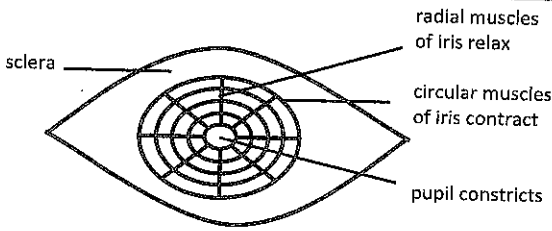
Accommodation

Accommodation refers to the ability of the eye to alter the convexity (shape) of the lens to ensure that a clear image always falls on the retina whether the object is near or distant.

For near vision (object less than 6 metres away)	For distant vision (object more than 6 metres away)
▫ The ciliary muscles contract ▫ The suspensory ligaments become slack ▫ The tension on the lens decreases ▫ The lens becomes more convex ▫ The refractive power of the lens is increased ▫ A clear image of the near object is now formed on the retina	▫ Ciliary muscles relax ▫ Suspensory ligaments become taut ▫ Tension on the lens capsule increases ▫ The lens becomes flattened (less convex) ▫ The refractive power of the lens is decreased ▫ A clear image of the distant object is now formed on the retina
	

Pupillary mechanism

The pupillary mechanism refers to the process by which the diameter of the pupil is altered so as to control the amount of light entering the eye.

In dim light	In bright light
▫ The radial muscles of the iris contract ▫ The circular muscles relax ▫ The pupil dilates ▫ The amount of light entering the eye is increased	▫ The circular muscles of the iris contract ▫ The radial muscles relax ▫ The pupil constricts ▫ The amount of light entering the eye is reduced
	

Diseases and Disorders of the Eye

- **Cataracts**

The clear, transparent lens of the eye sometimes becomes cloudy and opaque. The cloudy, opaque parts are called cataracts.

The treatment for cataracts involves the removal of the lens by surgery and replacing it with a synthetic lens.

- **Astigmatism**

If the cornea has an uneven surface it leads to astigmatism. Astigmatism results in the following symptoms:

- Distortion or blurring of images at all distances
- Headache and fatigue
- Squinting and eye discomfort or irritation

If the degree of astigmatism is great, prescription lenses will be needed for clear and comfortable vision.

Long-sightedness (Hypermetropia)

This may be caused by one of the following:

- The eyeball being too-rounded
- The inability of the lens of the eye to become more convex

In both cases, the image of the near object that falls on the retina is blurred while the best image (the most clearly focused) falls behind the retina. Persons who are affected in this way cannot see near objects clearly. However, their ability to see objects further than 6 metres from the eye is not affected and are said to be long-sighted.

Long-sighted persons can correct their ability to see near objects by wearing glasses with convex lenses.

Short-sightedness (Myopia)

This may be caused by one of the following:

- The eyeball being too long
- The inability of the lens of the eye to become flat enough (less convex)

In both cases, the image of the near object that falls on the retina is blurred while the best image (the most clearly focused) falls in front of the retina. Persons who are affected in this way cannot see distant objects clearly. However, their ability to see objects less than 6 metres from the eye is not affected and are said to be short-sighted.

Short-sighted persons can correct their ability to see near objects by wearing glasses with concave lenses.

THE EAR

Structure of the Ear

The ear consists of three regions viz. the outer ear, middle ear and inner ear.

The outer ear has the following functions:

- The pinna directs sound waves through the auditory canal to the tympanic membrane.
- The auditory canal conducts sound waves to the tympanic membrane; the cerumen (wax) and hairs found in the canal prevent small organisms

from entering the ear; the wax also prevents the ear drum from drying out.

The middle ear has the following functions:

- The tympanic membrane vibrates transmitting the sound waves to the ossicles.
- The ossicles transmit the vibrations from the tympanic membrane to the inner ear.
- The Eustachian tube maintains equal pressure on either side of the eardrum.

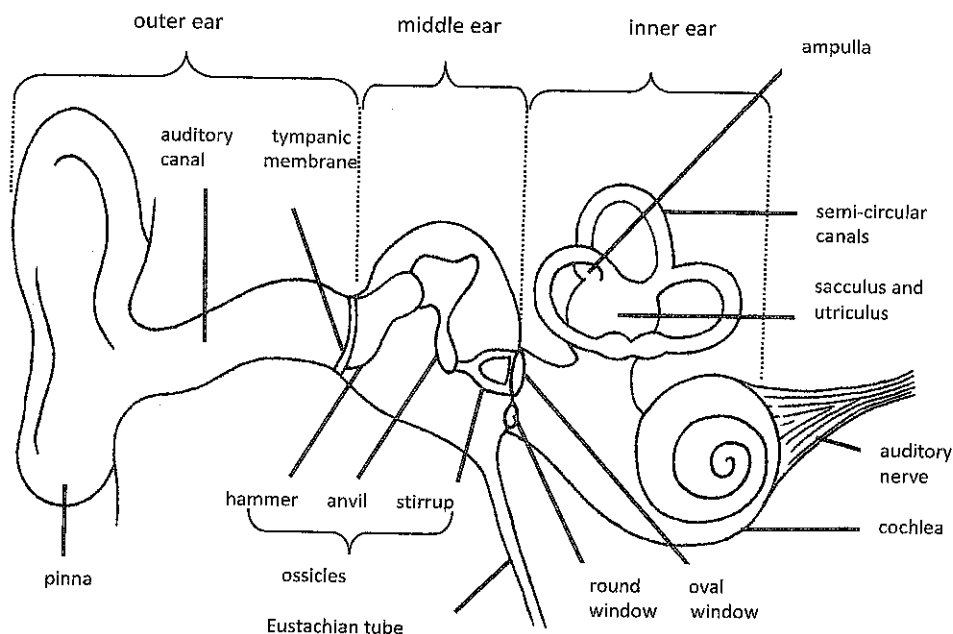


Fig. 6.21 Structure of the ear

The oval window transmits the vibrations of ossicles into the inner ear.

The round window absorbs the pressure set up in the inner ear.

The inner ear has the following functions:

The semicircular canals, sacculus and utricle are concerned with balance and equilibrium of the body,

The cochlea contains the organ of Corti which converts the stimulus of sound into an impulse.

The auditory nerve arising from the cochlea transmits the sound impulse to the brain.

Functioning of the ear

The ear is responsible for hearing and balance.

Hearing

The pinna traps and directs the sound waves into the auditory canal.

The sound waves strike the tympanic membrane and cause it to vibrate.

The vibrating membrane causes the ossicles, including the stirrup, to vibrate.

The stirrup causes the membrane on the oval window to vibrate.

This sets up waves in the fluid in the cochlea

The organ of Corti in the cochlea becomes stimulated.

The stimulus is converted to a nerve impulse.

The nerve impulse is carried by the auditory nerve to the cerebrum where the sound is interpreted.

The pressure in the cochlea is then eased out through the round window into the Eustachian tube.

Balance

Sudden changes in speed and direction causes the endolymph within the semicircular canals to move.

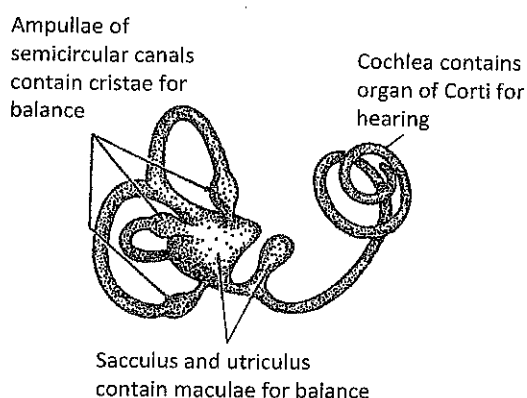
Since the three semi-circular canals are in three different planes, the fluid in at least one of the canals will move if your speed or direction changes.

The movement of the fluid stimulates the receptors called **cristae** within the ampullae situated at the base of each semi-circular canal.

When the direction of the head changes, gravitational pull stimulates different receptors

called **maculae**, within the sacculus and utricle.

- Within the cristae and maculae the stimuli are converted to nerve impulses.
- These impulses are transmitted by the vestibular branch of the auditory nerve to the cerebellum.
- The cerebellum sends impulses to the muscles to restore the balance.



Diseases and Disorders of the Ear

Middle Ear Infections

Middle ear infections are caused by viruses and bacteria. These micro-organisms cause the production of fluids which accumulate in the middle ear causing pressure and pain.

Sometimes, **grommets** are inserted into the eardrum. The grommet allows air to continuously enter the middle ear until infection clears.

Deafness

Hearing loss may be due to fluid in the middle ear, a damaged eardrum, hardened wax in the ear, hardening of ear tissues, injury to parts of the ear, nerves and parts of the brain responsible for hearing or simply due to the ageing process.

Medication, drainage of the middle ear, and hearing-aids, have all been used successfully. Hearing aids help in making the sounds louder. A hearing aid has three basic parts: a microphone, amplifier, and speaker.

For severe hearing problems, a cochlear implant is surgically implanted inside the ear. It works by stimulating any functioning auditory nerves inside the cochlea with an electric field.

TERMINOLOGY REVIEW

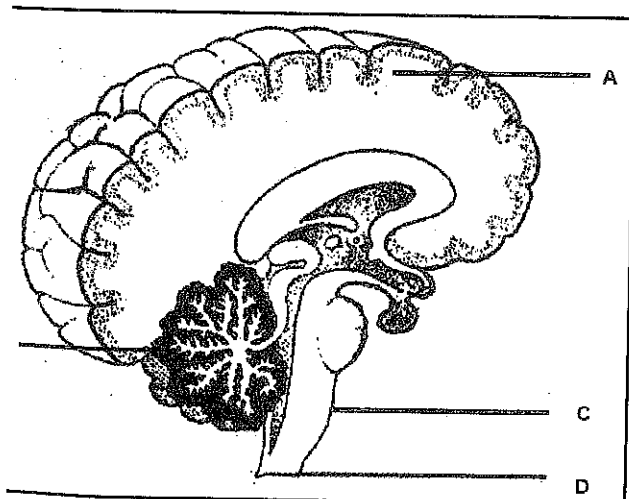
TERM	DESCRIPTION
Accommodation	The ability of the lens of the eye to alter its shape for clear vision
Alzheimer's disease	Disease caused by nerve defects usually in older people and characterised by memory loss and confusion
Astigmatism	Eye defect caused by an uneven corneal surface
Auditory nerve	Nerve transmitting impulses from the ear to the brain
Autonomic nervous system	Nervous system containing a sympathetic and parasympathetic section
Binocular vision	The use of two eyes to form an image, giving a wider field of vision
Blind-spot	Area in the retina that does not contain photoreceptors and therefore cannot form an image
Cataract	Cloudy, opaque portion in the lens of the eye
Central nervous system	Nervous system made up of the brain and the spinal cord
Cerebellum	The part of the brain which co-ordinates voluntary actions and which is responsible for balance
Cerebrum	The region of the brain associated with problem-solving
Cerebrum	The part of the brain where the sensation of sound is interpreted
Choroid	A pigmented layer in the eye which absorbs light and prevents its reflection.
Ciliary muscles	Muscles that contract or relax to change the shape of the lens in the eye
Cones	Receptor cells, sensitive to colour, found in the eye
Conjunctiva	Protective membrane situated over the cornea of the eye
Cornea	Transparent part of the sclera in front of the eye
Cristae	Receptors in the semi-circular canals of the ear that are sensitive to speed and direction

TERM	DESCRIPTION
Dendrites	Fibres that transmit impulses to cell body in a neuron
Effector	Structure that responds to stimulus received by receptor/senseorgan
Eustachian tube	The tube which connects the middle ear to the pharynx
Grommet	Structure inserted into the tympanic membrane to allow air to pass into the middle ear
Interneuron	Neuron that transmits impulse from the sensory neuron to the motor neuron
Iris	The part of the eye which is coloured black, brown, green, grey or blue
Long-sightedness	The ability to see objects far away clearly, but not objects close by
Maculae	Receptors in the sacculus and utricle of the ear that are sensitive to the position of the body
Medulla oblongata	A part of the brain responsible for involuntary actions such as breathing and dilation and constriction of blood vessels
Meninges	Protective membranes surrounding the central nervous system
Motor neuron	Neuron that transmits impulses from the central nervous system to the effectors
Multiple sclerosis	Disease caused by damage to the myelin sheath of neurons and characterised by physical and mental disabilities
Myelin sheath	Structure that insulates a neuron in order to speed up the transmission of impulses
Neuron	The structural unit of the nervous system.
Optic nerve	Nerve transmitting impulses from the eye to the brain
Organ of Corti	The structure, within the cochlea, responsible for picking up the stimulus of sound
Peripheral Nerves	Nerves linking receptor and effector organs with the brain and spinal cord.
Pupillary mechanism	Changes that occur in the diameter of the pupil under different light conditions
Radial muscles	The iris muscles that contract in dim light

TERM	DESCRIPTION
Receptor	Structure that receives a stimulus and converts it into an impulse for transmission
Reflex action	A rapid, automatic (involuntary) response to an external stimulus
Reflex arc	Path taken by an impulse during a reflex action
Retina	Layer of the eye containing photoreceptors and where images are formed
Rods	Photoreceptors in the retina that are stimulated under dim-light conditions
Sensory neuron	Neuron that transmits impulses from the sense organs to the central nervous system
Short-sightedness	The ability to see objects close by clearly, but not objects far away
Suspensory ligaments	Structures that hold the lens of the eye in position
Synapse	The physiological connection between the axon of one neuron and the dendrite of another
Yellow spot	Area of the retina with the highest concentration of cones.
Yellow-spot	Area in the retina that contains the highest amount of cones and therefore forms the clearest image

QUESTIONS

Study the diagram below and answer the questions that follow.

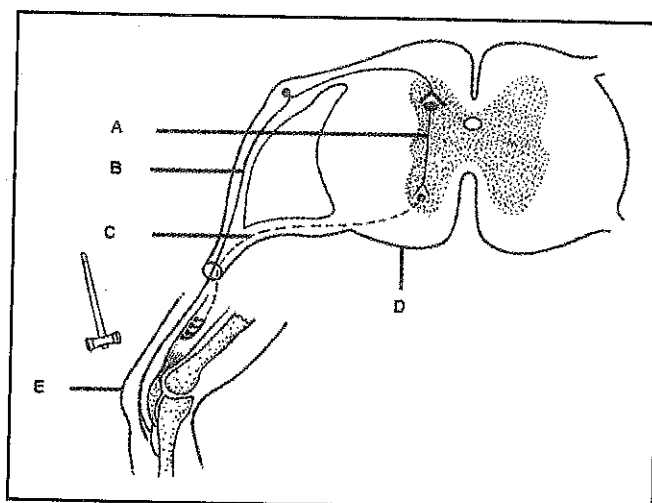


Write down the letter and the name of the part which:

- 1.1.1 Controls heartbeat (2)
- 1.1.2 Contains the centres that control balance, muscle tone and equilibrium (2)
- 1.1.3 Has centres that interpret what you see (2)
- 1.1.4 Coordinates voluntary muscle movements (2)
- 1.1.5 Has grey matter on the inside and white matter on the outside (2)

2.

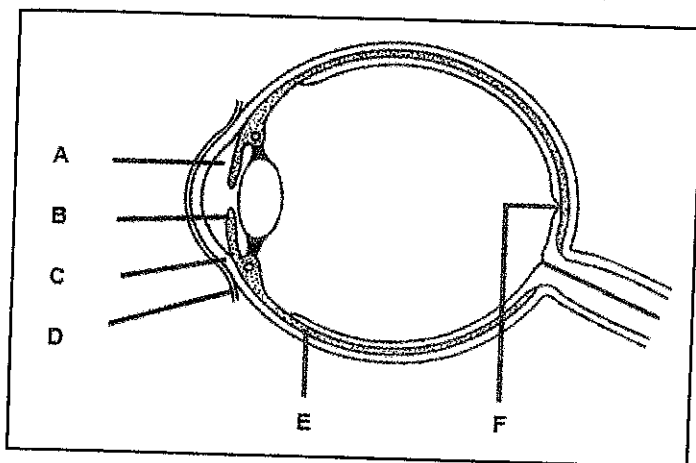
The following diagram shows the pathway through which impulses are transmitted in bringing about the knee-jerk in humans. Study the diagram and answer the questions that follow.



- 2.1 The knee jerk is an example of a reflex action. Differentiate between a reflex action and a reflex arc. (4)
- 2.2 Name and describe the role of parts B, A and C in the reflex action. (6)
- 2.3 Explain what would happen if part C is severed. (2)
- 2.4 Name the microscopic gap between structure A and structure C. (1)
- 2.5 Why are reflex actions important to the human body? (1)

3.

Study the following diagram and answer the questions that follow.



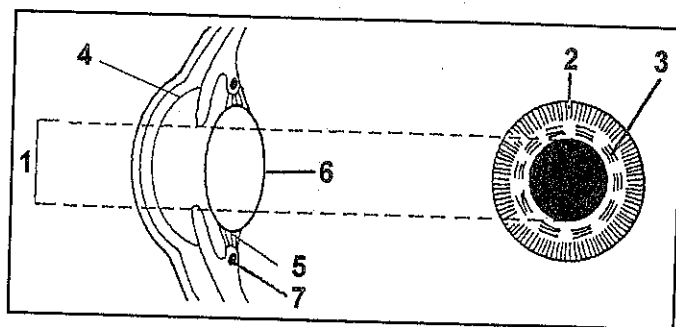
3.1 Write the **letter** and the **name** of each of the following:

- 3.1.1 Liquid that helps maintain the shape of the cornea (2)
 3.1.2 Region where the clearest image is formed (2)
 3.1.3 Part responsible for the colour of the eye (2)
 3.1.4 Layer that contains blood vessels and a brown pigment (2)

3.2 Describe the changes that occurs in the eye to focus on a bird that is flying off into the distance. (5)

4.

Study the diagrams below that illustrate a longitudinal section and anterior view of the human eye of a person looking at a nearby object in dim light, and answer the questions that follow.



4.1 Label parts 4 to 7. (4)

4.2 Name parts 1, 2 and 3 and describe the changes they bring about if the person walks into bright light from dim light. (6)

5.

Topsie did an investigation to determine the effect distance on the curvature (thickness) of the lens of human eye.

- She sat in a well-lit room.
- She covered her one eye with an eye patch.
- A pencil was held in front of her uncovered eye for seconds.
- She focussed on the pencil until a clear image could be seen and at the same time the curvature of the lens of her eye was measured with an optical instrument.

The pencil was then moved to different distances from eye and the curvature of the lens of the eye was measured each time. The results of the investigation are shown in table below.

DISTANCE OF THE PENCIL FROM THE EYE (cm)	CURVATURE OF THE LENS OF THE EYE (mm)
10	4,0
20	3,6
30	3,2
50	2,9
100	2,7
150	2,6
200	2,6

5.1 In this investigation:

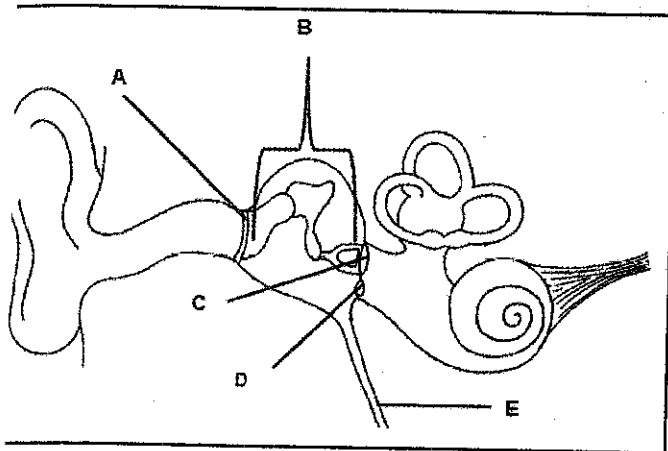
- 5.1.1 Which is the dependent variable? (1)
 5.1.2 Which is the independent variable? (1)
 5.2 State TWO factors that must be kept constant during the investigation. (2)
 5.3 Explain why the factors named in QUESTION 5.2 must be kept constant. (2)
 5.4 Describe the relationship between the distance of the pencil from the eye and the curvature of the lens of the eye. (3)
 5.5 Name TWO structures in the eye that are responsible for the changes in the curvature of the lens. (2)

6.

State the role played by each of the following in nervous co-ordination:

- 6.1 Receptors (1)
 6.2 Neurons (1)
 6.3 Effectors (1)

Study the diagram below showing a portion of the human ear and answer the questions that follow.



- 7.1 Provide labels for parts A, C and D, respectively. (3)
- 7.2 State ONE function for parts B and D, respectively. (2)
- 7.3 How are parts A and C together suited for the amplification of sound? (2)
- 7.4 Explain why hearing would be affected if part E becomes blocked with mucus. (3)

3. Name the receptors that are sensitive to each of the following and state where each is found in each organ.

- 3.1 Colour vision/vision in bright light (2)
- 3.2 Vision under dim-light conditions (2)
- 3.3 Sound vibrations (2)
- 3.4 Changes in direction and speed (2)
- 3.5 Changes in the position of the body (2)

4. Indicate whether each of the statements in COLUMN I apply 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.

COLUMN I	COLUMN II
4.1 Neuron located in the spinal cord only	A: Sensory neuron B: Interneuron
4.2 Nerves making up the peripheral nervous system	A: Cranial nerves B: Spinal nerves
4.3 Part of autonomic nervous system responsible for slowing the heartbeat	A: Sympathetic B: Parasympathetic
4.4 Responsible for balance and equilibrium	A: Cerebrum B: Cerebellum
4.5 Path taken by an impulse on stepping on a thorn	A: Reflex action B: Synapse

COLUMN I	COLUMN II
9.6 Characterised by damage to the myelin sheath of nerves	A: Alzheimer's disease B: Multiple sclerosis
9.7 Can be corrected by the use of convex lenses	A: Long-sightedness B: Short-sightedness
9.8 Changes in the eye in response to light conditions	A: Pupillary mechanism B: Accommodation
9.9 Used to treat middle-ear infections	A: Cochlear implants B: Grommets

9x2 (18)

ANSWERS

1.
 - 1.1 C✓ – medulla oblongata✓
 - 1.2 B✓ – cerebellum✓
 - 1.3 A✓ – cerebrum✓
 - 1.4 B✓ – cerebellum✓
 - 1.5 D✓ – spinal cord✓

(10)

2.
 - 2.1 - A reflex action is a rapid, automatic response✓ to a stimulus✓
- A reflex arc refers to the path taken by an impulse✓ during a reflex action✓

(4)

- 2.2 - B – sensory neuron✓: transmits impulses from the receptors to the spinal cord✓
- A – connector neuron✓/inter-neuron: transmits impulses from the sensory neuron to the motor neuron✓
- C – motor neuron✓: transmits impulses from the spinal cord to the effector organ✓ (muscle or gland)

(6)

- 2.3 The person will feel the pain✓ associated with the knee jerk but will not be able to react/move his or her leg✓.

(2)

- 2.4 Synapse✓

(1)

- 2.5 Protects the human body against damage✓

(1)

3.
 - 3.1
 - 3.1.1 A✓ – aqueous humour✓
 - 3.1.2 F✓ – yellow spot✓
 - 3.1.3 B✓ – iris✓
 - 3.1.4 E✓ – choroid✓

(2)

(2)

(2)

(2)

- 3.2 Accommodation occurs for distant vision✓
The ciliary muscles relax✓
The suspensory ligaments become taut✓
The tension on the lens increases✓
The lens becomes less convex✓
The refractive power of the lens decreases✓
The image of the bird falls on the retina✓ any

(5)

- 4.
- 4.1 4 – cornea✓
5 – suspensory ligaments✓
6 – lens✓
7 – ciliary muscles✓ (4)
- 4.2 Part 2 – radial muscles of iris✓ relax✓
Part 3 – circular muscles of iris✓ contract✓
Part 1 – pupil✓ constricts✓ (6)
- 5.
- 5.1 5.1.1 Curvature of the lens✓ (1)
5.1.2 Distance of pencil from the eye✓ (1)
- 5.2 Amount of light✓
Time✓ to focus on the pencil
Use the same pencil✓
Use the same eye✓ any (2)
- 5.3 - To increase the validity✓ of the procedure✓
- To ensure that the results are due to the distance of the pencil from the eye✓ and not any other factor✓ any 1 x 2 (2)
- 5.4 - The curvature of the lens of the eye decreases✓
- as the pencil moves further away✓ from the eye.
- Further than 150 cm there are no changes in the thickness✓ (3)
- 5.5 Ciliary muscles✓ (3)
Suspensory ligaments✓ (2)
- 6.
- 6.1 Receptors – receive stimuli and convert them into nerve impulses✓ (1)
- 6.2 Neurons – transmit impulses to and from the central nervous system✓ (1)
- 6.3 Effectors – respond to stimuli✓ (1)
- 7.
- 7.1 A – tympanic membrane✓
C – oval window✓
D – round window✓ (3)
- 7.2 B – transmit vibrations to the oval window✓
D – eases pressure from the inner ear✓ (2)
- 7.3 Part A has a large surface area✓
Part C has a small surface area✓ (2)
- 7.4 - Air will not be able to pass through the Eustachian tube✓
- to balance the pressure on either side of the tympanic membrane✓
- Tympanic membrane will not be able to vibrate✓
- Hearing will thus be affected if vibrations do not pass from the tympanic membrane (3)
- 8.
- 8.1 Cones✓ – located in the retina✓ (1)
- 8.2 Rods✓ – located in the retina✓ (1)
- 8.3 Organ of Corti✓ – located in the cochlea✓ (1)

- 8.4 Cristae✓ – located in the ampullae/semi-circular canals✓
- 8.5 Maculae✓ – located in the sacculus and utricle✓
- 9.
- 9.1 B only✓✓
- 9.2 Both A and B✓✓
- 9.3 B only✓✓
- 9.4 B only✓✓
- 9.5 None✓✓
- 9.6 B only✓✓
- 9.7 A only✓✓
- 9.8 A only✓✓
- 9.9 B only✓✓

7

Human
Endocrine System

INTRODUCTION

Humans use two systems to respond to the environment viz. the nervous system with its sense receptors and the endocrine system.

Our bodies have two kinds of glands. These are the 'endocrine glands' and 'exocrine glands'.

Endocrine glands do not have ducts. They pour their secretions into the blood which then transports

them to where they are required. The secretions of endocrine glands are called hormones.

Exocrine glands have ducts which carry their secretions to where they are required. The salivary glands and the sweat glands are examples of exocrine glands.

The pancreas functions both as an endocrine as well as an exocrine gland. When the pancreas secretes pancreatic juice, which is carried to the duodenum by means of the pancreatic duct, it functions as an exocrine gland. When special tissues inside the pancreas (called the islets of Langerhans) secrete the hormones insulin or glucagon, directly into the blood, it functions as an endocrine gland.

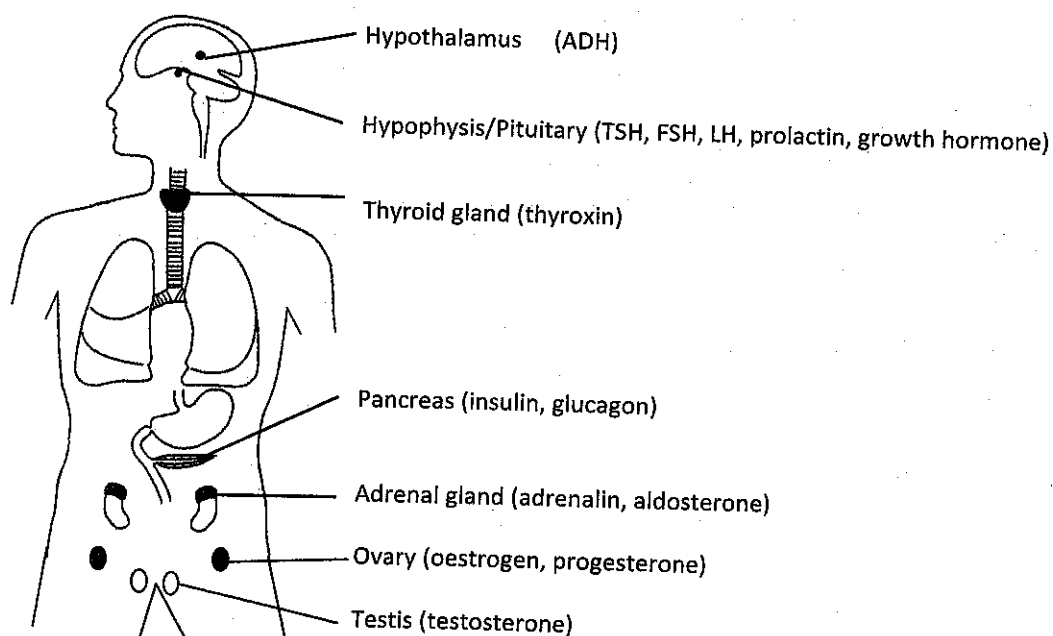


Fig. 7.1 Endocrine glands and their hormones

ENDOCRINE GLANDS AND THEIR FUNCTIONS

Gland	Location of gland	Hormone	Function/s of hormone
Hypothalamus	Underside of the brain	ADH	- Controls the level of water in the body by: - Controlling the permeability of the kidney tubules, - thus controlling the re-absorption of water in the body
Thyroid	Either side of the trachea	Thyroxin	- Regulates the metabolic rate e.g. respiration - Affects growth and functioning of the heart and nervous system

Gland	Location of gland	Hormone	Function/s of hormone
Pituitary/ Hypophysis	At the base of the brain, attached to the hypothalamus	TSH	- Controls the level of thyroxine in the blood by: - Stimulating the thyroid gland to secrete more thyroxine when its level is low - Decreasing stimulation of the thyroid gland so that less thyroxine is secreted when its level is high
		FSH	Stimulates the production of an ovum in the Graafian follicle in the ovary
		LH	Stimulates ovulation
		Prolactin	Converts the Graafian follicle into a corpus luteum
		Growth hormone	- Stimulates the production of milk in the mother - Controls the growth and development of the skeleton and the muscles
Pancreas	Attached to the duodenum/in the loop of the duodenum	Insulin	- Decreases blood glucose level by: - Promoting the absorption of glucose into the cells - Stimulating the conversion of glucose into glycogen for storage in the liver and muscles
		Glucagon	- Increases blood glucose level by: - Stimulating the conversion of glycogen to glucose
Adrenal	On each kidney	Adrenalin	- Prepares the body for an emergency by: - Stimulating the conversion of glycogen to glucose - Increasing the breathing rate - Increasing the heart-beat - Increasing the metabolic rate
		Aldosterone	- Regulates the amount of salt in the blood - Works with ADH to bring about water balance
Ovaries	Pelvic region of the abdominal cavity	Oestrogen	- Development of secondary sexual characteristics in females - Starts preparation for pregnancy by making the endometrium thicker, more vascular and more glandular
		Progesterone	- Continues the preparation for pregnancy by making the endometrium thicker, more vascular and more glandular - Maintains the endometrium during pregnancy
Testes	Pelvic region	Testosterone	Development of secondary sexual characteristics in males

NEGATIVE FEEDBACK MECHANISMS

Most living organisms, especially mammals and birds, are capable of homeostasis. In other words, they are able to keep their internal environment more or less constant, despite changes in the internal and external environment. Usually, homeostasis is brought about through various negative feedback mechanisms. We shall now consider two examples of negative feedback mechanisms that relate to the endocrine system.

TSH and Thyroxin

When the thyroxin level is too low, the pituitary gland is stimulated to secrete more TSH. The increased TSH causes the thyroid gland to secrete more thyroxin and the thyroxin level of the blood is raised to the normal limits.

When the thyroxin level of the blood is too high, the pituitary gland secretes little TSH. Little or no thyroxin is secreted and the thyroxin level is thus reduced to normal limits.

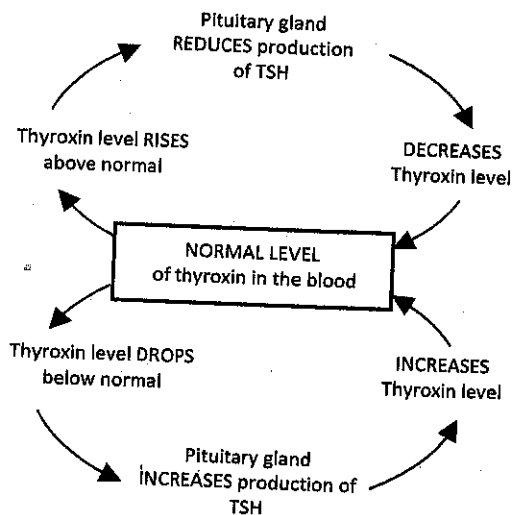


Fig. 7.2 Control of thyroxin level

Insulin and Glucagon

Two hormones, insulin and glucagon, secreted by the islets of Langerhans in the pancreas, control the concentration of the glucose level of the blood.

When the blood sugar level is higher than normal, the hormone insulin is secreted. Insulin reduces the blood sugar level in two ways:

- It increases the rate at which glucose is absorbed by the cells, especially the cells of the liver and muscles
- It stimulates the conversion of glucose into glycogen and fat in the liver and muscles.

When the blood sugar level is lower than normal, the hormone glucagon is secreted. Glucagon increases the blood sugar level by stimulating the conversion of glycogen to glucose for release into the bloodstream.

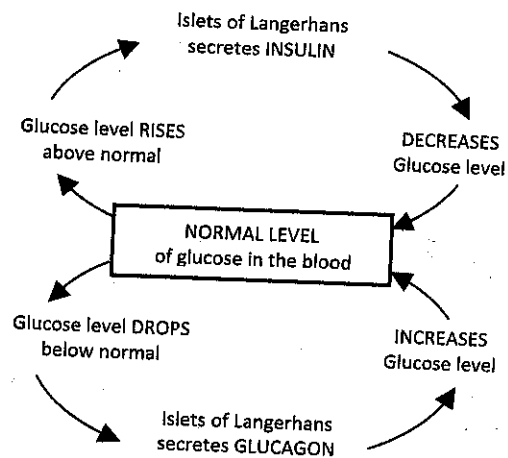


Fig. 7.3 Control of glucose level

Sometimes the glucose level of the blood rises and the body finds it difficult to restore the glucose to its normal levels. The kidneys excrete some of the excess glucose. This condition is termed diabetes mellitus. There are two types of diabetes mellitus:

Type 1 diabetes - occurs when the pancreas stops producing insulin. It usually starts in young people under the age of 30, including very young children and infants, and the onset is sudden and dramatic. People who have type 1 diabetes must inject insulin to survive. Insulin dosages are carefully balanced with food intake and exercise programmes.

Type 2 diabetes - is caused when the insulin, which the pancreas produces, is either not enough or does not work properly. Approximately 85 - 90% of all people with diabetes are type 2. Most type 2's are over 40. They are usually overweight and do not exercise. Type 2 diabetes may be treated successfully without medication. Often loss of weight alone will reduce glucose levels. Eating patterns and exercise play important roles in management. Tablets may be prescribed to help improve control; however, many type 2 patients will eventually use insulin.

Symptoms of diabetes include the following:

- Glucose in the urine
- Frequent urination
- Extreme thirst
- Fatigue/lethargy/faintness
- Nausea/vomiting
- Weight loss
- Blurred vision
- Non-healing of wounds

Treatment of diabetes includes the following:

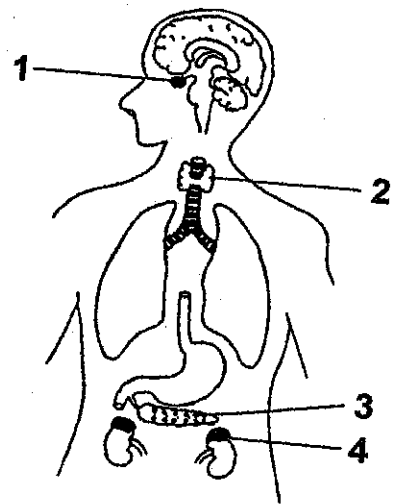
- Exercise
- Eating a diet suitable for diabetic person
- Using prescribed medication/drugs for the management of diabetes mellitus

TERMINOLOGY REVIEW

TERM	DESCRIPTION
ADH	Hormone that controls the re-absorption of water in the kidney
Adrenalin	Hormone that increases heart beat and blood pressure in emergency situations
Aldosterone	Hormone that maintains salt balance in the body
Diabetes	Condition caused by the absence of insulin or through ineffective insulin
Endocrine glands	Glands that pour their secretions directly into the blood stream
Glucagon	Pancreatic secretion that increases the blood sugar level
Growth hormone	Hormone that controls normal growth and development
Hypophysis/Pituitary	Gland that produces FSH and LH
Hypothalamus	Part of the brain to which the hypophysis is attached
Insulin	Hormone that promotes absorption of glucose into cells
Kidneys	Organ on which the adrenal glands are located
Negative feedback	Interaction between TWO endocrine glands, where a change in the hormonal production level of one, is referred back to it, resulting in an opposite response
Oestrogen	Hormone produced by the Graafian follicle
Oxytocin	Hormone responsible for stimulating childbirth
Pancreas	A gland that functions both as an endocrine and an exocrine gland
Progesterone	Hormone produced by the corpus luteum
Prolactin	Hormone responsible for stimulating milk production
Testosterone	Hormone responsible for secondary sexual characteristics in males
Thyroxin	Hormone that controls metabolism
TSH	A hormone which stimulates secretion of the thyroid gland

QUESTIONS

1. Study the diagram below and answer the questions that follow.

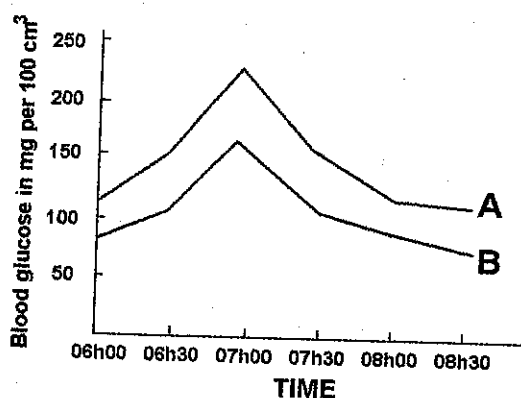


- 1.1 Label the parts numbered 1, 2, 3 and 4.
- 1.2 Write down only the NUMBER of the gland that:
 - 1.2.1 Produces the hormone glucagon
 - 1.2.2 Produces a hormone that controls the growth of long bones
 - 1.2.3 Produces an iodine-containing hormone
 - 1.2.4 Produces a hormone that is involved in the re-absorption of some salts by the kidneys
- 1.3 State TWO similarities between hormones and nerves with regard to their functions.
- 1.4 State ONE functional difference between hormones and motor nerves.
2. The kidneys normally start to excrete glucose when the glucose level exceeds about 180 mg per 100 cr blood. At this point glucose appears in the urine.

Two individuals, A and B, fasted for several hours and were then given 50g glucose dissolved in 150cr of water at 6h00. The glucose level of the blood was determined at the same time and subsequently every half-hour for two and a half hours in both individuals.

The results of the glucose test are shown in the following graph.

Human Endocrine System



- 2.1 What is the difference in the blood glucose level of individual A and B at 07h00? (2)
 - 2.2 Why was the testing continued for only two and a half hours? (2)
 - 2.3 Would a test have revealed glucose in the urine of individual B at 06h30? Give a reason for your answer. (2)
 - 2.4 Name the disease individual A probably has. (1)
 - 2.5 Experiments have shown that a drug called ALLOXAN destroys certain cells of the body. If individual B takes the drug ALLOXAN, results of B are similar to that of individual A. State the location and function of the cells which are destroyed by ALLOXAN. (3)
- (10)

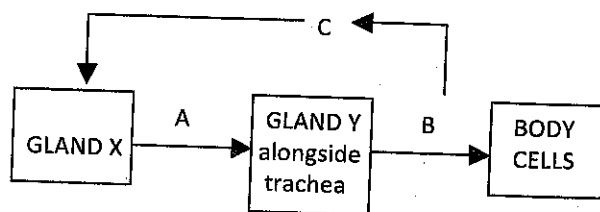
3. A hormone produced by the body during emergencies has the following effects:-

- A. The heartbeat increases
- B. The arteries supplying the gut constrict
- C. The arteries supplying the liver and muscles dilate

- 3.1 Name the hormone that brings about these changes. (1)
- 3.2 State where in the body this hormone is produced and how it reaches various parts of the body. (2)
- 3.3 Explain why this hormone has contrasting effects on the arteries to the gut and muscles. (7)

- 3.4 Explain why continued production of this hormone can lead to a high level of lactic acid in the muscles. (2)
 - 3.5 State the role of the liver during an emergency. (2)
- (15)

4. In the diagram below X and Y represent two endocrine glands in the body.



- 4.1 Identify glands X and Y. (2)
 - 4.2 Name hormones A and B produced by these glands and state ONE function of each hormone. (4)
 - 4.3 List THREE characteristic features of hormones. (3)
 - 4.4 Explain why pathway C is referred to as a negative feedback mechanism. (4)
 - 4.5 Tabulate TWO differences between hormonal and nervous co-ordination. (4)
 - 4.6 List FIVE ways in which adrenalin prepares the body for an emergency. (5)
- (22)

ANSWERS

1.
 - 1.1
 - 1 – Pituitary gland✓
 - 2 – Thyroid gland✓
 - 3 – Pancreas✓
 - 4 – Adrenal gland✓

(4)
 - 1.2
 - 1.2.1 3✓ (1)
 - 1.2.2 1✓ (1)
 - 1.2.3 2✓ (1)
 - 1.2.4 4✓ (1)
 - 1.3
 - They respond to internal and/or external stimuli✓
 - They bring about co-ordination✓

(2)
 - 1.4

Hormones: Responses are slow processes✓/may affect multiple sites

Nerves: Responses are quick reactions✓/affect localised sites

(2)

2. 75 mg✓/100 cm³✓ (2)
- 2.2 Level back to original level/by this time the level drops (2)
- 2.3 No✓ - it is only 100 mg/cm³ i.e. not above 180 mg/cm³✓ (2)
- 2.4 Diabetes mellitus✓ (1)
- 2.5 Pancreas/islets of Langerhans✓
 - Secretes insulin which stimulates the conversion of glucose to glycogen in liver and muscles✓ and
 - Promotes absorption of glucose into cells✓ (3)
3. Adrenalin✓ (1)
- 3.1 Adrenalin✓ (1)
- 3.2 - Adrenal glands✓
 - Carried by the blood and diffuses out of blood capillaries to the cells✓ (2)
- 3.3 - During an emergency more energy is required by the muscles✓
 - and less energy is required by the gut✓
 - The blood vessels of the gut constrict to reduce its blood supply✓
 - thus making more blood available for the muscles✓
 - The blood vessels of the muscles dilate to carry more blood✓
 - with more oxygen and glucose for cellular respiration✓
 - thus producing extra energy in the muscles✓ (7)
- 3.4 - Muscle cells undergo continued strenuous activity✓
 - Oxygen supply becomes depleted✓
 - Anaerobic respiration takes place✓
 - producing lactic acid✓ any (2)
- 3.5 - Converts stored glycogen to glucose✓
 - which is then released into the blood stream to be used as a source of energy for cellular respiration✓ (2)

4. 4.1 X - Pituitary✓
 Y - Thyroid✓
- 4.2 A: TSH✓ - stimulates thyroid gland to produce thyroxin✓
 B: Thyroxin✓ - regulates metabolic rate✓
- 4.3 - Chemical messengers✓
 - Mostly protein in nature✓
 - Transported by blood✓
 - Have specific effect on target organs✓
 - Required in minute quantities✓
 - Can stimulate or inhibit body functions✓
 - Responses controlled by hormones are slower than those under nervous control✓
 - Hormones may interact with each other to form an integrated system✓ any
- 4.4 - The output of thyroxin determines the level of its own production later✓
 - A high level of thyroxin inhibits production of TSH✓
 - and thyroid stimulation thus decreases
 - Less thyroxin is produced✓
 - And thus the correct level of thyroxin is maintained✓ any
- 4.5
- | Hormonal Co-ordination | Nervous Co-ordination |
|---|---|
| - impulses are chemical✓ | - impulses are electro-chemical✓ |
| - hormones carried by blood✓ | - impulses travel along nerves✓ |
| - responses are slow✓ | - responses are rapid✓ |
| - responses brought about by target organs✓ | - responses brought about by effectors✓ |
- 4.6 - Increases heart beat✓
 - Increases blood pressure✓
 - Reduces peripheral circulation✓
 - Increases circulation to brain and muscles✓
 - Increases muscle tone✓
 - Increases rate and depth of breathing
 - Dilates bronchi✓
 - Converts glycogen to glucose✓
 - Increase production of thyroxin and thus metabolic rate✓ any

Homeostasis in Humans

INTRODUCTION

Homeostasis is the tendency of living organisms to maintain a constant composition of their internal environment, within narrow limits. The internal environment of multicellular organisms is the tissue fluid in which the cells are bathed.

The composition of the tissue fluid is affected by its pH, water concentration, oxygen and carbon dioxide content, glucose concentration and its temperature. All these factors need to be controlled to keep the composition of the tissue fluid constant. If this constancy is not maintained the functioning of the body is negatively affected.

NEGATIVE FEEDBACK

The level of glucose, carbon dioxide, water and salt levels, amongst others, need to be kept constant, within narrow limits. If there is an imbalance in any one of these substances (too high or too low level) then information of this imbalance is reported or fed-back to a controlling centre which could be the central nervous system or an endocrine gland. The controlling centre then sends messages (through nerve impulses or hormones) to bring about a negative response i.e. to oppose the imbalance such that normal levels of these substances are restored. In this way homeostasis of the blood with regard to levels of these substances is maintained. This is called negative feedback.

Maintaining the Blood Glucose Level

When the blood glucose level is too high:

- The pancreas secretes insulin
- which reduces the blood glucose level in the following ways:
 - It promotes the absorption of glucose into the cells, for use in cellular respiration.
 - It stimulates the liver and muscles to convert glucose into glycogen, for storage in the liver and muscles.

When the blood glucose level is too low:

- The pancreas secretes glucagon
- which increases the blood glucose level
- by converting stored glycogen from the liver or muscles, into glucose.

In some persons, there is a shortage of the hormone insulin because of disease or damage to the cells of the islets of Langerhans. In some other cases, the quality of the insulin produced is very poor. Both types of people do not have the ability to reduce their blood glucose levels when it becomes too high. We say that they suffer from **diabetes mellitus**. Those who have diabetes mellitus show the following symptoms:

- Abnormally high blood glucose levels
- Excretion of glucose in the urine (the kidney tries to reduce the glucose level by getting rid of some glucose with the urine)

Maintaining Oxygen and Carbon Dioxide Levels

- When the carbon dioxide in the blood rises above the normal level
- the medulla oblongata of the brain becomes stimulated
- and sends impulses to the heart and to the breathing muscles.
- The heart beats faster and blood carrying carbon dioxide is pumped faster to the lungs from the tissues.
- The breathing muscles cause the breathing movements to be speeded up.
- Carbon dioxide is removed out of the body more quickly and more oxygen is taken in rapidly and supplied to the tissues.
- In this way, the levels of oxygen and carbon dioxide are brought back to their normal limits.

Maintaining Water Levels (Osmoregulation)

The nephron in the kidney controls the amount of water in the blood.

When the body has too much water

- due to low temperature, inactivity or the intake of a large amount of fluids,
- the volume of water in the blood increases.
- The hypothalamus is stimulated

- and a message is sent to the pituitary gland
- to secrete less ADH into the blood.
- The walls of the distal convoluted tubule and collecting tubule of the nephron become less permeable.
- Less water is thus re-absorbed from these tubules
- and more water remains in the tubule forming very dilute urine.
- In this way the level of water in the blood decreases.

When the body has too little water

- due to high temperature, strenuous activity or insufficient intake of fluids,
- the volume of water in the blood decreases.
- The hypothalamus is stimulated
- and a message is sent to the pituitary gland to secrete more ADH into the blood.
- The walls of the distal convoluted tubule and collecting tubule of the nephron become more permeable.
- More water is re-absorbed from the tubules into the blood capillaries.
- The amount of water in the blood thus increases
- The tubule however has less water, forming very concentrated urine.

Maintaining Salt Levels

The amount of sodium ions that is excreted can be regulated as follows:

When there is a shortage of sodium in the blood

- The adrenal gland secretes more aldosterone.
- More sodium is thus reabsorbed by the blood capillaries at the distal and collecting tubules
- so that less sodium ions are thus excreted.
- In this way the amount of sodium increases back to normal.

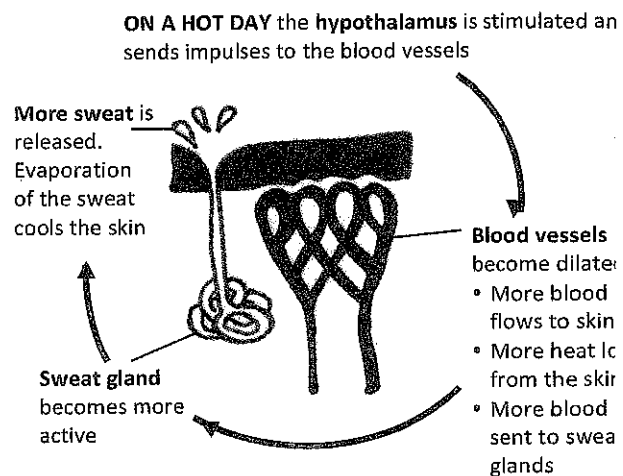
When there is an excess of sodium ions in the blood

- The secretion of aldosterone from the adrenal gland decreases.
- Less sodium is thus reabsorbed by the blood capillaries
- allowing more sodium to be excreted.
- The amount of sodium in the blood decreases back to normal.

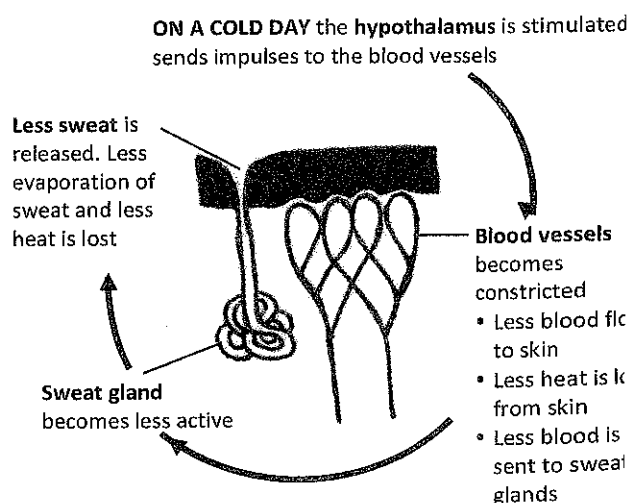
THERMOREGULATION

The normal human body temperature is around 37°C . The functioning of the body will be affected if the temperature drops far below or rises far above 37°C .

- When the body temperature is too high (such as on a hot day)
- the skin reduces the body temperature back to normal through vasodilation (increase in the internal diameter of the blood vessels) and increased sweating as indicated in the following diagram:



- When the body temperature is too low (such as on a cold day)
- the skin increases the body temperature back to normal through vasoconstriction (decrease the internal diameter of the blood vessels) and decreased sweating as indicated in the following diagram:

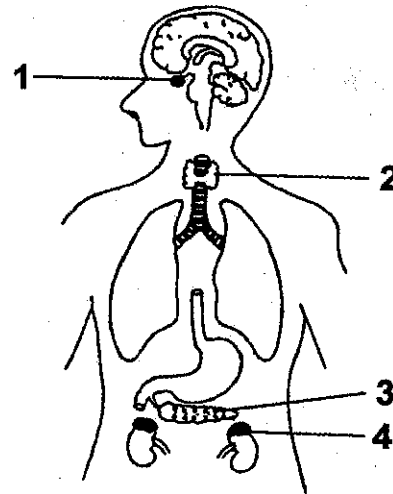


TERMINOLOGY REVIEW

TERM	DESCRIPTION
ADH	The hormone that is responsible for water re-absorption in the kidney tubules
Adrenal gland	The gland responsible for the secretion of adrenalin
Aldosterone	The hormone responsible for regulating the level of salt in the blood
Diabetes mellitus	Disease that results from a shortage of insulin or poor quality insulin
Glucagon	The hormone that increases blood-glucose level
Homeostasis	The maintenance of a constant internal environment in the body, with narrow limits
Hypothalamus	A part of the brain that controls body temperature
Insulin	The hormone that reduces blood glucose level
Medulla oblongata	A part of the brain that is stimulated by changes in the CO ₂ concentration in the blood
Negative feedback	The mechanism used to oppose an imbalance when conditions in the tissue fluid rise or fall below normal levels
Osmoregulation	Control of the level of water in the body
Pituitary	The gland responsible for the secretion of the ADH
Sweat glands	The glands that help to regulate body temperature through the production of sweat
Tissue fluid	The fluid that bathes the cells of the body
Vasoconstriction	A decrease in the internal diameter of blood vessels which decreases blood flow
Vasodilation	A increase in the internal diameter of blood vessels which increases blood flow

QUESTIONS

1. Study the diagram below and answer the questions that follow.



- 1.1 Write down the NUMBER and NAME of the gland that:
- 1.1.1 Secretes glucagon (1)
 - 1.1.2 Secretes ADH (1)
 - 1.1.3 Secretes aldosterone (1)
 - 1.1.4 Secretes insulin (1)
- 2.
- 2.1 Name the part of the brain that is stimulated when:
- 2.1.1 The water level is too low (1)
 - 2.1.2 CO₂ level is too high (1)
 - 2.1.3 The body temperature drops (1)
- 2.2 Describe the role of each of the following in maintaining homeostasis in the human body:
- 2.2.1 Aldosterone (2)
 - 2.2.2 Glucagon (2)
 - 2.2.3 The breathing muscles (2)
 - 2.2.4 ADH (2)
 - 2.2.5 Vasodilation (2)
- 2.3 In terms of homeostasis, explain why, after a period of strenuous exercise:
- 2.3.1 Concentrated urine is formed (3)
 - 2.3.2 The heart-beat increases (3)
 - 2.3.3 The skin appears flushed (3)

ANSWERS

- 1.
- 1.1 1.1.1 3 – pancreas✓ (1)
 1.1.2 1 – pituitary✓ (1)
 1.1.3 4 – adrenal✓ (1)
 1.1.4 3 – pancreas✓ (1)
- 2.
- 2.1 2.1.1 Hypothalamus✓ (1)
 2.1.2 Medulla oblongata✓ (1)
 2.1.3 Hypothalamus✓ (1)
- 2.2 2.2.1 - Aldosterone influences the re-absorption of sodium ions✓
 - from the kidney tubule into the blood✓ (2)
- 2.2.2 - Glucagon increases glucose level✓
 - by converting glycogen to glucose✓ (2)
- 2.2.3 - The breathing muscles increase the breathing rate✓
 - allowing CO₂ to be released quickly from the lungs✓ (2)
- 2.2.4 - ADH influences the permeability of the kidney tubules✓
 - and therefore the amount of water re-absorbed✓ (2)
- 2.2.5 - Vasodilation allows more blood to flow to the skin✓
 - so that more heat can be lost✓ (2)
- 2.3 2.3.1 - Excessive sweating during exercise✓
 - leads to excessive loss of water✓
 - so more water is re-absorbed from the kidney tubules into the blood✓
 - and less water is lost in the urine✓ making it concentrated any (3)
- 2.3.2 - Blood can be taken to the lungs at a faster rate✓
 - to eliminate the excess CO₂ formed✓
 - as a result of the high respiratory rate associated with exercise✓
 - and to collect more oxygen✓ any (3)

- 2.3.3 - More blood is sent to the skin✓
 - due to the dilation of the blood vessels✓
 - so that more sweat is formed✓
 - and more heat is lost✓
 any

9

Plant Responses to the Environment

INTRODUCTION

- A hormone is an organic substance produced in small amounts in one part of the body and transported to other parts where it controls the growth and development in some specific way.
- Auxins, gibberellins and abscisic acid are some examples of plant growth substances that may be considered to be hormones.

ROLE OF DIFFERENT HORMONES

Auxins

Auxins have the following functions:

- Bring about a bending reaction in plants known as tropism. Geotropism and phototropism are examples of tropisms
- Promote cell division
- Responsible for cell enlargement
- Responsible for apical dominance. Auxins in the apical bud will promote vertical growth and inhibit the growth of lateral branches. If the apical bud is removed (i.e. apical dominance is removed) then the growth of lateral branches is promoted.
- Promote root development.

Gibberellins

Gibberellins have the following functions:

- Bring about elongation of the internodes of stems
- Stimulates root growth
- Promote development of flowers
- Appear to promote sprouting of buds which have been dormant
- Helps in the germination of seeds
- Increases fruit size.

Abscisic Acid

Abscisic acid has the following functions:

- Brings about dormancy of seeds by slowing down germination, and dormancy of apical buds
- Induces flowering in some plants

- Helps in the closing of stomata during periods of water shortage or drought
- Promotes the ageing of leaves.

PHOTOTROPISM AND GEOTROPISM

Auxins are plant growth substances produced at the tips of roots and shoots. The most well-known auxin is indole-acetic acid (IAA). Auxins bring about bending reactions in plants referred to as **tropisms**.

A tropism is a growth movement or bending reaction of a plant (or part of a plant) in response to an external stimulus. The direction of growth or bending of the plant depends on the direction of the stimulus. When the external stimulus is light, this is known as phototropism. If the external stimulus is gravity, this is known as geotropism.

Phototropism is the growth movement of plant organs in response to the stimulus of light. Stems are positively phototropic i.e. they grow towards light. Roots are negatively phototropic i.e. they grow away from light.

Geotropism is the growth movement of plant organs in response to the stimulus of gravity. Roots are positively geotropic while stems are negatively geotropic.

Role of auxins in phototropism

- Auxins are produced at the tip of the stem from where they move downwards evenly.
- The even distribution of auxins brings about equal growth on all sides of the stem.
- Therefore, the stem grows straight upwards.
- When stems are exposed to unilateral light (light from one side) the brightly-lit side suffers from a shortage of auxins probably because the auxins are destroyed by the light or because they move to the darker side.
- A high concentration of auxins in stems promotes growth.
- Thus an uneven distribution of auxins causes uneven growth of the stem with the darker side growing faster.
- The stem thus bends towards the light i.e. stems are positively phototropic.

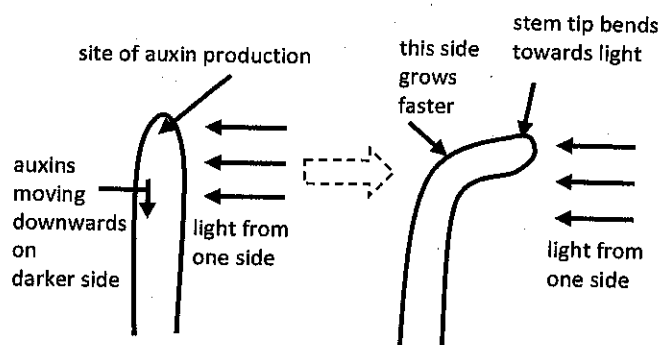


Fig. 9.1 Effect of unilateral light on stem tips

Role of auxins in geotropism

- Auxins are produced at the tip of the root from where they move upwards evenly.
- The even distribution of auxins brings about equal growth on all sides of the root.
- Therefore, the root grows straight downwards.
- When a root is placed horizontally the auxins accumulate on the lower side probably because of gravity.
- A high concentration of auxins in roots inhibits growth.
- Thus uneven distribution of auxins causes uneven growth of the root with the upper side growing faster.
- The root thus bends downwards i.e. roots are positively geotropic.

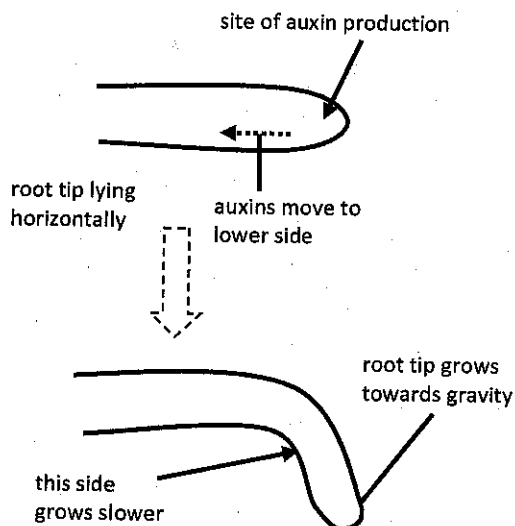


Fig. 9.2 Effect of gravity on a root tip placed horizontally

WEED CONTROL USING PLANT HORMONES

- Hormone weed-killers are auxin-based selective herbicides. They are chemicals that kill only one specific type of unwanted plant as long as they are used in the appropriate dosage.
- Hormone weed-killers target and kill weeds specifically.
- The auxin used in hormone weed-killers is made by chemical synthesis and is the main factor in controlling weed growth.
- For best effect it is recommended that one applies hormone weed-killers in quantities suggested by the manufacturer.

PLANT DEFENCE MECHANISMS

Plants are primary producers at the base of most food webs. They are therefore attacked and eaten by herbivores. Also, pathogenic viruses, bacteria and fungi may attack plants and cause them to become diseased. Plants protect themselves from these two threats using chemicals and thorns.

Thorns

Plants are unable to move or escape from threats such as herbivores. They develop thorns on their stems or leaves to protect them from being attacked by these herbivores.

Chemicals

The chemical secretions of some plants are poisonous to many organisms. For example, the fruits of plants contain large amounts of vitamin C and bioflavonoids, which are anti-bacterial and antiviral compounds.

In addition, sticky secretions given off by plants make it difficult for insects and animals to eat the plant.

A species of wild tobacco plant growing in the south-western United States, releases chemicals when attacked by hornworms. These chemicals attract insects that kill the larvae of the hornworm.

TERMINOLOGY REVIEW

TERM	DESCRIPTION
Abscisic acid	Plant growth substance that is responsible for bringing about dormancy in seeds
Apical Dominance	Inhibition of the growth of lateral buds by the auxins present in apical buds
Auxins	Plant growth substance that causes bending reactions in plant stems and roots
Geotropism	Growth or bending reaction by plants in response to gravity
Gibberellins	Plant growth substance that is responsible for the elongation of internodes in plants
Phototropism	Growth or bending reaction by plants in response to light
Tropism	Bending reaction of plants or parts of plants in response to an external stimulus

GROUP	TREATMENT		RESULT AVERAGE LENGTH OF COLEOPTILE (mm)
	TIP (PRESENT/ABSENT)	CONCENTRATION OF AUXIN INJECTED (ARBITRARY UNITS)	
A	Absent	1	36
B	Absent	2	60
C	Absent	3	32
D	Absent	4	24
E	Present	0	30

- 1.1 Formulate a hypothesis for the investigation above. (3)
- 1.2 Suggest why Sipho cut off the tips of each coleoptile before he injected them with auxin. (2)
- 1.3 Apart from the factors that were kept constant, state ONE other factor that Sipho should have kept constant in all the groups. (1)
- 1.4 What conclusion can be drawn from the results, about the effect of auxin concentration on cell elongation in the coleoptiles? (3)

2. A group of Grade 12 learners carried out an investigation to determine the effect of gibberellin on the germination of seeds.

The following procedure was followed:

- A sample of hazelnut seeds was divided into two groups, A and B.
- A gibberellin solution was added to the seeds in group A.
- Water was added to the seeds in group B.
- Both groups of seeds were allowed to germinate for 16 days.
- The percentage (%) of seeds germinating in the two groups was recorded.

The results of the investigation are shown in the graph below.

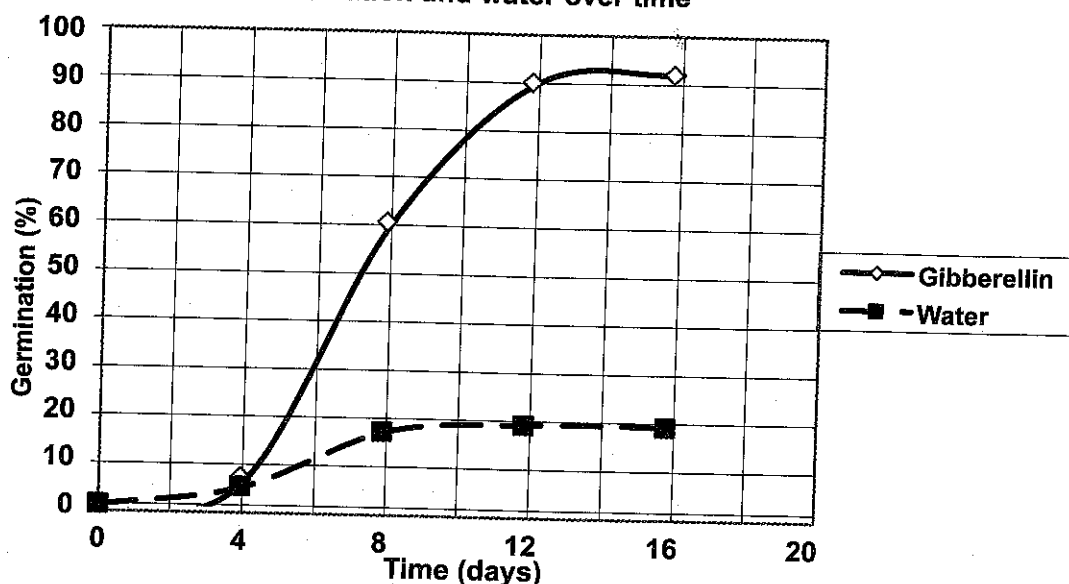
QUESTIONS

Sipho did an investigation in his laboratory to look at the effect of different concentrations of auxin on cell elongation in coleoptiles (young stems). He used the following procedure:

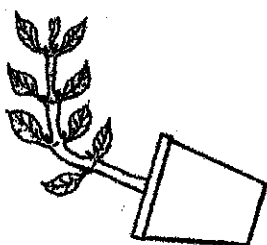
- Fifteen (15) coleoptiles from one species of oat plants were used.
- All the coleoptiles used were of the same length.
- The tips of twelve (12) coleoptiles were cut.
- These coleoptiles were put into four groups (A, B, C and D). Each group of three coleoptiles was injected with a different concentration of auxin as shown in the table below.
- The last group (E) was used as a control in which the coleoptiles were not injected with auxin and tips were not cut.

After four days the length of coleoptiles in each group were measured and an average was calculated.

Percentage germination of hazelnut seeds in gibberellin solution and water over time

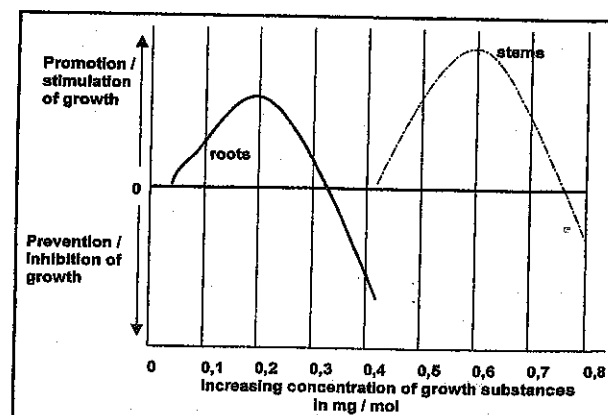


- 2.1 Formulate a possible hypothesis for this investigation. (3)
- 2.2 Using the information from the graph, determine the percentage germination of hazelnut seeds on the 10th day with the gibberellin treatment. (1)
- 2.3 Explain the purpose of group B. (2)
- 2.4 State TWO ways in which the validity of this investigation could have been improved. (2)
- 2.5 Give ONE possible reason why seeds of desert plants germinate only after heavy rains. (2)
3. The drawing below shows a potted plant that was placed on its side.



Explain why the stem is growing upwards.

(8)



- 4.1 Name the plant substance that can promote or inhibit growth.
- 4.2 At which concentration does the substance work best in:
- (a) Roots
- (b) Stems
- 4.3 At which concentration does the substance **promote** growth of the stems and **inhibit** growth of the roots?

Plant Responses to the Environment

ANSWERS

1.
 - 1.1
 - The cell elongation✓ in the coleoptile
 - will increase✓/decrease/remain the same/ differ
 - as the auxin concentration increases / decreases/differs✓

(3)
 - 1.2
 - To remove the effect of auxin✓ produced at the tip
 - as there can be varying concentrations✓ produced by each plant

(2)
 - 1.3

Type of soil✓/ amount of water/ light intensity/ temperature/ size of the pot/ same environmental conditions any

(1)
 - 1.4
 - Increasing the concentration of auxin results in an increase in the cell elongation✓
 - up to an optimum concentration✓
 - then it starts inhibiting/decreasing the cell elongation✓

(3)
2.
 - 2.1
 - Higher/lower percentage✓ of seeds
 - will germinate ✓
 - in gibberellin solution/water✓

OR

 - Same percentage of seeds✓
 - will germinate✓
 - in gibberellin solution and in water✓

(3)
 - 2.2

Accept any value between 77 to 78% ✓

(1)
 - 2.3
 - Water serves as a control✓ to verify that gibberellin does have an effect on germination ✓

(2)
 - 2.4
 - The number of hazelnut seeds in both sets must be the same✓
 - Same volume of gibberellin solution and water must be used✓
 - Use seeds from the same plant✓
 - Maintain the same environmental conditions✓ any

(2)
 - 2.5
 - Water is available✓
 - for the seeds to germinate✓ after the heavy rain

(2)
3.
 - Auxins accumulate on the lower side of stem✓
 - because of gravity✓
 - A higher concentration of auxins in stems accelerates growth✓
 - therefore the lower side grows faster than the upper side✓

- i.e. uneven distribution of auxins causes uneven growth✓
 - with the lower side growing faster✓
 - and the stem grows upwards✓
 - i.e. the stem shows negative geotropism✓
- (8)
4.
 - 4.1

Auxins✓

(1)
 - 4.2
 - (a) 0,2✓ mg/mol. ✓
 - (b) 0.6✓ mg/mol. ✓

(2)
 - 4.3

Approximately 0,42✓ mg/mol.

(2)

INTRODUCTION

According to the theory of biological evolution:

- All present-day life forms have descended from and are related to, those that lived in the past
- All present-day life forms may look different from those that they descended from because they became modified from one generation to another

EVIDENCE FOR EVOLUTION

Scientists provide us with information from various fields as evidence for their acceptance of the theory of evolution.

Evidence from Paleontology

Paleontology refers to the study of **fossils**. Fossils are the remains of ancient life forms preserved usually in rocks.

Scientists determine the age of a fossil by using relative dating and radiometric dating. In relative dating, we can only tell whether a particular fossil was formed before or after another fossil or geological event; it cannot be used to determine the age of a fossil. Radiometric dating can be used to determine the age of a fossil.

In addition to determining the age of a fossil (which indicates roughly when the organism existed), scientists also determine the characteristics of the organism from a study of its fossil. Knowledge of these characteristics allows us to see relationships amongst different organisms. This is usually represented as a phylogenetic tree.

Evidence from Homologous Structures

Homologous structures have the same basic plan even though they may look different or perform different functions.

Scientists interpret the presence of homologous structures to mean that all the species which show homologous structures have arisen from a common

ancestor which became adapted to live in different environments. This is also called modification by descent.

An example of this is the common basic plan of all vertebrate limbs (consisting of the same set of bones) but which have become modified for different functions, for example, for flight in birds, for digging in moles, for swimming in seals and for walking in horses.

Evidence from Biogeography

Biogeography refers to the study of past and present distribution of individual species. Such studies have shown that closely related species tend to be found in the same geographic region, whereas very similar habitats in distant regions are occupied by different species that are not closely related.

Evidence from Molecular Biology and Genetics

All life forms are related because they have identical DNA structure and identical protein synthesis.

Scientists have been able to determine how closely related two species may be by comparing the degree of similarity in each of the following:

- Sequence of Genes
- Portions of DNA with no function
- Proteins
- Respiratory pathways

SOURCES OF VARIATION

The individual organisms making up any one species are not identical. The differences in appearance may occur because of each of the following:

- **Mutations** – Mutations involve a change to the structure of a gene. This leads to an altered genotype resulting in a different or altered phenotype.
- Variation as a result of **meiosis** is due to:
 - **Crossing over:** During prophase 1 of meiosis, there is an exchange of chromatid segments between homologous chromosomes. When meiosis is complete, new combinations of genetic material result in the gametes, making them different from each other.

- **Random arrangement of chromosomes:** The chromosomes arrange randomly at the equator during metaphase 1 and metaphase 2. As a result, during anaphase 1 or anaphase 2, the chromosomes or chromatids may move to the poles in different combinations, leading to gametes that differ from each other.
- **Random fertilisation of gametes:** Firstly, the egg cells and the sperm cells produced by meiosis are different from each other. Since there is random fertilisation of these different gametes, there will be different combinations of genetic material in the offspring.

Variations in the individuals making up a species may be either **discontinuous** or **continuous**.

In **continuous variation**, there are a range of different phenotypes for a particular characteristic. If we take height as an example of a characteristic, we will find that there is a complete range of measurements from one extreme to the other.

In **discontinuous variation**, there is no range of different phenotypes for a particular characteristic. The characteristic is either present or not.

LAMARCKISM

Lamarckism is the idea that an organism can pass on characteristics that it acquired during its lifetime to its offspring. It is named after the French biologist Jean-Baptiste de Lamarck (1744–1829), who incorporated the idea of the inheritance of acquired characteristics to explain how organism became more complex over time.

Jean Baptiste de Lamarck tried to explain how animals changed over time by means of what he called two 'laws' as follows:

- According to his **law of use and disuse**:
 - Organs became modified or adapted according to how frequently they were used
 - If they were used more frequently it became bigger, stronger or changed so that it could work better
 - On the other hand if an organ was disused, it became smaller until it totally disappeared

- According to his **law of inheritance of modified/acquired characteristics**:

- The modifications brought about by the frequency of use or disuse were able to be transmitted to their offspring

In other words, Lamarck felt that animals deliberately made changes to become adapted to their environments. These structural changes were then handed down to the next generation.

Lamarck's explanation is rejected by most biologists since they say that:

- Organisms evolved, not because they wanted to evolve; instead these changes took place randomly, in response to the environment
- There is very little evidence to support Lamarck's idea that changes brought about by adaptation to the environment are inherited from parent to offspring

DARWINISM

Darwinism is a theory that explains the evolution of new species through natural selection. It is named after Charles Darwin (1809–1882).

In 1844, he wrote out his statement of his theory of evolution by **natural selection** which was later published in the form of a book *On the Origin of Species*, in 1859.

Observations on which Darwin based his theory of evolution by natural selection

Darwin's Theory of evolution is based on the following observations:

- **Variation:** There is variation in appearance and abilities of organisms within every species.
- **Offspring:** Species produce a large number of offspring but they do not all survive
- **Competition:** Organisms compete for limited resources, such as food.
- **Genetics:** Organisms pass favourable characteristics to their offspring.
- **Natural Selection:** Those organisms with the most beneficial traits are more likely to survive and reproduce.

Darwin's Theory of Evolution by Natural Selection

Darwin explained his theory of evolution by natural selection as follows:

- Organisms produce a large number of offspring.
- There is a great deal of variation amongst the offspring.
- Some have desirable characteristics and some do not.
- When there is a change in the environmental conditions or if there is competition
- then organisms with characteristics which make them more suited, survive
- whilst organisms with characteristics that make them less suited, die.
- This is termed 'natural selection'.
- The organisms that survive, reproduce
- and thus pass on the desirable characteristic to their offspring.
- The next generation will therefore have a higher proportion of individuals with the desirable characteristic.

Differences between Lamarckism and Darwinism

The table below shows the differences between Lamarckism and Darwinism.

Lamarckism	Darwinism
Variation in offspring brought about by individuals in the population changing	Offspring showed variation from the moment of their production
Change brought about because individuals in the population wanted to change i.e. deterministic theory	Change as a result of environmental factors working randomly on the population
Change brought about by individuals in the population adapting to the environment	Change brought by nature selecting those that are best suited to the environment to survive
Individuals in the population change	The population as a whole changes
Changes brought about by adaptation to the environment are inherited from parent to offspring	Characteristics are passed on from generation to generation because they enable the individuals to survive in the environment.

Artificial Selection

Artificial selection refers to the breeding of plants and animals for characteristics that are considered desirable to humans. Since particular desirable characteristics are selected, it is also known as selective breeding.

Artificial production can be used to increase food quantity as shown by each of the following examples

- By selecting cows which produce large amounts of milk and whose mothers and grand-mothers were also high milk producers, and allowing them to mate with bulls whose mothers and grandmothers were also high milk producers, cows which produce more milk than their ancestors, have been developed.
- By deliberate selection of polyploid plants, bigger plants of watermelons, marigolds, and snapdragons have been produced.

Artificial selection can, also ensure that a combination of desirable characteristics, which may sometimes appear independently in different organisms, appears in the same set of offspring. This is shown in the following example:

- For example, a breeder may cross a meaty male sheep with a woolly female sheep. Some of the offspring would show a combination of these two desirable characteristics. These offspring are then bred with each other. This process is continued until sheep with a large amount of meat and a large amount of wool is produced.

Differences between Natural Selection and Artificial Selection

Natural Selection	Artificial Selection
Nature is the selective force	Humans are the selective force
Selection is based on adaptation to the environment	Selection is based on what is desirable to humans
Selected individuals are able to survive in the wild since they are adapted to the environment	Selected individuals may survive only under controlled conditions since their characteristics were not selected according to adaptation to the environment

PUNCTUATED EQUILIBRIUM

According to Darwinism, 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.

As opposed to the above, punctuated equilibrium proposes the following:

- Evolution is not gradual as proposed by 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 through natural selection.
- 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.

SPECIATION

The accumulation of gradual changes associated with natural selection can lead to a new population of a particular species becoming so different from the original population that they become a new species. This is termed speciation and may occur as follows:

- If a population of a single species becomes separated by a geographical barrier (sea, river, mountain, lake),
- then the 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.
- They have thus become different species.

MECHANISMS OF REPRODUCTION ISOLATION

Reproductive isolation or reproductive isolating barriers are factors that prevent two species from producing viable, fertile offspring. This may occur in various ways as follows:

Breeding at different times of the year

If two species breed during different times (seasons) of the year, their chances of mating and producing viable, fertile offspring is greatly reduced.

Species-specific Courtship Behaviour

Some animals have very specific courtship behaviours that do not attract individuals of other species, even if they are closely-related species. This reduces the chances of different species reproducing with each other.

Adaptation to Different Pollinating Agents

Some closely related species of plants have different appearances that attract different pollinating agents, preventing cross-pollination between the different species.

Prevention of Fertilisation

In some closely-related species fertilisation of the different species is prevented by the different species having different copulatory organs. Since the male organs do not fit into female organs, the sperm cannot be transferred to the female.

Infertile Offspring

Some closely-related species may mate and produce offspring that are infertile. These offspring cannot in turn produce more offspring of its kind. In this way no new species is formed, since a group of individuals must be able to reproduce to form fertile offspring to be considered as belonging to an individual species.

EVOLUTION IN PRESENT TIMES

It is sometimes thought that evolution took place a long time ago and is not taking place now. It is also thought that evolution takes place only over thousands and millions of years.

The example that follows shows that evolution is still occurring currently and may also occur in a short period of time.

The Development of Resistance to Insecticides in Insects

- Malaria is caused by a parasitic protozoan called *Plasmodium* carried by mosquitoes. One of the methods used to prevent malaria is to spray the inside of the walls of the house with an aerosol insecticide such as DDT. When it was first introduced, DDT was very effective in reducing malaria by killing the mosquitoes. Unfortunately, the evolution of mosquitoes which are resistant to DDT has greatly reduced its effectiveness in many parts of the world. The development of a strain of DDT resistant mosquitoes can be explained by natural selection as follows:
- Mosquitoes produce a large number of offspring when they reproduce.
- There is a great deal of variation amongst the offspring.
- Whilst initially most mosquitoes were not resistant to DDT, a small number showed resistance to DDT.
- On the application of DDT, most of the mosquitoes died since they were not resistant to DDT.
- Only the resistant mosquitoes, which were smaller in number, survived.
- This is termed natural selection
- The DDT-resistant mosquitoes which survived were able to reproduce
- and thus passed the characteristic of DDT resistance to the next generation.
- In this way the next generation showed a larger proportion of offspring that were DDT resistant.
- In this way the mosquitoes over many generations became more and more resistant to DDT, eventually making DDT totally ineffective in killing mosquitoes.

In a similar way we are able to explain each of the following through natural selection:

- The variation in the bill and body size in the Galapagos finches
- Resistance to antibiotics in various bacteria (e.g. TB)
- HIV resistance to anti-retrovirals

TERMINOLOGY REVIEW

TERM	DESCRIPTION
Allopatric speciation	Speciation due to a geographical barrier
Analogous	Structures that are different/don't have a common origin
Artificial Selection	The production of offspring that have characteristics that are suitable for humans
Biodiversity	The range of life forms that exist on Earth
Biogeography	Similarities and differences in organisms due to their location on the earth planet
Continuous variation	A range of different phenotypes exist for a particular characteristic
Discontinuous variation	There is no range of different phenotypes for a characteristic; it is usually present or absent
Extinction	Elimination of a species from the Earth
Fossil	Remains of organisms that have existed in the past
Geographic isolation	The separation of a population into two by a geographical barrier such as a river, a lake or a mountain
Geographical barrier	A feature of the land such as a river, a lake or a mountain which may separate a population into two
Homologous	Structures that are similar/have a common origin
Hypothesis	A testable statement that can be accepted or rejected
Mutation	Sudden change to the structure of a gene or a chromosome
Natural Selection	Organisms survive if they have characteristics that make them suited to the environment
Paleontology	The study of fossils
Population	Group of organisms of the same species occupying the same habitat
Punctuated equilibrium	Evolution characterised by long periods of little or no change followed by short periods of rapid change
Radiometric dating	Process used to determine the age of a fossil by measuring the decay of radioactive substances such as carbon.
Relative dating	Process used to determine the order in which organisms appeared on Earth

Evolution by Natural Selection

TERM	DESCRIPTION
Speciation	The formation of a new species over a period of time
Species	Similar organisms capable of random interbreeding to produce fertile offspring
Theory	Based on a number of different hypotheses, explanations, principles and laws

QUESTIONS

1. Describe how each of the following contributes to variation:

- 1.1 Crossing over
- 1.2 Random arrangement of chromosomes during meiosis
- 1.3 Mutations
- 1.4 Chance fertilisation
- 1.5 Random mating

5 x 2 (10)

2. Describe how each of the following provides evidence for evolution:

- 2.1 Fossils
- 2.2 Homologous structures
- 2.3 Biogeography
- 2.4 Genetics

4 x 2 (8)

3. Tens of thousands of years ago, the animals that evolved into giraffes were not as tall as modern giraffes. Over a long period of time, the necks of giraffes became longer. They could reach leaves high in the trees and reach down for water.

- 3.1 Describe how the long necks of modern giraffes would have been explained by the following:

- 3.1.1 Darwin
- 3.1.2 Lamarck

(7)
(4)

- 3.2 Explain why Lamarck's theory is not accepted by scientists today.

(2)

The peppered-moth, *Biston betularia*, has two phenotypes for body colour, dark (blackish) and pale (whitish). The trunks of the trees on which the moths rest are black in polluted environments compared to the white trunks of trees in unpolluted environments. In both unpolluted and polluted environments, birds are the predators of the moths.

An investigation was carried out to determine the number of dark and pale peppered-moths

present in polluted and unpolluted environments using a sampling technique.

The results of the investigation are shown in the table below.

TYPE OF ENVIRONMENT	DARK MOTHS	PALE MOTHS
Polluted	150	40
Unpolluted	30	170

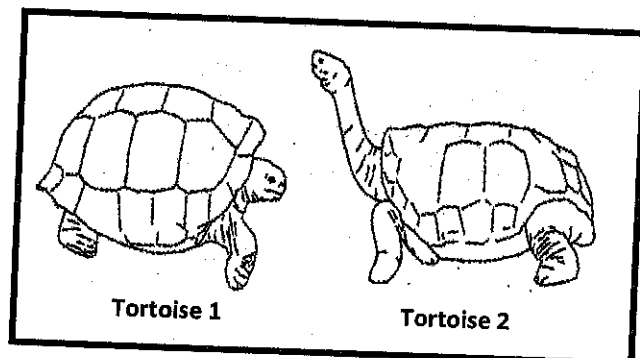
- 4.1 Formulate a hypothesis for the above investigation. (3)

- 4.2 Draw bar graphs on the same system of axes to represent the data above. (6)

- 4.3 Suggest THREE factors that might have decreased the validity of this investigation. (3)

- 4.4 Using the table and your understanding of natural selection, explain the results for the polluted environment. (4)

5. Darwin noticed different species of tortoises on the Galapagos Islands. Two of these tortoises, which are drawn to scale, are shown below.



- 5.1 Tabulate TWO visible differences between the two species of tortoises. (5)

- 5.2 Suggest what tortoise 2 might eat that tortoise 1 will not be able to eat. (1)

- 5.3 The two species of tortoises shown above lived on different islands. Darwin suggested that they might have evolved from a common ancestor. Explain how this could have occurred. (6)

6. List FIVE reproductive isolation mechanisms that may keep species separate from each other.

(5)

7. Explain how some strains of bacteria that cause TB have become resistant to antibiotics.

(6)

ANSWERS

1.

- 1.1 Crossing over – Exchange of chromatid segments✓ causes a different mix of maternal and paternal genetic material✓ in each chromosome.

- 1.2 Random arrangement of chromosomes during meiosis – This allows for different combinations of chromosomes or chromatid segments✓ to enter each new cell during meiosis, making the cells dissimilar. ✓

- 1.3 Mutations – A change to the structure of a gene leads to an altered genotype✓ which in turn may express a new, different phenotype. ✓

- 1.4 Chance fertilisation – Because gametes are dissimilar✓, different combination of gametes produce different offspring. ✓

- 1.5 Random mating – Because the gametes formed by different individuals differ from each other, ✓ random mating produces offspring different from each other. ✓

5 x 2

(10)

2.

- 2.1 Fossils – Fossils of differing ages✓ show progressive change in characteristics over time. ✓

- 2.2 Homologous structures – If structures in different species have a similar structure✓ this indicates that they descended from a common ancestor. ✓

- 2.3 Biogeography - Closely related species tend to be found in the same geographic region, ✓ whereas very similar habitats in distant regions are occupied by different species that are not closely related. ✓

- 2.4 Genetics - If different species have great similarity in their DNA or a similar sequence of genes, ✓ this indicates that they descended from a common ancestor. ✓

4 x 2

3.

3.1 Darwin

- As a result of genetic variation✓ in the giraffe population
- some giraffes have longer necks✓ than others
- Environmental change✓/competition for resources occurred
- causing those with shorter necks to die✓
- and those with longer necks to survive✓
- This is natural selection✓
- The alleles✓ for longer necks
- were passed on to subsequent generations✓
- increasing the proportion of giraffe that have long necks✓. any

(7)

3.2 Lamarck

- All giraffes had short necks✓ originally
- Giraffes frequently stretched✓/used their necks to reach
- for leaves of tall trees✓
- necks become longer✓
- The long necks acquired✓ in this way
- could be passed on to the next generation✓ /were inherited. any

(4)

3.3

- There is no evidence to show that acquired characteristics✓ are inherited✓

OR

- There is no evidence to show that structures change✓ through use or disuse. ✓

(2)

4.

- 4.1 More/fewer✓ dark peppered moths✓/ pale peppered moths survive in the polluted /unpolluted environment✓ than in the unpolluted / polluted environment

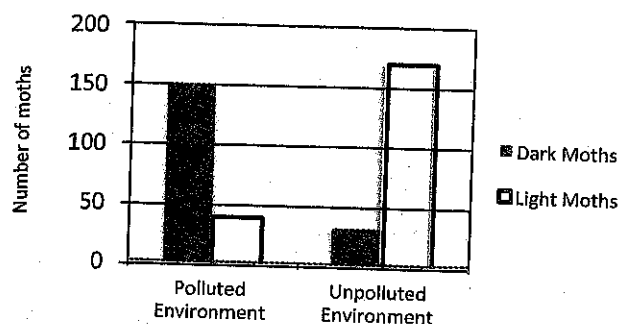
OR

- No difference✓ in the number of dark/ pale peppered✓ moths that survive in both environments✓

(3)

Evolution by Natural Selection

4.2



Rubric for the mark allocation of the graph

Correct type of graph	1
Caption for graph	1
Correct label for X-axis and appropriate width of bars	1
Graphs labelled/key provided for 2 graphs	1
Correct label for Y-axis and appropriate scale for Y-axis	1
Drawing of bars	1 – 1 to 3 bars plotted correctly 2 – All 4 bars plotted correctly

- 4.3
- Was not a closed system so moths could fly in and out of the environment✓
 - The number of predators might have been different in both polluted and unpolluted environment✓
 - Both environments could have been different with regard to vegetation found in them✓
 - Both environments could have been different with regard to climatic conditions✓
 - Human error during the process of sampling✓/ counting/recording any

(7)

(3)

- 4.4
- Variation in the moth population produces dark and pale forms✓
 - The dark moths were camouflaged by black tree trunks✓/not easily detected by birds/predators
 - More dark moths survived✓/ able to reproduce /fewer eaten by birds
 - Pale moths were NOT camouflaged by the black tree trunks✓/ easily detected by birds
 - Fewer pale moths survived✓/fewer able to reproduce/more eaten by birds

any (4)

5.

5.1

Tortoise 1	Tortoise 2
Short neck✓	Long neck✓
More rounded shell✓	More elongated shell✓

2 x 2 + 1 for table

(5)

5.2

5.3

- Tall plants✓/ shrubs/small trees
- On each island the population of tortoises with variation✓/ long and short necks)
 - lived under different environmental conditions✓ / had different sources of food.
 - After a period of time each group of tortoises underwent natural selection✓ independently
 - On each island only those tortoises with the characteristics✓ (long or short neck) favourable for its own conditions survived✓
 - Continued natural selection resulted✓ in each island having tortoises that are very different from each other✓/ they differ genotypically and phenotypically
 - Reproductive isolating mechanisms prevent them from interbreeding✓ even if they are allowed to mix i.e. each is a separate species

(1)

any (6)

6.

- Breeding at different times of the year✓
- Species-specific courtship behaviour✓
- Adaptation to different pollinating agents✓
- Prevention of fertilisation✓
- Infertile offspring in cross species hybrids✓

(5)

7.

- There is a large degree of variation amongst the TB bacteria✓
- Although a large number were not resistant to antibiotics, a few were resistant to antibiotics.✓
- Through the use of antibiotics, a large number of the non-resistant bacteria were eliminated.✓
- The resistant bacteria survived.✓
- and reproduced, thus passing the allele for resistance to the offspring.✓
- In this way, in each successive generation the proportion of resistant bacteria increased.✓

(6)

Human Evolution

OUR PLACE IN THE ANIMAL KINGDOM

All living things are classified into five kingdoms one of which is the Kingdom Animalia, commonly called the animal kingdom. There are two large groups within this kingdom viz. the **invertebrates** and the **vertebrates**. The vertebrates themselves can be sub-divided into the following five classes:

- Class Pisces (fishes)
- Class Amphibia (frogs)
- Class Aves (birds)
- Class Reptilia (snakes and lizards)
- Class Mammalia (rabbits, monkeys, humans)

In 1735, Carl Linnaeus classified modern humans in the Order Primates of the Class Mammalia. The scientific name given to modern humans is *Homo sapiens*. Sometimes, the name *Homo sapiens* is used to distinguish ourselves from the earlier species of *Homo sapiens* that lived a long time ago. Earlier humans belonged to many different species such as *Homo habilis*, *Homo erectus* and *Homo neanderthalensis*. Very early humans are often called ape men since they showed some characteristics of apes and some characteristics of humans.

The figure below shows the position of humans in relation to the other animals in the order Primates.

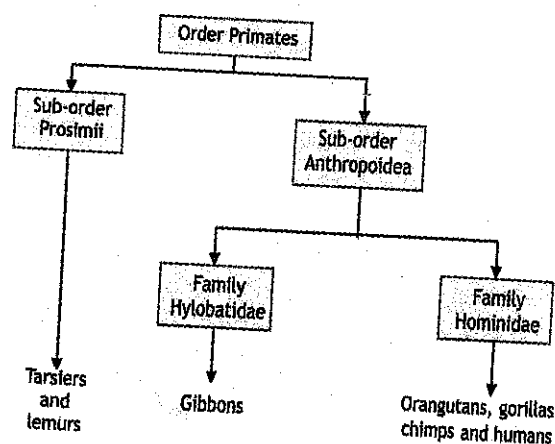


Fig . 11.1 The position of humans in relation to other primates

The terms 'hominid' and 'hominin' are frequently used in human evolution. These are defined as follows:

Hominid - the group consisting of modern humans, chimpanzees, gorillas and orang-utans plus all their immediate ancestors). It includes all members of the family Hominidae.

Hominin - the group consisting of modern humans, extinct human species and all our immediate ancestors (including members of the genera *Homo*, *Australopithecus*, *Paranthropus* and *Ardipithecus*).

In addition to the above humans are often compared with the 'African apes'. The term 'African Apes' refers to gorillas, chimpanzees and bonobos (slightly smaller than chimpanzees).

Later we will look at similarities and differences between humans and the African Apes. The similarities will help us understand why humans and the African apes belong to the same family (Hominidae). The differences will help differentiate between humans and the other hominid species.

EVIDENCE FOR COMMON ANCESTRY OF HOMINIDS, INCLUDING HUMANS

Scientists provide us with information from various fields as evidence for their acceptance of the theory of evolution.

Fossil Evidence

Paleontology refers to the study of **fossils**. Fossils are the remains of ancient life forms preserved usually in the rocks.

Scientists determine the age of a fossil by using relative dating and radiometric dating. In relative dating, we can only tell whether a particular fossil was formed before or after another fossil or geological event; it cannot be used to determine the age of a fossil. Radiometric dating can be used to determine the age of a fossil.

In addition to determining the age of a fossil (which indicates roughly when the organism existed), scientists also determine the characteristics of the organism from a study of its fossil. Knowledge of these characteristics allows us to see relationships amongst different organisms. This is usually represented as a phylogenetic tree.

Homologous structures have the same basic plan even though they may look different or perform different functions.

Scientists interpret the presence of homologous structures to mean that all the species which show homologous structures have arisen from a common ancestor which became adapted to live in different environments. This is also called modification by descent.

An example of this is the common basic plan of all vertebrate limbs (consisting of the same set of bones) but which have become modified for different functions, for example, for flight in birds, for digging in moles, for swimming in seals and for walking in horses.

A study of fossils of organisms found at different times in the past shows how certain characteristics changed over time such as the position of the foramen magnum, the size of the cranium, the brow ridge, dentition and palate shape. The trends obtained from this study provide information about the sequence of evolution.

Cultural Evidence: Tool-making

Cultural evidence from studies of tools and weapons, as well as language is also used to show similarities and differences between humans and other primates.

Early hominids used stones that were found on the ground and the branches of trees as weapons and tools. The first made tools were those made by *Homo habilis* (handy man) about 2 million years ago. Such weapons and tools were used for fishing, farming, and hunting and for tearing up food for eating.

Genetic Evidence: Mitochondrial DNA

Scientists state that organisms are closely related and are likely to have a common recent ancestor if they have:

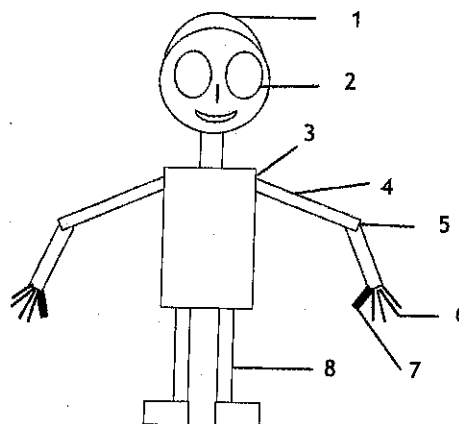
- Identical DNA structure
- Similar sequence of genes
- Similar portions of DNA with no functions
- Similar mutations on mitochondrial DNA

Species that are closely related have a greater similarity to each other than distant species. For example, the similarity of the DNA of humans to the chimpanzees is greater than with the gorilla. There is only a 1,4% difference in the DNA nucleotide sequence between humans and chimpanzees. This shows that humans are more closely related to the chimpanzees than the gorilla.

In addition to this, similarities in mutations present on mitochondrial DNA can be used to trace the ancestors of all modern humans existing today.

SIMILARITIES BETWEEN HUMANS AND THE AFRICAN APES

The diagram below can be used to help you remember the characteristics that are common to the African apes and humans (and in general common to all primates). The list of similarities summarised are numbered to correspond with the parts numbered on the diagram.



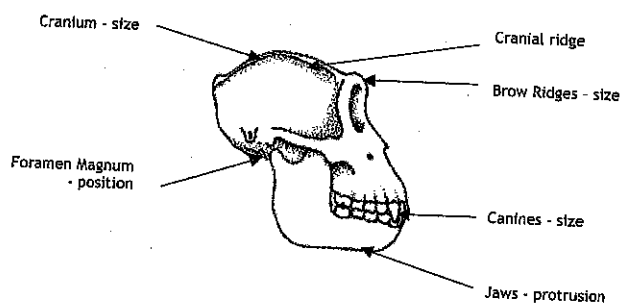
1. Large brain/skull compared to their body mass
Olfactory brain centres reduced/reduced sense of smell
Parts of the brain that process information from the hands and eyes are enlarged
2. Eyes in front/binocular vision/stereoscopic vision
Eyes with cones/colour vision
3. Freely rotating arms
4. Long upper arms
5. Elbow joints allow rotation of the forearm
6. Flat nails instead of claws/bare finger tips
7. Opposable thumbs which work in opposite direction to their fingers
8. Upright posture

DIFFERENCES BETWEEN HUMANS AND THE AFRICAN APES

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

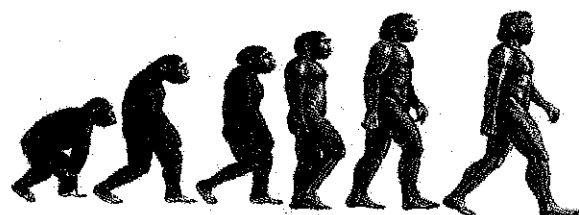
The diagram below shows some of the features that have been compared in humans and in the African apes.



TRACING THE SEQUENCE OF HUMAN EVOLUTION

Scientists believe that the factors that led to the evolution of all other organisms, have also led to the development of humans. These scientists do not all agree on how, when and where modern humans developed. They do agree, however, on the general pattern of human development and that the chimpanzees are 'our closest living relatives' since we share 98% of our DNA sequences with chimpanzees. It is important to note that scientists are not saying that we have evolved from chimpanzees. Instead, they are saying that we and the chimpanzees probably share a common ancestor.

The general pattern of human development that most scientists usually agree on is as follows:



Ape-like ancestor → Ape men → Early humans → Modern humans

According to scientists, the order of appearance of species of *Ardipithecus*, *Australopithecus* and *Homo* as well as a study of their characteristics indicate that the following changes took place gradually leading to the development of humans:

- A shift of the foramen magnum to a forward position suggesting bipedalism
- The development of a more rounded skull
- An increase in cranium size (which would mean a larger brain)
- A flatter face due to:
 - A less sloping forehead
 - Less protruding jaws (decreased prognathous)
 - A more developed chin
- A more rounded jaw
- Increased in the size of the skeleton (which would mean increased height)
- Increase in the curvature of the spine
- Shortening and widening of the pelvis
- Decreased development of brow ridges

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

From the characteristics of each fossil in the table it can be clearly seen that there was a gradual change in the characteristics over a period of time.

The information in the table also shows the following evolutionary trend relating to each of the following characteristics:

- Brain size: Increase in brain size
- Position of foramen magnum: Movement to a more forward position
- Prognathous jaws: Change from more prognathous to less prognathous
- Dentition: Decrease in the size of the teeth OR decrease in the size of the canines
- Development of brow ridges: Brow ridges became less developed.

Let us now examine the significance of the changes that occurred as it applies to each of the different characteristics.

Brain size	Increased brain size allows for processing information more quickly and for processing a larger amount of information.
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.
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.
Dentition	The change from large to smaller teeth was due to the change in diet from raw food to cooked food
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

We can further elaborate on the advantages of bipedalism as follows:

- The hands became free for carrying food, tools and babies
- A better view of the surroundings in search of food and predators
- Movement from place to place becomes more efficient
- Faster cooling of the body, which was essential in their original hot tropical environments
- Display of the male sex organs as part of courtship behaviour

OUT OF AFRICA HYPOTHESIS

According to the 'Out of Africa' hypothesis, most scientists believe humans originated in Africa and then migrated out of Africa to all parts of the world.

The 'Out of Africa' hypothesis is based on fossil evidence as well as on genetic evidence.

Fossil Evidence for the 'out of Africa' Hypothesis

Most scientists accept that *Ardipithecus*, *Australopithecus*, *Homo habilis* and *Homo erectus* are all on the same line of development as modern humans (*Homo sapiens*). There is fossil evidence to show that all of these human ancestors lived in Africa. Forty percent of all human ancestor fossils having been found in Gauteng including the following:

- Taung Child (*Australopithecus africanus*), a 2.6 to 2.8 million old fossil found by Raymond Dart in 1924, outside the village of Taung in the Northern Cape.
- Mrs Ples (*Australopithecus africanus*), an adult form of the Taung child, found by Robert Broom in the Sterkfontein Caves in 1947.
- Kromdraai (*Paranthropus robustus*) discovered by Robert Broom in 1938, about 1.4 km from Sterkfontein.
- Florisbad man (an earlier form of *Homo sapiens*), a 250 000 year fossil found in Florisbad in the Free State.

Important fossils found outside South Africa, but still within the continent include:

- Nutcracker man (*Paranthropus boisei*) 1.2 to 2.2 million year fossil found by Mary and Louis Leaky in 1959 at the Olduvai Gorge in Tanzania
- Handy man (*Homo habilis*) discovered by Peter Nzube in 1968 in the Olduvai Gorge in Tanzania. *Homo habilis* is the earliest species of the genus *Homo*
- The 3.6 million year-old Laetoli footprints found by Mary Leaky at Tanzania.
- Toumai (*Sahelanthropus tachadensis*), a 6-7 million year old fossil found in Chad in 2001 by Micheal Brunet and his team, made up of people from France as well as from Chad
- In 1992–1993 a research team headed by Tim White discovered seventeen fragments including the skull, mandible, teeth and arm bones of *Ardipithecus* in Tanzania
- In August 2012, Maeve Leaky (daughter-in-law of Louis and Mary Leaky) and her daughter, Louise announced that they had found new fossils in Kenya. These fossils suggest that there were two additional species of our genus – *Homo* – living alongside our direct human ancestral species, *Homo erectus*, almost two million years ago.

It is also widely accepted that a population similar to *Homo erectus* was directly ancestral to the earliest members of all living *Homo sapiens*. *Homo erectus* appears to have evolved in Africa about 1.8 million years ago. *Homo erectus* then migrated to Asia and then to Europe. We know this since the oldest fossils of *Homo erectus* were found in Africa, followed by Asia and the youngest fossils were found in Europe.

Genetic Evidence for the 'Out of Africa' Hypothesis: Mitochondrial DNA

When DNA is analysed for the purpose of tracing ancestry, a search is made for mutations since individuals who have the same mutation must share the same common ancestor. These mutations therefore serve as markers of descent.

Every cell has organelles called mitochondria within which the energy-releasing process of cellular respiration takes place. Mitochondria also contain DNA, referred to as mitochondrial DNA (mt DNA).

During fertilisation, only the nucleus of the sperm cell enters the egg cell to fuse with its nucleus. The original egg cell there becomes the cell of the zygote after fertilisation. The mitochondria of the egg cell continue as the mitochondria of the zygote. In this way mitochondrial DNA is handed down from mother to child.

By following mutant nucleotides in mitochondrial DNA, we are able to trace our female line of descent. Analysis of mitochondrial DNA leads to an ancestral female who also lived in east Africa, around 150 000 years ago.

Scientists believe that other species of humans, such as *Homo erectus*, *Homo heidelbergensis*, *Homo neanderthalensis* and *Homo floresiensis* were also present at this time. However, these other species all became extinct and our species (*Homo sapiens*) was the only one which survived.

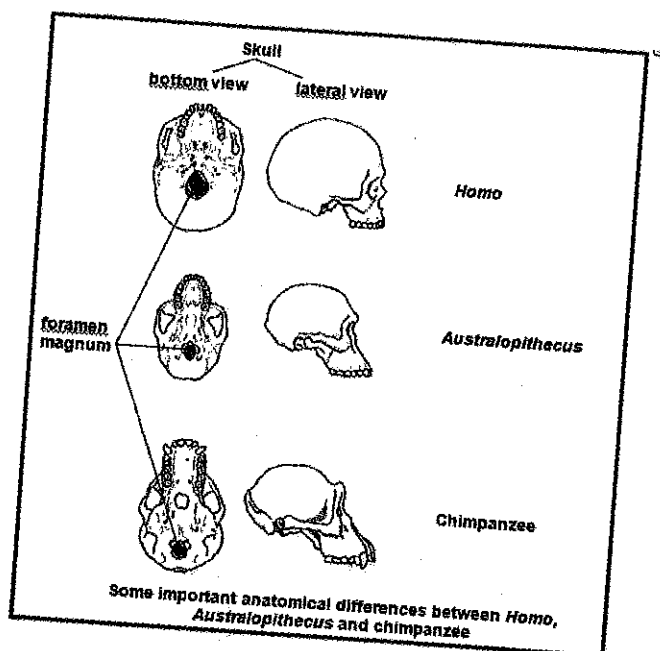
On the basis of DNA analysis, scientists believe that early humans migrated across the continent of Africa from east Africa. Then they moved out of the continent through north-east Africa in several groups. Through many different and complex pathways they migrated into every habitable continent on Earth within 50 000 years.

TERMINOLOGY REVIEW

TERM	DESCRIPTION
Bipedalism	The act of walking on two feet
Dentition	Arrangement of teeth on a jaw
Foramen magnum	Opening in the skull through which the spinal cord enters
Hominidae	Order to which humans, chimps, apes, gorillas, lemurs and gibbons belong
Hominin	Modern humans and all our immediate ancestors (including members of the genera <i>Homo</i> , <i>Australopithecus</i> , and <i>Ardipithecus</i>)
Hypothesis	A testable statement that can be accepted or rejected
Mitochondrial DNA	Genetic material used to trace female ancestry
Mutation	Sudden change to the structure of a gene or a chromosome
Opposable thumb	A thumb that works in opposite direction to the fingers
Phylogenetic tree	Diagram showing evolutionary relationships amongst organisms
Prognathous	Having a pointed face because of projecting jaws and nose
Quadrupedalism	The act of walking on all four limbs
Theory	Based on a number of different hypotheses, explanations, principles and laws
Transitional fossil	Fossil having characteristics of species that arose before it as well as species that arose after it

QUESTIONS

1. A comparison of the anatomical features of organisms has helped scientists to propose evolutionary relationships.



- 1.1 Tabulate THREE observable differences between the side view of the skulls of *Homo* and the chimpanzee. (7)
- 1.2 Which ONE of the organisms (*Australopithecus* or chimpanzee) is/was a quadruped? (1)
- 1.3 Give ONE observable reason for your answer to Question 1.2. (1)
- 1.4 Name TWO fossils of *Australopithecus* found in South Africa. (2)
2. Professor Lee Berger and his colleagues studied the fossils they found in a cave at the Cradle of Humankind. The skeletons from the cave are ranked amongst the most complete finds to date. The adult female, *Australopithecus sediba*, was remarkably well preserved and some of the following characteristics were identified:

Some characteristics of *Australopithecus sediba*:

- A small brain size
- Bipedal
- Smaller canines
- Projecting nose
- Small body size

[Adapted from 'Part Ape Part Human', Josh Fischmann, *National Geographic*, August 2011]

- 2.1 Write down THREE characteristics from the list above that also apply to the *Homo* species.

- 2.2 State TWO advantages of *A. sediba* being bipedal.

- 2.3 Professor Berger called *Australopithecus sediba* a transitional fossil. Using the information in the list above, explain why he called *A. sediba* a species in transition.

3. Study the table below, which indicates some of the hominid fossils found in the world and answer the questions that follow.

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

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

- 3.1 Explain why the information in the table supports the 'Out of Africa' hypothesis. (3)
- 3.2 If a fossil of *Australopithecus afarensis*, dated 3,2 mya, is found in Asia, explain the implications for the 'Out of Africa' hypothesis. (2)
- 3.3 Describe a genetic line of evidence that supports the 'Out of Africa' hypothesis. (2)

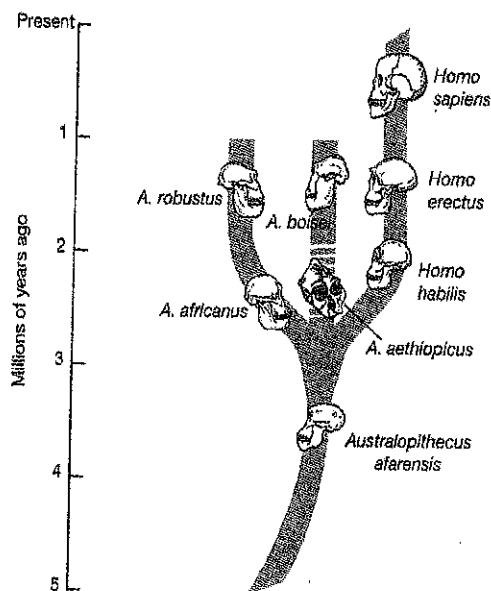
Human Evolution

4. Study the information below on three different species.

Organism	When existed	Characteristics
<i>Ardipithecus ramidus</i>	5-4 mya	- Brain size: 300-350ml - Very prognathous - Bipedal but tree climbing
<i>Australopithecus africanus</i>	3 – 2 mya	- Brain size: 428-625ml - Prognathous - Teeth large, canines not long - Long arms - Bipedal
<i>Homo sapiens</i>	200 000 years ago - present	- Brain size: 1200 – 1800ml - Non-prognathous - Small teeth - Bipedal - Short arms but longer legs

- 4.1 What evolutionary trend does the above information show with regard to brain size? (1)
- 4.2 What is the significance of a larger brain size? (1)
- 4.3 Suggest why the teeth in *Homo sapiens* are smaller than those of *Australopithecus africanus*. (3)
- 4.4 Account for the very prognathous skull of *Ardipithecus ramidus* as opposed to that of *Homo sapiens*. (4)

5. Study the phylogenetic tree shown below showing a possible trend in human evolution. Use information provided in the phylogenetic tree to answer the questions set.



- 5.1 Which is the only human species that exists today? (1)
- 5.2 Name the common ancestor to all the organisms shown in the phylogenetic tree. (1)
- 5.3 Which other species existed at the same time as *A. boisei*? (2)
- 5.4 How long ago did *Australopithecus robustus* become extinct? (1)
- 5.5 How long ago did *A. africanus* evolve from *A. afarensis*? (1)
- 5.6 Is *Homo sapiens* more closely related to *Homo habilis* or to *A. robustus*? (1)
- 5.7 Provide an observable reason for your answer. (1)
- 5.8 *H. erectus* may be regarded as a transitional species. Explain what this means in terms of the above phylogenetic tree. (2)
- 5.9 State the significance of transitional species in understanding evolutionary trends. (2)
- 5.10 Name the three species that are in the same line of development as *Homo sapiens*? (3)
- 5.11 Consider the following three brain sizes of the three *Homo* species, not given in order:
- 900ml 1400ml 650ml
- Which of the above will be the brain size of *H. erectus*? (1)

- 5.12 Explain how you arrived at your answer in Question 5.11. (3)

ANSWERS

1.

1.1

Homo	Chimpanzee
Canines not well developed ✓	Canines well developed ✓
Less protruding jaws ✓/not prognathous	Protruding jaws/prognathous ✓
Brow-ridge less pronounced ✓	Heavily pronounced brow-ridge ✓
Proportionally large cranium ✓	Proportionally smaller cranium ✓
Proportionally shorter cheekbone ✓	Proportionally larger cheekbone ✓
No ridge at base/back of skull ✓	Ridge at base/back of skull ✓

Any 3 x 2 + 1 for the table (7)

- 1.2 Chimpanzee ✓ (1)
- 1.3 The foramen magnum is towards the posterior/back of the skull ✓ (1)
- 1.4 - Taung child ✓
 - Mrs Ples ✓
 - Little-foot ✓
- Any (2)

2.					5.				
2.1	-	Projecting nose✓			5.1	<i>Homo sapiens</i> ✓			(1)
	-	Smaller canines ✓			5.2	<i>Australopithecus afarensis</i> ✓			(1)
	-	Bipedal✓	(3)		5.3	<i>A. robustus</i> ✓ and <i>H. erectus</i> ✓			(2)
2.2	-	They had a wider view✓ to spot danger			5.4	1 million years ago✓			(1)
	-	They could carry offspring✓/food/tools			5.5	2-7 to 2-8 million years ago✓			(1)
	-	Large surface area for thermoregulation✓	Any (2)		5.6	<i>Homo habilis</i> ✓			(1)
2.3		Have characteristics of both <i>Homo</i> ✓ species and <i>Australopithecus</i> ✓ species	(2)		5.7	- Both belong to the same genus✓			
3.						- Both are in the same line as development✓			
3.1		The oldest fossils ✓ of hominids (<i>Australopithecines</i> and <i>Homo habilis</i>) are only found in Africa✓, whilst the younger fossils are found worldwide✓ which suggests that humans originated in Africa.				- <i>Homo habilis</i> is an ancestor of <i>Homo erectus</i> ✓	Any		(1)
		OR			5.8	<i>Homo erectus</i> has characteristics of both <i>Homo sapiens</i> ✓ as well as <i>Homo habilis</i> ✓			(2)
		The oldest <i>Homo erectus</i> fossils ✓ were found in Africa and later in Europe and Asia✓, which suggests that <i>Homo erectus</i> migrated✓ out of Africa	(3)		5.9	- Transitional species help to show how certain features gradually changed✓ over time✓			
3.2		The hypothesis will be rejected✓ since it would imply that the origin of humans was in Asia✓ and not Africa	(2)			- Transitional species also help to show relationships✓ between other species that might not normally be considered related✓	Any 1x2		(2)
3.3		Mutations in mitochondrial DNA (mtDNA)✓ can be traced to a female ancestor in Africa✓	(2)		5.10	<i>Homo erectus</i> ✓, <i>Homo habilis</i> ✓ and <i>Australopithecus afarensis</i> ✓			(3)
4.					5.11	900ml✓			(1)
4.1		Increase in brain size over time✓	(1)		5.12	- There was an increase in brain size over time✓			
4.2	-	It allows for faster processing of information✓				- so <i>Homo sapiens</i> will have the largest brain size and <i>Homo habilis</i> will have the smallest brain size✓			
	-	It allows for the processing of a large amount of information✓	Any (1)			- <i>Homo erectus</i> being intermediate between the above two will have the intermediate brain size✓			(3)
4.3		With the advent of fire and the cooking of food✓, the softer food eaten by <i>Homo sapiens</i> did not require as much chewing✓ as the raw food eaten by <i>Australopithecus africanus</i> . ✓	(3)						
4.4	-	The large jaw✓ of <i>Ardipithecus ramidus</i> required for chewing hard, raw food✓ led to a prognathous skull							
	-	Whereas the smaller jaw✓ of <i>Homo sapiens</i> suitable for chewing softer, cooked food✓ lead to a non-prognathous skull.	(4)						

12

Human Impact on the Environment

INTRODUCTION

As we interact with the environment to satisfy our needs, we may have many negative impacts on the environment such as:

- The atmosphere and climate change
- Water quality and water availability
- Food security
- Loss of biodiversity
- Solid waste disposal

THE ATMOSPHERE AND CLIMATE CHANGE

Introduction

Carbon dioxide, water vapour and methane allow incoming sunlight to pass through but absorb heat radiated back from the earth's surface. This is known as the 'greenhouse effect' and carbon dioxide, methane and water vapour are therefore referred to as 'greenhouse gases'.

The greenhouse effect is important in keeping the Earth warm so that it can sustain life. However, an increase in the concentration of greenhouse gases leads to the 'enhanced greenhouse effect'. As a result, there may be a significant rise in the average temperature of the surface of the Earth over a period of time. This is known as 'global warming'.

Increased concentration of carbon dioxide in the atmosphere is due mainly to:

- Burning of fossil fuels
- Deforestation: Large scale destruction of natural forests decreases the amount of carbon dioxide used by plants during photosynthesis. This increases the amount of carbon dioxide in the atmosphere.

Increased concentration of methane in the atmosphere is due mainly to:

- The production, distribution and combustion of fossil fuels
- The decomposition of biodegradable solid waste in landfills
- The decay of organic matter in waterlogged soils such as rice paddies

- The increased number of livestock which release methane gas through their digestive tracts

Increased temperatures through global warming may lead to:

- More evaporation of water which can lead to increased rain which eventually increases the potential of flooding
- Rising sea levels caused by melting ice in the glaciers which can eventually increase the potential of flooding
- Dry conditions that could increase the chances of wildfires which increase the chances of soil erosion and eventually desertification
- Increased loss of biodiversity as species are unable to cope with rapidly rising temperatures
- Increased drought in some areas leading to food insecurity

Carbon footprint

This is a measure of the total amount of greenhouse gas emissions of an individual, a defined population or a company per year.

Strategies to reduce the carbon footprint include the following:

- Reusing and recycling – less fossil fuels will thus be burnt in the production of new materials
- Driving less – by using public transport, walking, bicycles, thus reducing emissions
- Using alternative energy (solar and wind) thus reducing our dependence on fossil fuels
- Reforestation, which increases the number of trees using carbon dioxide from the atmosphere

Destruction of the ozone layer

Ozone is a greenhouse gas that is found at low concentrations 15 – 50km above the Earth's surface. It absorbs the ultraviolet rays from the sun. The ultraviolet rays damage the DNA and cause skin cancer. The ozone layer is being damaged by the chemicals called CFCs (chlorofluorocarbons), released by refrigerators, aerosol sprays and fast-food packaging.

If the measures to reduce the destruction of ozone layer fail:

- There will be a significant increase in the number of skin cancer cases
- Ultraviolet rays reaching the Earth's surface may cause permanent damage to our eyes

WATER QUALITY AND WATER AVAILABILITY

Availability of water

The availability of water may be influenced by the following factors:

Construction of Dams

- Dams increase the quantity of water available for use by people and in agriculture.

Destruction of wetlands

- Wetlands trap and provide water for domestic and livestock use as well as for irrigation.
- The vegetation in the wetlands also helps in purifying the water naturally.

Water wastage

- Open drain irrigation leads to loss of water by evaporation.
- Availability is also affected by wastage of water through leaking taps and toilets and faulty pipelines.
- Wastage of water can be reduced by reducing the pressure in the pipes, by educating people to use water wisely and by maintaining all plumbing in good condition.

Cost of water

- The cost of water is influenced by costs involved in increasing the availability and quality of water.
- The cost per kilolitre (kl) of water increases with increased use of water. This is meant to discourage over-use of water, thus allowing for its sustained use.

Poor farming practices

- Contamination of water sources by fertilisers and pesticides will decrease the amount of clean water available, thus increasing costs involved in purification.
- Over-grazing leads to soil erosion. On land that is eroded, water runs off rapidly rather than soaking into the ground, and is thus wasted.

Droughts and floods

- During periods of drought, water availability decreases. Water used from the dams during the drought periods cannot be easily replaced.
- Natural vegetation can hold back water from floods. If the natural vegetation is removed, flood waters are lost.

Boreholes and its effect on aquifers

- Constant use of boreholes to increase water availability eventually leads to the drying up of aquifers (the source of borehole water) thus decreasing water availability in the future.

Water recycling

- Some water used in the household can be used for the garden.
- Sewage water can be treated and used again.

Exotic plantations and the depletion of the water table

- Some exotic plants use a large quantity of water from the ground.
- As a result, this decreases the level of the water table, making less water available to other vegetation in the area.

Quality of water

The quality of water may be influenced by the following factors:

Eutrophication and algal bloom

- Water used for agriculture may contain pesticides, herbicides and fertilizers which pollute the water in rivers, dams and lakes, causing eutrophication.
- The added nutrients lead to an increase in algal growth (algal bloom). These algae deplete the oxygen in the water, thus reducing the potential for life in such water.

Thermal pollution

- Thermal pollution is caused by the release of heated water from industries into rivers or lakes.
- The water becomes heated after it is used to cool down power-stations and machines used in industries.
- Heated water has a lower oxygen content, making it difficult to support life.

Pollution of water through domestic, agricultural and industrial use

- After water is used for domestic purposes it may contain detergents (such as from washing) and pathogenic bacteria (such as in sewage).
- This polluted water has to be treated before it can be used again.

- After water is used for industrial purposes it may contain many heavy metals, oil, heat and fertilizers. This adversely affects the quality of the water and all life that depends on it.
- Fertilisers and pesticides may run off into rivers, ponds and dams and pollute the water.

Mining

- Water returned to the environment from mines is generally acidic and toxic. This water is hot and thus also contributes to thermal pollution.

Alien Plants

- Alien invasive water plants block the waterways, reducing light to other aquatic plants.
- These plants eventually die and decompose.
- Bacteria that decompose these plants eventually deplete the oxygen supply in the water.

Water purification

- The quality of water is improved through purification methods. Undrinkable water can be made drinkable.

FOOD SECURITY

Food security refers to the access, by all people at all times, to adequate, safe and nutritious food for a healthy and productive life. Food security may be influenced by the following factors:

Exponential growth of the human population

- Food production needs to increase as rapidly as the world population; otherwise many countries would experience food insecurity.

Droughts and floods

- Droughts result in crop losses and livestock death, which reduces the food available in an area.
- Floods cause extensive damage in a short period of time and decrease the amount of farmland available to grow crops.

Poor farming practices – monoculture, pest control, loss of topsoil and the need for fertilizers

- **Monoculture** is the growing of one type of crop over large areas of land year after year. Monoculture depletes nutrients and water

supplies and therefore impacts negatively on the quality of the topsoil.

- **Pest control** involves the use of pesticides to kill pests that compete with humans for food. Pesticides may kill or get into the tissues of healthy plants. This may reduce crop production and, since pesticides are expensive, increases the cost of food and thus reducing access to poor consumers. Many farmers now use biological control, which uses a natural predator/parasite to get rid of the pest instead of using expensive pesticides.
- **Topsoil:** The tilling of the soil between plantings and heavy rainfall cause much of the topsoil to be lost, leading to the loss of valuable nutrients over time, reducing crop yield.
- **The use of fertilizers** replaces nutrients in the soil that is lost when crop plants absorb them. Fertilizers can be expensive, contributing to the high cost of food, thus reducing access to poor consumers.

Alien plants and reduction of agricultural land

- Alien plants deplete the topsoil of water and nutrients. These alien plants out-compete indigenous plants because they have no natural predators, growing rapidly and invading land that could be used to grow crops.

The loss of wild varieties and its impact on gene pools

- Crop plants have replaced wild varieties. The preservation of wild varieties is important because, if changing environmental conditions destroy the present crop plants, then wild varieties could be used as alternative sources of food.
- If wild varieties get wiped out, it will reduce the genetic diversity and thus the gene pool.

Genetically engineered food

- Through genetic modification it is possible to insert a gene for drought resistance into a crop plant that grows in areas where water is scarce. This can increase the amount of food available.

Food wastage

- Wastage includes food thrown away and food not eaten.

LOSS OF BIODIVERSITY

Biodiversity refers to the variety of plant and animal species on Earth.

Factors that Reduce our Biodiversity

- **Habitat destruction through:**

Farming methods

Monoculture: Monoculture is the growing of one type of crop over large areas of land year after year.

- Monoculture replaces indigenous plants and reduces biodiversity.
- Insects that specialise in feeding on one type of crop spread rapidly because there are no natural enemies or barriers to stop them.
- This means the farmer needs to use more pesticides to kill them.
- Intensive use of fertilisers and pesticides often end up in rivers, streams and groundwater, poisoning species in the area and causing eutrophication. This results in a large loss of biodiversity.

Overgrazing: It occurs when livestock such as sheep or cattle are kept in an area for too long; the vegetation is grazed to a point where it will not grow back.

- Overgrazing causes soil erosion by removing the plants that bind the soil together with their roots.
- Topsoil is lost during rainstorms, leading to extensive destruction of land through desertification, resulting in the loss of biodiversity.

Golf Estates

Developments such as golf estates are a form of monoculture that require large amounts of water, pesticides and fertilisers which may runoff and poison aquatic ecosystems.

Mining

Mining alters the environment and can negatively affect the biodiversity in an area. Pollutants in the form of dust and smoke may be released into the air while vegetation is removed and replaced with rock and waste dumps. Underground water may be poisoned because of sulphates and heavy metals released into them.

Urbanisation

The growth of large cities (urbanisation) also negatively impacts on biodiversity. Surfaces are covered with concrete, and natural habitats are destroyed to build houses and businesses.

Deforestation

Deforestation is the permanent destruction of indigenous forest and woodland areas. Deforestation leads to the destruction of the habitats of other organisms, like frogs and insects, and this leads to the loss of biodiversity.

Loss of wetlands and grasslands

Grasslands and wetlands have unique plant and wildlife and provide many ecological services to humans. Destruction of these habitats will lead to the loss of species.

- **Poaching**

Poaching refers to the illegal hunting of animals, either for food or because certain body parts can be sold for money. 'Poaching' may also be applied to plants that are removed and sold for profit e.g. medicinal plants.

- **Alien plant invasions**

These plants are species that have been introduced into an area and which compete with the natural plants in the area. They can outcompete indigenous plants, thus reducing the biodiversity.

Ways in which our biodiversity can be maintained

- **Control of alien plant invasions**

- Mechanical methods involve chopping down plants or physically removing them by hand and is very time consuming.
- Chemical control involves spraying herbicides on the plants; this can pollute the environment and is expensive.
- Biological methods involve introducing a natural enemy from the alien plant's environment and allowing it to reproduce and feed on the invasive plant.

- **Sustainable use of the environment**

- Sustainable use of the environment means using resources without harming the ability of future generations to use that resource.
- Substances from indigenous plants such as the African potato, *Hoodia*, rooibos and

Grade 12 CAPS – Study Guide

Devil's claw all have economical and medicinal value.

- These indigenous plants can be used sustainably by encouraging traditional healers to grow their own plants
- Legislation should be passed to limit the numbers of plants that can be harvested at one time and seeds of medicinal plants could be collected and distributed to increase plant numbers.

SOLID-WASTE DISPOSAL

Solid waste is any solid material that is of no use to humans and which needs to be disposed of in a safe and environmentally friendly way.

Managing dumpsites for rehabilitation and prevention of soil and water pollution

- The simplest and most cost effective way of disposing of solid waste is to bury it in landfill sites. Rain seeps through the waste to produce a toxic substance called leachate. To prevent the toxic leachate from reaching the groundwater, a plastic liner is placed under the dumpsite area.
- Rehabilitation of landfill sites occurs before it is closed down. This involves the covering of the old landfill site with clay soil, which is impermeable to water, and then it is covered with topsoil. Grass or other vegetation is then planted on the old landfill site.

The need for recycling

Various methods may be used to manage solid waste, including the reduction of waste, re-using waste and recycling of waste.

- Re-using waste products includes re-using plastic shopping bags, re-using glass and plastic containers – this helps to reduce the waste produced.
- Recycling is a process whereby used materials/waste products are recycled to make new products, for example plastic, glass, tin and paper. The advantage of recycling is that it provides employment, reduces the use of raw materials and energy, and reduces air, ground and water pollution.

Using methane from dumpsites for domestic use: heating and lighting

Methane is a gas produced as a result of the decomposition of organic waste. The methane gas can be used as a fuel. Methane can be collected from landfill sites and used to generate electricity.

Safe disposal of nuclear waste

- South Africa uses radioactive material such as uranium to power its nuclear power station.
- A by-product of using uranium is nuclear waste that is still radioactive and therefore dangerous to living organisms.
- The nuclear waste is stored in thick steel drums and buried in trenches at special protected sites.

TERMINOLOGY REVIEW

TERM	DESCRIPTION
Algal bloom	Increased growth of algae due to a large input of nutrients
Alien invasive	Organisms that occupy an area they do not normally inhabit and where they outcompete the natural species of that area
Aquifer	Water-bearing rock from which water is obtained using bore-holes
Biodiversity	The range of living organisms on Earth
Biological control	Use of the natural enemy of a pest to control the population size of that pest
Carbon footprint	A measure of the total amount of CO ₂ emissions of an individual, a defined population or a company per year
Deforestation	The large scale removal of natural forests
Desertification	The conversion of fertile land into infertile land due to the loss of topsoil over a period of time
Drought	Prolonged dry periods usually due to little or no rainfall
Erosion	Loss of topsoil due to flooding or overgrazing
Eutrophication	A sudden increase in the nutrient content in bodies of water such as lakes, rivers and dams
Extinction	The elimination of a species from the earth
Food Security	The access, by all people at all times, to adequate, safe and nutritious food
Fossil fuels	Source of energy in the fossilised remains of plants and animals

TERM	DESCRIPTION
Genetic modification	The transfer of a gene from one organism into another to improve its characteristics
Global warming	An increase in the average temperature of the world
Greenhouse effect	Trapping of heat within the earth's atmosphere by gases such as carbon dioxide
Monoculture	Growing crop of a single species only
Overgrazing	Allowing more livestock to graze in an area than the area has resources for.
Ozone	A gas consisting of three atoms of oxygen and that shields the earth from ultraviolet light
Pesticide	Chemical substance used to eliminate pests
Poaching	The illegal killing of organisms or stealing of parts of organisms
Recycling	Converting waste into re-usable material
Sustainability	Use of resources in such a way that they are available for future generations
Thermal pollution	Increase in temperature of water in rivers, lakes due to release of extremely hot water by industries
Wetlands	An area containing soil that is saturated with water such that water may appear on the surface of the ground

QUESTIONS

1. A type of bacterium called *Escherichia coli* (*E. coli*) normally lives in the large intestine of humans. To determine whether *E. coli* is present in water, a chemical indicator is used.

If the chemical indicator changes from a clear red colour to a cloudy yellow colour, this indicates that *E. coli* is present.

In an investigation conducted by a group of Grade 12 learners, samples taken from **THREE rivers** (X, Y, and Z) were investigated for the presence of *E. coli*. Samples were taken from each river and put into a glass bottle which contained the clear red indicator solution. The bottle was then incubated at 37 °C for 2 days.

The results of the investigation are shown in the table that follows.

Colour of chemical indicator	River X	River Y	River Z
Before incubation	Clear red	Clear red	Clear
After incubation	Clear red	Cloudy yellow	Clear

- 1.1 Explain TWO safety precautions that the learners should take when conducting this investigation.
- 1.2 Suggest ONE reason for incubating the sample at 37°C.
- 1.3 Which river/s (X, Y or Z) showed the presence of *E. coli*?
- 1.4 Give a reason for your answer in QUESTION 1.3 above.
- 1.5 Explain ONE way that *E. coli* could have got into the river/s stated in QUESTION 1.3
2. Scientists have shown that the average carbon dioxide concentration in the atmosphere increased each year from 2009 to the present.
 - 2.1 Describe how deforestation could lead to an increase in the carbon dioxide concentration in the atmosphere.
 - 2.2 Mention ONE human activity that might have led to an increase in carbon dioxide concentration in the atmosphere.
 - 2.3 What is the dependent variable in the investigation carried out by the scientists?
 - 2.4 Explain how the excess carbon dioxide in the atmosphere could lead to climate change.
 - 2.5 Mention ONE way in which humans can reduce the amount of carbon dioxide released into the atmosphere.
3. Deforestation is the destruction of natural forests the removal of trees in large numbers. The table below shows statistics related to deforestation in different regions from the years 1990 to 2000.

Human Impact on the Environment

Region	Total land area (ha)	Total forest cover (ha)	Forest cover (%)	Deforestation rate 1990 – 2000 (%)
Africa	2 978 394	649 866	21.8	0.8
Asia	3 084 746	547 793	X	0.1
North and Central America	2 136 966	549 304	25.7	0.1
Oceania and Australia	849 096	197 623	23.3	0.2

- 3.1 Which region had the highest rate of deforestation in the 10 year period? (1)
- 3.2 Calculate the forest cover (%) of Asia indicated as X. Show all working. (3)
- 3.3 List any TWO reasons for deforestation. (2)
- 3.4 Describe TWO consequences that deforestation has on the ecosystem. (4)
- 3.5 Explain THREE management strategies to reduce deforestation. (6)

The table below shows how the yield of grass varies when different amounts of nitrate fertiliser are added to the crop.

Amount of nitrate fertiliser added to crop (kg/hectare)	Yield of grass (100 kg/hectare)
0	8
225	14
425	18
650	20
700	20
750	19

Explain why farmers use fertiliser. (2)

What was the yield (100 kg/hectare) of grass when 225 kg of nitrate fertiliser was added? (1)

Use the table to determine the minimum amount of fertiliser that has to be added to the grass crop in order to achieve maximum yield. (2)

4.4 Describe the relationship between the amount of fertiliser added and the yield of grass. (3)

4.5 Explain why fertilisers should not be added to the soil immediately before and during the rainy season. (2)

4.6 Describe the effect of the excessive use of nitrate fertilisers on rivers, dams and lakes. (3)

5. Typhoid only affects humans and is a severe illness that is caused by swallowing water that is contaminated by the bacterium *Salmonella typhi*. When human waste disposal (sewage) systems are inadequate and human faeces contaminate drinking water, it creates perfect conditions for the spread of typhoid.

An investigation was carried out to determine the number of cases of typhoid in a province. The average rainfall per month during the year was also recorded.

The results of the above-mentioned investigation are shown in the table below.

The average rainfall and the number of typhoid cases in one year		
Month	Average rainfall (mm)	Number of cases of typhoid
January	166	22
February	180	27
March	39	13
April	35	12
May	9	10
June	3	5
July	5	2
August	16	4
September	24	10
October	49	13
November	114	15
December	116	16

5.1 In which month was typhoid most common in this province? (1)

5.2 What is the relationship between the number of cases of typhoid and the average rainfall in the province during the year? (2)

5.3 Draw a bar graph to show the number of typhoid cases from January to July. (6)

5.4 Name THREE strategies that can be used to reduce water pollution in our country. (3)

6. The following table shows the total amount of solid waste and the amount of recyclable material dumped in a South African city landfill site over a number of years.

YEAR	TOTAL AMOUNT OF SOLID WASTE (MILLIONS OF TONS)	AMOUNT OF RECYCLABLE MATERIAL IN SOLID WASTE (MILLIONS OF TONS)
2003	1,49	0,78
2004	1,59	0,82
2005	1,80	1,20
2006	1,93	1,30

- 6.1 Describe the general trend in the total amount of waste produced and the amount of recyclable materials dumped from 2003 to 2006. (2)
- 6.2 Explain TWO advantages of recycling. (4)

7. The table below shows the composition of household waste from a community.

TYPE OF WASTE	PERCENTAGE COMPOSITION
Organic matter	30
Plastic	25
Paper	15
Glass and tin	10
Other	20

Draw a pie chart to represent the data in the table above. Show ALL working. (6)

8. Alien invader plants may fall in one of three categories based on their impact on the environment, each requiring a particular action as follows:

Category 1: Invader plants must be removed & destroyed immediately

Category 2: Invader plants may be grown under controlled conditions only

Category 3: Invader plants may no longer be planted

- 8.1 Explain why it is better to remove alien plants through biological control rather than through the use of chemicals. (4)

- 8.2 Describe how alien invader plants may have a negative impact on the environment with regard to each of the following:

- 8.2.1 Water availability
8.2.2 The quality of water
8.2.3 Food security
8.2.4 Biodiversity

ANSWERS

- 1.
- 1.1 - Wear rubber gloves when taking the samples✓ so as not to get contaminated with germs✓
- Samples should be taken by using a container attached to a string✓ to avoid stepping too close to the river bank✓/prevent falling into water
- 1.2 It is the normal body temperature of the humans✓ in which the bacterium normally lives✓
- 1.3 River Y✓
- 1.4 The chemical indicator changed to a cloudy yellow colour✓ which indicates the presence of *E.Coli*✓
- 1.5 Absence of proper sewage systems✓ leads to sewage disposal in or near rivers✓
- 2.
- 2.1 Cutting down of trees decreases the amount of carbon dioxide✓ taken up by the plants during photosynthesis✓
- 2.2 Burning of fossil fuels✓
- 2.3 Average carbon dioxide concentration
- 2.4 - Carbon dioxide is a greenhouse gas✓
- which prevents heat from escaping back into the atmosphere✓
- An increase in the concentration of carbon dioxide leads to an increase in the greenhouse effect✓
- which may result in global warming✓
- 2.5 - Drive less✓ / use public transport, walking, bicycles more
- Use alternative energy sources✓ (solar and wind)
- Reuse and recycle✓ any

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3.
3.1 Africa✓ (1)

3.2 $\frac{547\,793}{3\,084\,746} \times \frac{100}{1}$
= 17,8✓ (3)

3.3 Trees used for:
- Fuel✓/fire
- Building houses✓/Furniture✓
- Medicinal purposes✓ any (2)

3.4 - Loss of habitat✓resulting in death✓/
migration of organisms
- Increase in carbon dioxide due to decrease
in the number of plants
photosynthesising✓
- Result in increased soil erosion✓reducing
fertility of soil✓ any 2 x 2 (4)

3.5 - Introduce legislation✓ to control
deforestation✓
- Educate people✓ about the negative
effects✓ of deforestation
- Research✓ new technologies to find other
materials for building✓/furniture/fuel 3 x 2 (6)

4.
4.1 - To enrich the soil✓
- to increase crop yield✓ (2)

4.2 14✓ (1)

4.3 650✓ kg/hectare✓ (2)

4.4 - As the fertiliser increases to 650 kg/hectare
the yield of grass increases✓
- Further increase up to 700 kg/hectare
causes the yield to remain the same✓
- With increases beyond 700 kg/hectare
there is a decrease✓in yield (3)

4.5 - Much of the fertiliser may run off into rivers
or lakes✓
- and will thus be wasted✓/leading to
eutrophication (2)

4.6 - Causes eutrophication✓
- leading to overgrowth of algae✓.
- When the algae die✓
- The amount of decomposition bacteria
increases✓
- decreasing the oxygen levels in the water✓
- causing other organisms to die✓. any (3)

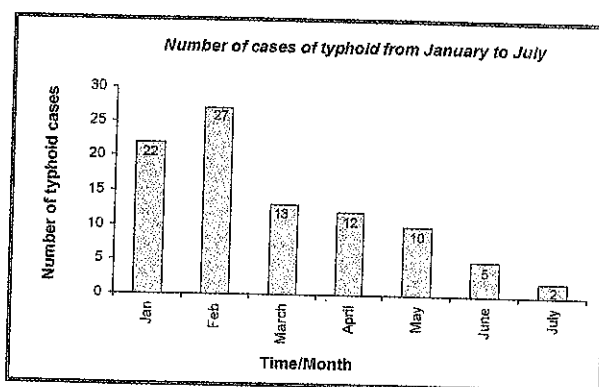
5.
5.1 February✓

5.2 The higher the rainfall✓ the higher the number
of cases of typhoid✓ (1)

OR

The lower the rainfall✓ the lower the number
of cases of typhoid✓ (2)

5.3 (6)



Criteria for assessment

Bar graph drawn from Jan to July for typhoid only	1		
Title of graph (with two variables)	1		
Correct label for X-axis and equal width and interval between bars	1		
Correct label and scale for Y-axis	1		
Plotting of the bars	No bars correctly plotted	1 – 3 bars correctly plotted	4 – 7 bars correctly plotted
	0	1	2

5.4 - Increase awareness about the bad effects
of water pollution✓
- Institute clean-up campaigns✓
- Monitor water quality✓
- Upgrade sanitary systems
- Institute penalties for polluting water✓
- Prevent the release of chemicals and
other waste into the environment✓
- Must treat waste water properly to
remove all harmful chemicals before
water is released into the environment✓ (3)

6.
6.1 - Both✓ the total amount of waste
produced and the amount of
recyclable material increased✓ from 2003
to 2006 (2)

6.2 - People collect and sell waste at buy-back
centres✓ and benefit economically✓

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- People who collect waste and take it to recycling depots✓ contribute to sustainable use of materials✓
- Recycling saves energy✓ and therefore reduces the amount of energy used to make new products✓

any 2 x 2 (4)

7. Calculations of sectors for pie chart.

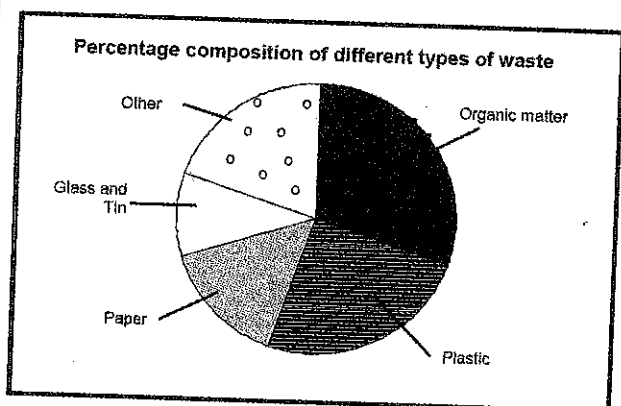
$$\text{Organic matter: } \frac{30}{100} \times \frac{360}{1} = 108^\circ$$

$$\text{Plastic: } \frac{25}{100} \times \frac{360}{1} = 90^\circ$$

$$\text{Paper: } \frac{15}{100} \times \frac{360}{1} = 54^\circ$$

$$\text{Glass and tin: } \frac{10}{100} \times \frac{360}{1} = 36^\circ$$

$$\text{Other: } \frac{20}{100} \times \frac{360}{1} = 72^\circ$$



Criteria for assessment

Calculation/working to determine the correct proportions	1-4 calculations correct – 1 mark ALL calculations correct – 2 marks
Correct type of graph	1
Title of graph	1
Correct proportions for each labelled sector/slice	1-3 sectors correct – 1 mark 4-5 sectors correct – 2 marks

8.

- 8.1 - Chemicals seep into the ground or run-off into nearby streams✓
- where they affect other organisms✓
 - With biological control, the introduced organism feeds on the alien invader plants✓
 - with no damage to the environment✓

(4)

- 8.2 8.2.1 - Some alien invader plants use a large quantity of water from the ground✓.
- thus decreasing the level of the water table, making less water available to natural vegetation in the area✓.

(2)

- 8.2.2 - Alien invasive water plants block the waterways, reducing light to other aquatic plants✓.
- These plants eventually die and decompose✓.
 - Bacteria that decompose these plants eventually deplete the oxygen supply in the water✓.

(3)

- 8.2.3 - These alien plants out-compete indigenous plants because they have no natural predators✓,
- growing rapidly and invading land that could be used to grow food crops✓.

(2)

- 8.2.4 - Alien invader plants compete with the natural plants in the area for resources✓.
- They can outcompete/replace indigenous plants, thus reducing the biodiversity✓.

(2)