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**Topic 1**

**DNA: The code of life**

**Unit 1**

**The nucleus and nucleic acids**

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**The cell**

- Cells carry out various cellular activities within the cytoplasm. During cellular activities, useful substances such as water and nutrients enter the cell from the outside. Waste products are removed from the cell. See Figure 1.1 below.
- The **cytoplasm** is a watery solution that consists of a mixture of substances such as dissolved salts, gases, proteins, carbohydrates and suspended fats. Suspended in the cytoplasm are different organelles.
- **Ribosomes** are small, granular organelles that occur in rows on the surface of rough ER (endoplasmic reticulum) or in groups in the cytoplasm. A ribosome is made of RNA and protein. It is the site of protein synthesis.
- The **nucleus** is the control centre of the cell. It controls activities such as the synthesis of proteins and transmits hereditary information into daughter cells during cell division.
- A double nuclear membrane with nuclear pores surrounds the nucleus. The pores allow substances to move between the nucleus and the cytoplasm.
- The jelly-like substance called nucleoplasm fills the nucleus.
- The chromatin network forms chromosomes during cell division.
- The nucleolus is composed of protein and ribonucleic acid (RNA). The stored RNA is involved in the synthesis of proteins in the cell.

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**Figure 1.1** An animal cell
Nucleic acids

Nucleic acids are biological molecules that are essential for all life forms. They include DNA (deoxyribonucleic acid) and RNA (ribonucleic acid).

DNA makes up the genes located on chromosomes found in the nucleus.

RNA is formed in the nucleus but functions in the cytoplasm.

Nucleic acids are polymers. Polymers are made of smaller, similar building blocks called monomers. The monomers of nucleic acids are called nucleotides. Each nucleotide, as shown in Figure 1.2, consists of three parts:

- a phosphate group (P)
- a sugar (S)
- a nitrogenous base (N)

Figure 1.2 The diagrammatic structure of a nucleotide

Test yourself

1. Give the correct biological term for each of the following:
   1.1 The monomer of nucleic acids
   1.2 The membrane surrounding the nucleus
   1.3 An organelle where the site of protein synthesis
   1.4 A nucleic acid formed in the nucleus but functions in the cytoplasm occurs
   1.5 The structure in the nucleus composed of protein and ribonucleic acid

2. 2.1 Give two functions of the nucleus.
   2.2 Draw a nucleotide showing its different parts.
   2.3 Explain why DNA can be classified as a polymer.
   2.4 How does DNA differ from RNA?

(Answers on page 179)
Deoxyribonucleic acid (DNA)

Location
- Most DNA occurs in the nucleus. This is called nuclear DNA. DNA is wound around protein molecules called histones, to form the chromosomes. DNA and these proteins form the chromosomes that make up the chromatin network.
- Small amounts of DNA occur outside the nucleus. This is known as extra-nuclear DNA. It occurs in the mitochondria where it is known as mitochondrial DNA (mtDNA), and in the chloroplasts where it is known as chloroplast DNA (cpDNA).

The discovery of the structure of DNA
Table 1.1 Scientist and developments or events leading up to the discovery of the structure of DNA

<table>
<thead>
<tr>
<th>Date</th>
<th>Scientist</th>
<th>Development/Event</th>
</tr>
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<tr>
<td>1952</td>
<td>Rosalind Franklin</td>
<td>Took many X-ray photographs of DNA. These showed the double helix structure of DNA, but she did not realise it.</td>
</tr>
<tr>
<td>1952</td>
<td>Maurice Wilkins</td>
<td>Showed one of the X-ray photographs to Watson and Crick without Franklin's permission.</td>
</tr>
<tr>
<td>1953</td>
<td>James Watson and Francis Crick</td>
<td>Formulated the double-helix structure of DNA with the aid of a three-dimensional model. Published their findings in the journal Nature while working at the Cavendish Institute in Cambridge.</td>
</tr>
<tr>
<td>1953</td>
<td>Rosalind Franklin and Raymond Gosling</td>
<td>Published a paper in the same issue of Nature as Watson and Crick, which supported the regular, double-helix model suggested by Watson and Crick.</td>
</tr>
<tr>
<td>1953</td>
<td>Maurice Wilkins and co-authors</td>
<td>Published a paper in the same issue of Nature as Watson and Crick, which supported the regular, double-helix model suggested by Watson and Crick.</td>
</tr>
<tr>
<td>1962</td>
<td>Watson and Crick and Wilkins</td>
<td>Received the Nobel Prize in Physiology or Medicine for discovering the molecular structure of DNA.</td>
</tr>
<tr>
<td>1990</td>
<td>James Watson</td>
<td>First director of the Human Genome Project.</td>
</tr>
<tr>
<td>2003</td>
<td></td>
<td>Scientists mapped the human genome in its entirety.</td>
</tr>
</tbody>
</table>

Structure of DNA
- DNA is a double-stranded molecule that forms a double helix. It contains deoxyribose sugar.
- DNA contains four different nitrogenous bases – adenine (A), thymine (T), guanine (G) and cytosine (C). These bases form base pairs in the DNA molecule. Adenine always joins to thymine and guanine always joins to cytosine. The bases are linked to each other by weak hydrogen bonds. See Figure 1.3.
- DNA is arranged so that the sugar and the phosphate group form a long chain. This chain is often regarded as the ‘backbone’ of the molecule. The nitrogenous bases are attached at right angles to this chain onto the sugar.
The main functions of DNA

- DNA:
  - contains the genetic instructions (codes) to make different proteins in the body
  - maintains the structure of the chromosomes and regulates the function of genes
  - regulates protein synthesis
  - sections of DNA form genes that carry hereditary material from parent to offspring.

Extraction of DNA from cells

- Special chemicals and specific methods are used in laboratories to extract DNA. Similar procedures can be used in the classroom using household products to extract DNA.
- Collect the sample from which the DNA is to be extracted. Peas or onions are a good sample.
- Break open the cells using dishwashing liquid and salt. This breaks up the cells to get to the DNA.
- Add meat tenderiser, which contains protease enzymes to break down the proteins around the DNA.
- Purify the DNA with ice-cold alcohol. The DNA will settle out (float to the top), because it is insoluble in alcohol.

DNA Replication

- DNA replication is the process whereby DNA makes an identical copy of itself.
- DNA replication takes place in the nucleus.
- DNA replication takes place just before cell division. It occurs during interphase.

The process of DNA replication

Figure 1.4 shows the steps of DNA replication. All stages of the process are controlled by specific enzymes.

- The double helix DNA molecule unwinds. DNA looks like a ladder-shaped molecule.
- The weak hydrogen bonds between the nitrogen base pairs break.
- The two DNA strands start separating from each other along the whole length of the DNA strand.
- Each original DNA strand now serves as a template to form a new strand on each.
Free DNA nucleotides in the nucleoplasm attach to the exposed complementary bases on the DNA strands.

Adenine nucleotides combine with thymine nucleotides, and guanine nucleotides join with cytosine nucleotides.

Each DNA molecule now consists of one original strand and one new strand.

The result is two genetically identical DNA molecules.

Each DNA molecule then winds up into a double helix again.

The enzyme, DNA polymerase, is involved in this process.

**Figure 1.4 DNA replication**

The importance of DNA replication

DNA replication:
- ensures that each daughter cell produced during mitosis has the identical genetic make-up as the parent cell.
- ensures that the number of chromosomes present in each generation of daughter cells is the same as the original parent cell.
- ensures that genetic information is transmitted from one generation to the next.

**Test yourself**

1. Give the correct biological term for each of the following:
   - 1.1 The structure of a DNA molecule
   - 1.2 The type of bond between bases
   - 1.3 The four bases in DNA
   - 1.4 The full name of DNA
   - 1.5 The type of base that thymine and cytosine are classified as

   *(Answers on page 179)*
2. **2.1** Explain the concept of ‘complementary base pairing’ in DNA. (2)

**2.2** Explain why DNA can be classified as a polymer. (2)

**2.3** You extract and analyse a chemical from a cell. You determine that the amount of adenine in the extract is the same as the amount of thymine. Explain the conclusion that this information may allow you to make. (3)

3. **3.1** Describe the discoveries from 1952 that led to the discovery of the structure of DNA. (6)

**3.2** Why did Watson, Crick and Wilkins receive the Nobel Prize? (1)

4. **4.1** Tabulate the differences between DNA and RNA. (9)

**4.2** DNA samples taken from an ill person were analysed and showed the following results:

<table>
<thead>
<tr>
<th>Tube 1:</th>
<th>Tube 2:</th>
</tr>
</thead>
<tbody>
<tr>
<td>19.8% T; 30.2% G; 30.2% C; 19.8% A</td>
<td>26.4% T; 23.6% C; 26.4% G; 23.6% A</td>
</tr>
</tbody>
</table>

**4.2.1** Which tube contained the viral DNA? (1)

**4.2.2** Explain your answer to question 4.2.1. (3)

**4.2.3** Draw a bar graph showing data from both the tubes. (11)

5. The diagram on the right shows the structure of part of a DNA molecule.

**5.1** Name the parts labelled 1-4. (4)

**5.2** Identify the molecules represented by X and Y. (2)

**5.3** What is represented by Z? (1)

**5.4** Name the sugar that occurs in DNA. (1)

**5.5** Name two functions of DNA. (2)

**5.6** Explain why DNA is able to play a role in the transmission of hereditary information. (2)

6. **6.1** During which stage of the cell cycle does DNA replication occur? (1)

**6.2** Explain why DNA replication is important. (3)

**6.3** Draw a flow diagram to outline the steps of DNA replication. (7)

7. **7.1** The following sequence of nucleotides sequence represents one of the original strands of a section of DNA: A A G T C C G A T. Write down the complementary sequence of the nucleotides. (2)

**7.2** The following sequence of base pairs shows the order of the base pairs in a section of DNA after replication has occurred:

<table>
<thead>
<tr>
<th>A</th>
<th>A</th>
<th>G</th>
<th>T</th>
<th>C</th>
<th>C</th>
<th>G</th>
<th>A</th>
<th>T</th>
</tr>
</thead>
<tbody>
<tr>
<td>T</td>
<td>T</td>
<td>C</td>
<td>C</td>
<td>T</td>
<td>T</td>
<td>C</td>
<td>T</td>
<td>A</td>
</tr>
</tbody>
</table>

The strand on the top is the original strand.

**7.2.1** Did replication occur correctly? (2)

**7.2.2** Explain your answer to question 7.2.1. (4)

[Total marks: 65]
DNA profiling

DNA profiling is the use of a person’s DNA to identify them or to trace the genetic relationships between people. This is also known as DNA fingerprinting.

DNA is extracted from a body tissue or body fluid such as blood, skin or saliva.

A genetic profile or fingerprint is a pattern of black bars left on X-ray film that shows the unique DNA of the person. See Figure 1.5 below.

Figure 1.5 The bar code of a DNA fingerprint

Uses of DNA profiling

DNA profiling can be used to detect genetic diseases and disorders such as haemophilia and sickle cell anaemia.

DNA evidence can confirm a person as a suspect in a crime.

To identify relatives, for example:
- to determine who the father of a child is if the mother is uncertain, or if the father denies paternity
- to help parents find a missing child
- to identify a body that cannot be identified after death.

Views for and against the use of DNA profiling

DNA fingerprinting has been challenged on the following grounds:

- Only short DNA segments, rather than complete DNA strands are compared, so it is possible that two individuals may produce identical results on a short DNA section.
- There is a chance of human error during the interpretation of DNA results.
- DNA profiling is expensive.
- DNA performed at some laboratories may not follow the correct procedures and may thus lead to false results.
- DNA profiling can reveal confidential information such as HIV status that could be used against the person with the disease.
1. Read the passage below, study the diagrams of the DNA fingerprints of Louise, Gary, Malcolm and the child and then answer the questions.

Louise and her boyfriend, Gary, had a sexual relationship, which resulted in her falling pregnant. When Louise told Gary, he said that the child was not his. He accused Louise of having an affair with his friend Malcolm. Louise said this was not true, but Gary did not believe her. After the baby was born, Louise insisted that everyone involved have DNA tests done. This would allow the baby’s DNA to be compared with the DNA of Louise, Gary and Malcolm. The DNA fingerprints below show the test results.

1.1 Using the DNA profile, explain how you can show that Louise is the baby’s mother. (2)
1.2 Using the DNA profile, explain who the baby’s father is. (2)
1.3 Explain how genetic profiling can be used to prove the identity of the father of the child. (2)
1.4 Give one reason why this evidence is considered reliable. (1)
1.5 Give one reason why this evidence may not be reliable. (1)
1.6 Name two benefits of DNA profiling. (2)

[Total marks: 10]
RNA (ribonucleic acid) is also a nucleic acid.
- RNA carries genetic information from the DNA in the nucleus to the parts of the cell where it is needed.
- RNA plays a vital role in protein synthesis.
- RNA is less stable than DNA and breaks down easily. This allows it to break down once it has completed its function after protein synthesis.

**Structure of RNA**
- Look at Figure 1.6. RNA is a single-stranded molecule. The monomers of RNA are also nucleotides but sugar is ribose, not deoxyribose.
- RNA contains four different nitrogenous bases – adenine (A), uracil (U), guanine (G) and cytosine (C). Thymine (T) is replaced by uracil (U).
- There are no base pairs in RNA, as RNA is single stranded.

![RNA structure diagram](image)

**Types of RNA**
There are three types of RNA, each with a specific function:
- **Messener RNA** (mRNA) is formed in the nucleus, then moves out of the nucleus to attach to the ribosome in the cytoplasm. mRNA copies the genetic code for a specific protein from the DNA and carries it to the ribosome in the cytoplasm.
- **Ribosomal RNA** (rRNA) combines with other molecules to form the ribosomes in the cytoplasm, which are the site of protein synthesis.
- **Transfer RNA** (tRNA) is found in the cytoplasm, carries amino acids to the mRNA on the ribosome, and arranges them in the correct order according to the code on the mRNA.

**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

Table 1.2 Differences between DNA and RNA

<table>
<thead>
<tr>
<th>DNA</th>
<th>RNA</th>
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<tr>
<td>1 Double helix (two complementary</td>
<td>1 Single stranded</td>
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<td>strands)</td>
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<tr>
<td>2 Contains the sugar deoxyribose</td>
<td>2 Contains the sugar ribose</td>
</tr>
<tr>
<td>3 Bases: adenine, thymine, cytosine</td>
<td>3 Bases: adenine, uracil, cytosine, guanine</td>
</tr>
<tr>
<td>4 Base pairing occurs: A-T and C-G</td>
<td>4 No base pairing</td>
</tr>
<tr>
<td>5 Found in the nucleus, chloroplast</td>
<td>5 Found in the nucleus and cytoplasm</td>
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Functions of RNA

All three types of RNA play an important role in protein synthesis.

Protein synthesis

- Protein synthesis uses the genetic code of a specific protein that occurs in DNA. It takes place in living cells when there is a need for a specific protein. It takes place in two stages (see Figure 1.7).
  - **Transcription** is the first stage of the process. During this stage the mRNA copies the genetic code of a specific protein form of a section of the DNA molecule.
  - **Translation** is the second stage. During this stage the genetic code of the mRNA is changed or translated into a protein.

![Figure 1.7 Protein synthesis](image-url)
Transcription

- Transcription takes place in the nucleus. mRNA strands are transcribed (copied) from DNA with the aid of an enzyme.
- New mRNA sequences are complementary (matching) to their DNA template.

The process of DNA transcription

- A small section of DNA containing the protein code unwinds to its ladder shape. Weak hydrogen bonds between the nitrogen bases break.
- The two DNA strands now unzip.
- This process is controlled by an enzyme.
- One strand is used as a template to form mRNA.
- Free RNA nucleotides in the nucleoplasm pair with the nucleotides on the exposed ‘template’ DNA strand to form the mRNA.
- The mRNA is complementary to the DNA.
- The mRNA strand separates from the DNA.
- Three adjacent bases on mRNA make up a codon, which codes for an amino acid.
- mRNA then moves out of the nucleus through the nucleopores.
- The two strands of DNA join and return to its double-stranded helical shape.

Translation

- The section of DNA is translated into a protein using the section of mRNA that was formed during transcription.

The process of mRNA translation into proteins

- The newly-formed mRNA has left the nucleus and moved into the cytoplasm. It attaches itself to the surface of a ribosome.
- The nitrogen bases of the mRNA strand are exposed.
- The tRNA molecules have groups of three exposed bases called anticodons. The anticodons are complimentary to the codons on the mRNA.
- The tRNA molecules collect free-floating amino acids in the cytoplasm, as determined by their anticodons.
- The tRNA molecules move to the ribosome where the mRNA strands are attached. The anticodon of the tRNA links with the codon on the mRNA. In this way the tRNA molecules place the amino acids in a certain order to form a specific protein.
- The ribosome moves along the full length of the mRNA strand. This ensures that all the codons of the mRNA strand are ‘read’ by the ribosome.
- The amino acids link together by means of peptide bonds. Enzymes control this process.
- The tRNA molecules that have released their amino acids move back into the cytoplasm where they can pick up more amino acids to carry to the ribosomes.
- A protein is composed of 50 or more amino acids arranged in the order that corresponds to the order of codons on the mRNA strand.
Mistakes in protein synthesis

DNA usually replicates accurately, but sometimes there are copying errors. This results in the wrong nucleotide or too many nucleotides being inserted into a sequence. Most of these replication mistakes are corrected by DNA repair processes that are brought about by repair enzymes.

- Some replication errors are not detected and corrected and become permanent mutations. Some of these mutations are not significant, but others can lead to genetic problems or cancer.

- Occasional copying errors are natural and enable a species to adapt if they are useful, which helps the organisms survive. Mutations can increase genetic variation within the species.

Test yourself

1. **1.1** Name the three types of RNA.  
   **1.2** Where in a cell:  
   - 1.2.1 does DNA occur  
   - 1.2.2 is tRNA made and where does it occur  
   - 1.2.3 is mRNA made and where does it occur?  
   **1.3** Briefly describe the structure and functions of mRNA.  
   **1.4** List the similarities between DNA and RNA.  

   **[17]**

2. Part of a protein molecule consists of six amino acids. The codons for these amino acids are AAG, AUG, CAA, CAU, AUA and CGU.  
   **2.1** Where do the codons occur?  
   **2.2** Name the anticodons for the amino acids represented by the codons listed above.  
   **2.3** Where do the anticodons occur?  
   **2.4** Give the order of bases in the DNA molecule for this part of the protein.  
   **2.5** The genetic code in DNA for some of the amino acids is:  

<table>
<thead>
<tr>
<th>DNA</th>
<th>Amino acid</th>
<th>DNA</th>
<th>Amino acid</th>
<th>DNA</th>
<th>Amino acid</th>
</tr>
</thead>
<tbody>
<tr>
<td>TTC</td>
<td>Lysine</td>
<td>GGC</td>
<td>Proline</td>
<td>GGT</td>
<td>Glycine</td>
</tr>
<tr>
<td>TGA</td>
<td>Threonine</td>
<td>GTT</td>
<td>Leucine</td>
<td>TAC</td>
<td>Tyrosine</td>
</tr>
<tr>
<td>TCA</td>
<td>Serine</td>
<td>GCA</td>
<td>Alanine</td>
<td>TAT</td>
<td>Tyrosine</td>
</tr>
<tr>
<td>GTA</td>
<td>Histidine</td>
<td>GCT</td>
<td>Alanine</td>
<td>AAG</td>
<td>Phenylalanine</td>
</tr>
</tbody>
</table>

   List the six amino acids, in the correct sequence, which occur as part of this protein molecule.  

   **[16]**

3. If a strand of DNA is 24 nucleotides long, how many:  
   **3.1** amino acids will be in the polypeptide that is made from this strand of DNA  
   **3.2** nucleotides will be in the mRNA that is made from this strand of DNA  
   **3.3** anticodons will be involved in the process of making this polypeptide?  

   **[Total marks: 40]**
Chromosomes
- The nucleus is the control centre for all cellular activities.
- Just before cell division, the chromatin network contracts and becomes visible as individual chromosomes.
- Each chromosome consists of DNA molecules (which makes up genes) wrapped around proteins.
- The number of chromosomes in a cell is a characteristic of an organism. For example, humans have 46 chromosomes.
- During DNA replication, single-stranded chromosomes replicate (make copies) to become double stranded. The chromosome consists of two chromatids joined by a centromere.
- Replication ensures that all daughter cells contain the same hereditary information as the parent cells.
- Just before cell division, chromosomes are arranged in pairs called homologous chromosomes. See Figure 2.1.
- Each chromosome of the homologous pair is the same length and contains the same genes.

![Figure 2.1 Structure of homologous chromosomes](image)

Types of chromosomes
- In cells, there are two types of chromosomes, autosomes and gonosomes.
- **Autosomes** control features common in both males and females. For example, eye colour and blood group genes are carried on autosomes. There are 22 pairs of autosomes in humans.
- The **gonosome** or the sex chromosome determines the sex of the organism. There are two types of gonosomes, an X and a Y chromosome. Females have two X chromosomes (XX) in their cells, while males have one X and one Y chromosome (XY).
Introduction to meiosis

- Meiosis is a special type of cell division necessary for sexual reproduction.
- The process of meiosis begins with one diploid \((2n)\) cell containing two copies of each chromosome.
- One copy is from the organism's mother and the other is from its father.
- The number and appearance of chromosomes in the nucleus of a cell is called its karyotype.
- Meiosis produces four haploid \((n)\) cells containing half the number of chromosomes as in the original parent cell.
- Each haploid cell is genetically different from each other.
- During sexual reproduction, one of the haploid male gametes fuses with one of the haploid female gametes. This process is called fertilisation and produces a diploid zygote.

Where does meiosis occur in animals?

- Meiosis occurs in the gonads (reproductive organs). The gonads are called the testes (in the male) and ovaries (in the female).
- The cells produced by meiosis are called gametes (reproductive cells) and the process is known as gametogenesis.
- The male \((♂)\) gametes are called spermatozoa (sperm cells). They are produced by the process known as spermatogenesis.
- The female \((♀)\) gametes are called ova (egg cells). They are produced by the process known as oogenesis.

Where does meiosis occur in plants?

- The gametes of plants are called spores.
- Meiosis occurs in the anther to produce pollen grains in the male and in the ovary to produce the ovule in the female plant.

The process of meiosis

- Meiosis begins with one diploid cell containing two copies of each chromosome, one from the organism's mother and the other from its father. See Figure 2.2.
- According to the cell cycle, meiosis follows interphase.

Interphase

- DNA replication takes place to double the genetic material.
- The chromosomes duplicate during DNA replication to create an exact copy of each maternal and paternal chromosome.
- These copies are called homologous chromosomes. Each chromosome is made up of two chromatids joined by a centromere.
Meiosis I

Meiosis I is a reduction division. It involves separating the pairs of homologous chromosome into two separate daughter cells.

- Each daughter cell contains half the number of chromosomes found in the original cell, the haploid number ($n$).

Prophase I

- The nuclear membrane starts to disappear.
- The chromatin network becomes visible as separate threads, called chromosomes.
- The chromosomes arrange themselves into homologous pairs.
- Crossing over occurs between chromatids. See Figure 2.3. Homologous chromosomes lie next to each other. They touch at points along the chromatids called chiasma. Where they touch, there is an exchange of genetic material.
Metaphase I
- A spindle-shaped structure, consisting of protoplasmic threads forms in the cell.
- The homologous pairs randomly arrange along the equator.
- The centromere of each chromosome attaches to the spindle threads formed by the centrioles.

Anaphase I
- Spindle threads contract.
- The homologous chromosomes separate and whole chromosomes move towards the poles.

Telophase I
- The chromosomes uncoil and lengthen.
- The spindle disappears.
- The nuclear membrane reforms.
- The cytoplasm divides to form two new cells.
- There are two haploid daughter cells. The new cells are genetically different from each other due to crossing over.

Meiosis II
- The two cells resulting from meiosis I divide again during meiosis II.
- The chromatids of the chromosomes now separate from each other, creating four haploid daughter cells.

Prophase II
- In each haploid daughter cell, the chromosomes are visible as two chromatids.
- The centromere now splits between the sister chromatids. The sister chromatids are now called daughter chromosomes.

Metaphase II
- The daughter chromosomes randomly arrange along the equator.
- The centromere of each daughter chromosome attaches to the spindle threads.

Anaphase II
- Spindle threads contract.
- The centromere splits, allowing the spindle threads to pull the daughter chromosomes apart. The daughter chromosomes move towards opposite poles.

Telophase II
- The chromosomes uncoil and lengthen.
- The spindle disappears.
- The nuclear membrane reforms.
- The cytoplasm divides to form four new cells.
- There are four haploid daughter cells.
- The new cells are genetically different from one another.
- The nuclear envelopes reform.
Test yourself

1. Define the following terms:
   1.1 karyotype
   1.2 genome
   1.3 crossing over
   1.4 diploid chromosome number \((2n)\)
   1.5 haploid chromosome number \((n)\)
   1.6 homologous chromosome pair.

2. Study the diagram below of a phase during cell division and answer the questions.

   ![Cell Division Diagram]

   2.1 Identify the type of cell division that is represented in Figure 2.2.
   2.2 Give two visible reasons for your answer to question 2.1.
   2.3 Explain the significance of this type of nuclear division in terms of the ploidy of the daughter cells.
   2.4 Provide labels for the parts numbered 1 to 10.
   2.5 What is the diploid chromosome number of this cell?
   2.6 Identify the specific phase of cell division that is represented here.
   2.7 Which process is taking place at the chromosome pair labelled X?
   2.8 What is the biological importance of the process mentioned in question 2.7?
   2.9 Make a neat, labelled biological drawing of the phase that will follow the phase shown in the diagram above.

3. The diagram below shows cells undergoing meiosis.

   ![Meiosis Diagram]

   3.1 Name each stage of meiosis represented by the cells labelled 1–6.

   [Total marks: 30]
The importance of meiosis

Meiosis is biologically significant because it:
- results in the formation of gametes in a process called gametogenesis.
- reduces the number of chromosomes by half to produce haploid gametes. This counteracts the doubling effect of fertilisation.
- introduces genetic variation as a result of crossing over and the random arrangement of chromosomes during metaphase.

Gametogenesis
- Gametogenesis is the process whereby gametes are formed. See Figure 2.4.
  - In males this process is called spermatogenesis and produces mature sperm cells.
  - In females this process is called oogenesis and produces mature ova (singular: ovum).

![Diagram of cell inside a follicle in ovary and germinal epithelial cell in testes]

**Figure 2.4** The process of gametogenesis shows the basic pathways of oogenesis and spermatogenesis.

Reduction of the chromosome number
- Meiosis ensures that all gametes contain half the diploid \((2n)\) number of chromosomes.
  - So, all gametes contain the haploid \((n)\) number of chromosomes.
  - This prevents the chromosome number from doubling when fertilisation occurs.

Genetic variation
Genetic variation due to meiosis is a result of the following processes.

Crossing over
- Crossing over results in the exchange of genetic material between the paternal and maternal chromosome of each homologous pair.
  - New genetic combinations occur in the chromosomes with the exchanged segments. This ensures that all the gametes of both parents contain a unique combination of genes.
  - When different gametes of the same parents combine during fertilisation, the resultant offspring will all contain a unique karyotype, ensuring variation in the offspring.
Random arrangement of chromosomes

- Each homologous chromosome pair is randomly arranged along the equatorial line, which results in random separation of chromosomes.
- The paternal and the maternal chromosomes move randomly to one of the two poles of the cell. This ensures that the combination of genetic material received by each gamete is random.

Test yourself

1. Give the correct scientific term for each description:
   1.1 phase in meiosis in which the chromosomes are pulled apart
   1.2 point of overlap of chromatids during crossing over
   1.3 chromosome number representing a single set of chromosomes in each cell
   1.4 structures to which chromosomes attach in metaphase
   1.5 phase where crossing over occurs

2. Name and explain the processes that occur in meiosis that will cause genetic variation to occur.

3. List the reasons why meiosis is important for living organisms.

4. Study the diagrams representing different phases of meiosis.

4.1 Label structures A, B and C.
4.2 Which phase is represented by:
   (a) Diagram 1
   (b) Diagram 2?
4.3 Write down the numbers of the diagrams to show the correct sequence in which the phases occur.
Consequences of abnormal meiosis

Abnormal meiosis
- When the process of meiosis does not occur properly, chromosomal abnormalities will occur. These are referred to as chromosomal mutations.
- The frequency of chromosomal mutation increases as women increase in age.

Methods by which chromosomal mutations can occur
- Chromosomal mutations result in a change in the structure or distribution of one or more of the chromosomes. This means that there has been a change to the cell’s karyotype.

Non-disjunction
- A chromosome may be lost or gained when they do not separate correctly during meiosis. This can occur during the separation of the homologous chromosomes during Anaphase I or when the sister chromatids separate during Anaphase II.
- If one pair of chromosomes fails to separate, then one cell receives two copies of that chromosome while the other cell does not receive any.
- This is known as non-disjunction.
- Non-disjunction may lead to aneuploidy or polyploidy.
- Aneuploidy refers to gametes that have one extra or one less chromosome.
- Polyploidy refers to gametes that have an entire extra set of chromosomes.
  (for example: $3n/4n$)

Trisomy
- Trisomy occurs when an individual has three of the same chromosome in a cell instead of two. This condition is usually fatal for the zygote/embryo suffering from this condition.
- Individuals born with this condition suffer from a variety of abnormal physical and mental characteristics. The specific group of characteristics associated with each condition is referred to as a syndrome.

Down’s syndrome
- Down’s syndrome occurs as a result of chromosome pair 21 not separating during metaphase I of meiosis. There will be a gamete that contains two number 21 chromosomes, and not one as is normal.
- In meiosis I, chromosome pair 21 may not separate. In meiosis II the chromatids of chromosome 21 do not separate.
- Should this gamete (ovum) be fertilised by a normal sperm cell, the resulting zygote will contain 47 chromosomes instead of the normal 46, as shown in Figure 2.5.

![Figure 2.5 Karyotype of a human female with Down’s syndrome](image)
Test yourself

(Answers on page 183)

1. 1.1 Explain the term ‘non-disjunction’.
   (2)
1.2 Explain when it can occur in meiosis.
   (2)
1.3 Describe how Trisomy 21 occurs.
   (6)

2. Study the information below regarding the age of pregnant women and the occurrence of children born with Down’s syndrome. Then answer the questions.

<table>
<thead>
<tr>
<th>Age in years of women giving birth</th>
<th>Incidence of Down’s syndrome births</th>
</tr>
</thead>
<tbody>
<tr>
<td>20–24</td>
<td>1 in 1 450</td>
</tr>
<tr>
<td>25–29</td>
<td>1 in 1 210</td>
</tr>
<tr>
<td>30–34</td>
<td>1 in 698</td>
</tr>
<tr>
<td>35–39</td>
<td>1 in 216</td>
</tr>
<tr>
<td>40–44</td>
<td>1 in 59</td>
</tr>
<tr>
<td>45–49</td>
<td>1 in 30</td>
</tr>
</tbody>
</table>

2.1 Use the information in the table above to compile a second table that shows the incidence of Down’s syndrome births per 1 000 babies in the different female age groups.
   (6)
2.2 Draw a column graph using the information in the table compiled in question 2.1.
   (14)
2.3 2.3.1 Calculate the percentage of Down’s syndrome babies born to women between the ages of 40 and 44 years. Show your calculations.
   (3)
2.3.2 Calculate the percentage of Down’s syndrome babies born to women 40 years of age or older. Show your calculations.
   (3)
2.4 Identify the:
   2.4.1 independent variable
   2.4.2 dependent variable in this study.
   (1)
2.5 Draw a conclusion from the graph.
   (2)

[Total marks: 40]
Unit 4

Comparison of mitosis and meiosis

Similarities between mitosis and meiosis
- DNA replication takes place.
- The nucleus divides.
- The cytoplasm divides
- New cells are formed

Differences between mitosis and meiosis

Table 2.1 Main differences between mitosis and meiosis

<table>
<thead>
<tr>
<th>Mitosis</th>
<th>Meiosis</th>
</tr>
</thead>
<tbody>
<tr>
<td>It takes place in somatic cells.</td>
<td>It takes place in reproductive (sex) cells/gametes.</td>
</tr>
<tr>
<td>The cell nucleus divides once.</td>
<td>The cell nucleus divides twice.</td>
</tr>
<tr>
<td>Two daughter cells are formed.</td>
<td>Four daughter cells are formed.</td>
</tr>
<tr>
<td>Daughter cells are identical to one another and to the parent cell.</td>
<td>Daughter cells are non-identical to one another and to the parent cell.</td>
</tr>
<tr>
<td>Chromosome number remains constant.</td>
<td>The chromosome number is halved.</td>
</tr>
<tr>
<td>Homologous chromosomes do not pair.</td>
<td>Homologous chromosomes form pairs.</td>
</tr>
<tr>
<td>Exchange of genetic material/crossing over does not occur.</td>
<td>Exchange of genetic material/crossing over does occur.</td>
</tr>
<tr>
<td>It does not allow variation to occur.</td>
<td>It allows variation to occur.</td>
</tr>
<tr>
<td>Single chromosomes lie on the equator (during metaphase).</td>
<td>In the first meiotic division (Metaphase I), the homologous pairs lie on the equator; in the second meiotic division (Metaphase II), single chromosomes lie on the equator.</td>
</tr>
<tr>
<td>The centromere divides (during anaphase).</td>
<td>In the first meiotic division (Metaphase I), the centromere does not divide; it only divides in the second meiotic division (Metaphase II).</td>
</tr>
<tr>
<td>Daughter chromosomes move to opposite poles.</td>
<td>One chromosome of each homologous pair moves to opposite poles in the first meiotic division; in the second meiotic division, daughter chromosomes move to opposite poles.</td>
</tr>
</tbody>
</table>

Test yourself

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. Write A only, B only, both A and B, or none next to the relevant question number (1.1 to 1.10).

<table>
<thead>
<tr>
<th>COLUMN I</th>
<th>COLUMN II</th>
<th>COLUMN I</th>
<th>COLUMN II</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Reduces the diploid number of chromosomes to the haploid number</td>
<td>A. Mitosis B. Meiosis</td>
<td>1.6 Daughter cells are non-identical</td>
<td>A. Mitosis B. Meiosis</td>
</tr>
<tr>
<td>1.2 Takes place in the gonads</td>
<td>A. Mitosis B. Meiosis</td>
<td>1.7 Bivalents occur</td>
<td>A. Mitosis B. Meiosis</td>
</tr>
<tr>
<td>1.3 Allows variation to occur</td>
<td>A. Mitosis B. Meiosis</td>
<td>1.8 A spindle is formed</td>
<td>A. Mitosis B. Meiosis</td>
</tr>
<tr>
<td>1.4 Genetic material moves to opposite poles</td>
<td>A. Mitosis B. Meiosis</td>
<td>1.9 Centromeres are visible</td>
<td>A. Mitosis B. Meiosis</td>
</tr>
<tr>
<td>1.5 Karyokinesis occurs</td>
<td>A. Mitosis B. Meiosis</td>
<td>1.10 Only occurs in diploid cells</td>
<td>A. Mitosis B. Meiosis</td>
</tr>
</tbody>
</table>

(Answers on page 184)

[Total marks: 20]
Reproduction is the process of producing a new generation of organisms from an existing generation. All vertebrates reproduce sexually.

Sexual reproduction involves the production of gametes in male and female parents. A gamete from each parent fuses to produce a zygote. The zygote eventually develops into a new organism.

The gametes must be brought into contact with each other, the developing embryo must be fed and protected. The young must survive long enough to reach sexual maturity. Different organisms use various strategies to ensure that the process happens.

Vertebrate groups carry out the stages of sexual reproduction in different ways to ensure that it will be successful. The stages are:

- Fertilisation
- The development of the zygote/embryo into a new individual
- The development of the young after hatching or birth
- The absence or presence of parental care for the young; the level of parental care.

Reproductive strategies are the way in which each animal species ensures that each stage is completed successfully. These strategies include structural, functional and behavioural adaptations that improve the chances of fertilisation and/or increase the survival of the offspring. The combination of reproductive strategies that each species has enables it to make the most of its reproductive success in its environment.

During fertilisation, the nucleus of a sperm cell enters the egg cell (ovum) and fuses with the nucleus of the ovum.

Ova are non-motile and cannot actively move.

Sperm are motile, and they swim actively. The sperm must be protected from drying out and be guided to the ova.

Fertilisation can be external or internal.

External fertilisation

External fertilisation occurs in most animals that breed in water, for example, fish and amphibians. They release eggs and sperm into the water and fertilisation occurs outside the body of the female. See Figure 3.1.

Disadvantages of external fertilisation

- Animals are dependent on water for reproduction (fertilisation).
- Large amounts of sperm and eggs are released into the water to increase the chances of fertilisation.
- Many gametes will be eaten by predators.
- The gametes are exposed to unstable environmental factors such as temperature changes, unsuitable pH and water currents.
Advantages of external fertilisation

- There is little or no need for parental care. The offspring obtain food from the environment. This reduces the energy input from parents to offspring as they do not feed them.
- The young are widely dispersed by water currents. This reduces competition between the offspring and the parents for living space and food.

Internal fertilisation

- Internal fertilisation occurs mainly in terrestrial organisms such as mammals, birds, reptiles and some invertebrates. It is an adaptation to living on land. The ovum is fertilised inside the body of a female.
- In egg-laying species, a waterproof shell protects the zygote/embryo.

Disadvantages of internal fertilisation

- There must be co-operation between the male and female so that the sperm can be placed inside the body of the female.

Advantages of internal fertilisation

- Animals are not dependent on water for reproduction (fertilisation).
- Fewer gametes are produced as the chances of fertilisation occurring are high.
- There is protection inside the body for the gametes from drying out and from predators.
- The gametes meet in a contained environment. This ensures a greater chance of fertilisation taking place.

Nutrition, development and protection of the embryo

- In organisms that have internal fertilisation, the egg or offspring must be fed and protected as it develops and grows.
- There are three strategies to accomplish this:
  - ovipary – animals lay eggs
  - ovovivipary – animals produce eggs that hatch inside the female’s body, or that hatch as soon as they are laid
  - vivipary – animals give birth to ‘live’ young.

Table 3.1 Comparison of the strategies for feeding, protecting, growth and development of the offspring of animals

<table>
<thead>
<tr>
<th>Oviparous animals</th>
<th>Ovoviviparous animals</th>
<th>Viviparous animals</th>
</tr>
</thead>
<tbody>
<tr>
<td>External or external fertilisation</td>
<td>Internal fertilisation</td>
<td>Internal fertilisation</td>
</tr>
<tr>
<td>Eggs laid outside female's body</td>
<td>Eggs kept inside female's body</td>
<td>Ovum/ova kept inside female's body</td>
</tr>
<tr>
<td>Eggs protected by a gelatinous mass in frogs, a leathery shell in reptiles and a hard, brittle calcareous shell in birds</td>
<td>Eggs protected by a soft shell inside female’s body</td>
<td>Ova protected by female’s body</td>
</tr>
<tr>
<td>Protective membranes present</td>
<td>Protective membranes present</td>
<td>Follicle cells, membranes and the uterus assist with protection</td>
</tr>
<tr>
<td>Development of embryo occurs in an egg outside female's body</td>
<td>Development of embryo occurs in an egg inside female's body</td>
<td>Development of embryo occurs in the uterus</td>
</tr>
<tr>
<td>Embryo gets food from egg yolk, and not from mother</td>
<td>Embryo gets food from egg yolk, and not from mother</td>
<td>Embryo embeds in the uterine wall and gets food from mother via placenta and umbilical cord</td>
</tr>
</tbody>
</table>

EXAM TIP

ovi = egg laying
ovoviv = egg but gives birth to live young
vivi = live young

EXAM TIP

Learn Table 3.1 well.
### Oviparous animals
- Eggs hatch outside the body
- Eggs/embryos rely on environmental temperature for development

### Ovoviviparous animals
- Egg hatches inside the body just before birth
- Eggs/embryos kept at constant, ideal temperature for development
- Live young appear

### Viviparous animals
- Gestation (pregnancy) followed by birth of fully developed foetus
- Incubation temperature regulated by mother to keep foetus at ideal temperature
- Live young are born

<table>
<thead>
<tr>
<th>Eggs/hatch outside the body</th>
<th>Egg hatches inside the body just before birth</th>
<th>Gestation (pregnancy) followed by birth of fully developed foetus</th>
</tr>
</thead>
<tbody>
<tr>
<td>Eggs/embryos rely on environmental temperature for development</td>
<td>Eggs/embryos kept at constant, ideal temperature for development</td>
<td>Incubation temperature regulated by mother to keep foetus at ideal temperature</td>
</tr>
<tr>
<td>Live young appear</td>
<td>Live young are born</td>
<td>Live young are born</td>
</tr>
</tbody>
</table>

- Eggs/offspring usually have no/little parental care
- Offspring/young may or may not have parental care

### Examples:
- Fish, amphibians, reptiles, birds, few mammals
- Some amphibians, some reptiles and some fish
- Mammals

### The amniotic egg
- Reptiles, birds and egg-laying mammals lay eggs that have a shell and can survive and develop on land. The embryo develops inside an amnion and the egg shell is calcium-based or leathery. This type of egg is called an **amniotic egg**. See Figure 3.2.

The amniotic egg contains a number of membranes that perform functions that are vital to the development and survival of the embryo.

- The **yolk sac** provides the embryo with food.
- The **amnion** contains amniotic fluid, which protects and supports the developing embryo.
- The **allantois** is a bag that collects the waste products from the embryo.
- The **chorion** grows around the amnion, yolk and allantois, and allows the embryo to exchange gases.
- Blood vessels connect the embryo with the yolk and the allantois to form a structure called the **umbilical cord**.
- The air space in the egg acts as a shock absorber.
- The hard, porous shell gives protection. The shell and the chorion allow gaseous exchange to occur.
- The **yolk and albumin** provide the developing embryo with food.

---

**Figure 3.2 The structure of a developing amniotic egg**

- The advantage of amniotic eggs is their resistance to drying out. The strong outer shell enables the embryo to survive out of water. The amniotic egg is an important factor in the ability of reptiles to live and reproduce on land.
- The amniotic egg contains a number of membranes that perform functions that are vital to the development and survival of the embryo.
  - The **yolk sac** provides the embryo with food.
  - The **amnion** contains amniotic fluid, which protects and supports the developing embryo.
  - The **allantois** is a bag that collects the waste products from the embryo.
  - The **chorion** grows around the amnion, yolk and allantois, and allows the embryo to exchange gases.
  - Blood vessels connect the embryo with the yolk and the allantois to form a structure called the **umbilical cord**.
  - The air space in the egg acts as a shock absorber.
  - The hard, porous shell gives protection. The shell and the chorion allow gaseous exchange to occur.
  - The **yolk and albumin** provide the developing embryo with food.

---

**The albumin is the main protein that occurs in the white of an egg.**
The development of the young after hatching or birth

- When an embryo has reached a specific level of development inside the egg or its mother's body, it hatches or is born.
- Newly-hatched fish, amphibians and reptiles can move around and feed themselves soon after hatching.
- Birds and mammals vary in the level of development of the newly-born young.

Precocial and altricial development

- There are two levels of development of newborn birds and mammals:
  - **Precocial** development is the pattern of growth and development of species in which the young are relatively mature and mobile from shortly after birth or hatching.
  - **Altricial** development is the pattern of growth and development of species in which the young are born or hatched helpless. They cannot move around independently shortly after hatching or being born. See Table 3.2.

### Table 3.2 Comparison of precocial and altricial development

<table>
<thead>
<tr>
<th>Precocial development</th>
<th>Altricial development</th>
</tr>
</thead>
<tbody>
<tr>
<td>The young are relatively mature and can move around independently from shortly after birth or hatching.</td>
<td>The young are relatively immature, unable to move around or care for themselves after birth or hatching.</td>
</tr>
<tr>
<td>At birth or hatching the young's eyes are open, they have hair or down and can run from predators.</td>
<td>At birth or hatching the young's eyes are closed, they have little or no down or fur and depend on their parents.</td>
</tr>
<tr>
<td>Predators cannot target all the infants at once.</td>
<td>The young are vulnerable to predators.</td>
</tr>
<tr>
<td>Young can regulate their body temperature at birth/hatching.</td>
<td>Young cannot regulate their body temperature at birth/hatching.</td>
</tr>
<tr>
<td>Their independence enables them to survive if one or both parents die. They are able to feed themselves.</td>
<td>The young are dependent and would not survive the death of a parent. They cannot feed themselves.</td>
</tr>
<tr>
<td>Examples of precocial animals are guinea fowls and ducks.</td>
<td>Examples of altricial animals are 60% of all bird species.</td>
</tr>
</tbody>
</table>

Parental care

- Parental care is the time and energy parents spend protecting and improving the survival chances and general health of their offspring. The type and level of parental care in animals varies greatly between species.
- Humans look after their babies longer than any other animal, while some animals such as fish, desert their young at birth or desert the eggs once they are laid, leaving them to fend for themselves.
- The terrestrial environment is much harsher than the aquatic environment. Amphibians were the first vertebrates to develop different kinds of protective parental care. The development of similar strategies in reptiles, birds and mammals occurred as each vertebrate group evolved.

Parental care may occur in the following ways:

- building nests
- guarding nests
- incubating the eggs
- carrying broods
- providing food for the offspring
- protecting the offspring
- teaching the offspring.
1. Give the correct biological term for each description.

1.1 The process during which a male reproductive organ deposits sperm cells inside a female’s body to increase the chance of fertilisation

1.2 The reproductive strategy where the embryo develops inside the female’s uterus and the young are born live

1.3 The type of egg that occurs in reptiles, birds and certain mammals

1.4 The layer between the chorion and the shell that serves as reserve food for the developing embryo in an egg

1.5 The developmental strategy that occurs in species where the young are not fully developed and not mobile when born or hatched

1.6 The innermost extra-embryonic membrane that occurs in an amniotic egg

1.7 The fusion of the male and female gametes that occurs outside the body of the female

1.8 Organisms that produce eggs that mature and hatch after they have been laid

1.9 The care and nurturing of adult organisms for their offspring

1.10 The pattern of growth and development of organisms which can move around independently soon after birth or hatching

2. Indicate whether each statement in Column 1 applies to A only, B only, both A and B, or none of the items in Column 2. Write A only, B only, both A and B or none next to the question number.

<table>
<thead>
<tr>
<th>Column 1</th>
<th>Column 2</th>
</tr>
</thead>
</table>
| 2.1 Have an amniotic egg | A Fish  
B Amphibians |
| 2.2 Have internal fertilisation | A Fish  
B Birds |
| 2.3 All species are viviparous | A Reptiles  
B Mammals |
| 2.4 Exhibit altricial or precocial development | A Mammals  
B Birds |
| 2.5 Parental care is rare | A Mammals  
B Birds |
| 2.6 All species are oviparous | A Reptiles  
B Amphibians |

3. Study the diagram below of an amniotic egg and then answer the questions.
3.1 Identify the parts labelled 1 to 6.

3.2 Write down the numbers and names of the different embryonic membranes, and give the function of each.

3.3 Describe the functions of each of the following:
   3.3.1 yolk sac
   3.3.2 allantois
   3.3.3 shell.

3.4 Amniotic eggs evolved in early reptiles. Explain why amniotic eggs are advantageous for evolving reptiles as opposed to eggs that are covered by a layer of jelly as found in fish and amphibians.

4. Discuss the advantages and disadvantages of precocial and altricial development in bird species.

5. This question relates to the level of development of the offspring at birth or hatching.

5.1 Describe the term ‘precocial development’ by referring to the level of development at birth or hatching, the number of offspring produced.

5.2 Tabulate a comparison of altricial and precocial species in respect of:
   5.2.1 the degree of development of the offspring at hatching.
   5.2.2 the number of offspring produced by the adults.

6. 6.1 Explain the meaning of ‘reproductive strategies’.

6.2 List three reproductive strategies used by vertebrates.

7. Define the concept of parental care.

8. The cladogram below shows the sequence of the evolution of the different groups of vertebrates.

   A cladogram is a chart that shows the relationship of organisms with shared characteristics.

   EXAM TIP
   This is a high order question. Try to answer it and then check your answer.

   8.1 Which groups in the sequence lay amniotic eggs?

   8.2 Suggest why the developing mammalian foetus has so many similar structures to an amniotic egg.

   8.3 Name two important differences between the developing mammalian foetus and the amniotic egg.

[Total marks: 80]
This unit revises the information learnt in Grades 7 and 9 and expands on that knowledge. During sexual reproduction a haploid sperm and haploid ovum fuse to form a diploid zygote. The zygote undergoes mitosis to produce an embryo.

**The male reproductive system**

- The main function of the male reproductive system is to produce spermatozoa (sperm cells) and deliver them to the female. See Figure 4.1.
- It consists of these basic structures:
  - the primary sex organs – the testes
  - various ducts/tubules – epididymis, vas deferens (sperm duct) and the urethra
  - accessory glands – prostate gland, Cowper’s gland and seminal vesicles
  - external genitalia – penis.
- Structure and functions of the parts of the male reproductive system:

![Diagram of the male reproductive system](image)

**Figure 4.1 The male reproductive system**

- **seminal vesicle**: sac-like glands that secrete a sugary substance that is as an energy source for sperm
- **prostate gland**: gland that produces a milky alkaline fluid that makes the sperm more active. It neutralises the acidic vaginal secretions and acidic pH of the urethra.
- **Cowper’s gland**: gland secretions help to lubricate the head of the penis, clear the urethra of urine residues and maximise sperm motility (ability to move)
- **vas deferens**: a muscular tube that transports sperm from the epididymis to the urethra
**penis:** made of erectile tissue that fills with blood making the penis erect. An erection is essential for transferring semen to a female’s vagina

**epididymis:** stores sperm as they mature and until they are released

**testis:** one of two oval-shaped glands that produce sperm. See Figure 4.2. Each testis is divided into compartments filled with tightly coiled tubules, called seminiferous tubules. See Figure 4.3. The testes produce sperm and the male sex hormone, testosterone.

**scrotum:** skin sac hanging outside the abdominal cavity to protect the testes. The scrotum regulates temperature and keeps the testes 2° to 3 °C lower than body temperature for sperm production.

**glans:** sensitive head of the penis

**urethra:** a duct that transports semen and urine through the penis to the exterior at different times.

---

**Structure of a testis**

![Diagram of a longitudinal section through a testis](image)

**epididymis:** sperm cells mature and are temporarily stored for 2 to 3 months here

**seminiferous tubule:** sperm are formed here from puberty onwards; the tubules join to form the epididymis

---

**Structure of the seminiferous tubules**

![Cross section through seminiferous tubules of the testis](image)

**germinal epithelial cells:** divide to form new sperm cells

**sperm cell:** immature sperm cell formed by the maturation of the spermatids

**cell of Sertoli:** provides the developing sperm with food

**interstitial cells (cells of Leydig):** cells which secrete testosterone (male sex hormone)

---

*Figure 4.2* Diagram of a longitudinal section through a testis

*Figure 4.3* Cross section through seminiferous tubules of the testis
The female reproductive system

- The main function of the female reproductive system is to produce ova for fertilisation and to nurture the growing foetus during pregnancy.

- It consists of these basic structures:
  - the primary sex organs – the ovaries
  - ducts/tubules – Fallopian tubes or oviducts
  - accessory organs – uterus and vagina
  - external genitalia – vulva.

Structure and function of female reproductive system

- 1 Fallopian tube
- 2 uterus
- 3 ovary
- 4 uterus wall
- 5 endometrium
- 6 cervix (ring of muscle)
- 7 vagina
- 8 vulva
- 9 opening of vagina
1. **Fallopian tube (oviduct):** one of two muscular tubes that occur on each side of the uterus. One end opens into an upper corner of the uterus, while the other end opens into the abdominal cavity near the ovary. It is lined with ciliated epithelium that helps move the ovum/zygote towards the uterus. Peristalsis also plays a part in moving the ovum/zygote.

2. **uterus:** hollow pear-shaped muscular organ. It houses and protects the developing foetus during pregnancy until birth.

3. **ovary:** one of two almond-shaped oval organs that occur in the pelvic cavity. A layer of germinal epithelium surrounds each ovary. This layer produces the primary follicles that develop into the ova. The ovaries produce ova and the female sex hormones produce oestrogen and progesterone.

4. **uterus wall:** made of three layers – loose connective tissue around the uterus for support and protection; middle layer consisting mainly of smooth muscle to induce uterine contractions during childbirth; inner mucous membrane layer where implantation occurs.

5. **endometrium:** inner mucous membrane of the uterus. This glandular layer lines the uterus. During the menstrual cycle it thickens as it is rich in blood vessels and is ready for the implantation of a blastocyst on its arrival in the uterus.

6. **cervix:** thick muscular canal found at the base of the uterus that contains glands.

7. **vagina:** thin muscular tube running from the cervix to the exterior of the body. It receives the penis during sexual intercourse and acts as the birth canal during childbirth.

8. **vulva:** opening of the vagina covered by two vaginal covers.

**Structure of ovary**

- There are two ovaries, each about 3–5 cm long. A layer of cells, called the germinal epithelium, surrounds each ovary.
- The ovary contains the follicles in various stages of development. Each follicle forms one ovum.

**Figure 4.6 The internal structure of the ovary**

- **Primary follicle:** first stage of follicle development when the follicles continue developing after puberty
- **Mature Graafian follicle:** mature ovarian follicle: contains an immature ovum (oocyte)
- **Corpus luteum** secretes progesterone, a hormone that causes added changes in the endometrium and prevents the shedding of the endometrium

**Test yourself**

1. Explain why the testes are located outside the body. [2]
2. Create a flow chart to show the pathway of the sperm from the testes to the penis. [5]
3. Name three functions of the female reproductive system. [3]

[Total marks: 10]
Puberty

Puberty is the stage in the human life cycle when the organs of the reproductive system mature. This prepares them for reproduction.

Puberty begins when the pituitary gland starts to release specific hormones into the bloodstream. These hormones trigger the testes and ovaries to produce and release the sex hormones. These sex hormones are:

- Testosterone – produced by and released from the testes; testosterone is sometimes referred to as the male sex hormone
- Oestrogen and progesterone – produced by the ovaries; oestrogen, in particular, is sometimes referred to as the female sex hormone.

Secondary sexual characteristics

Testosterone and oestrogen are responsible for the development of the secondary sexual characteristics in males and females once puberty has started.

Secondary sexual characteristics start happening earlier in females than in males.

The bodies of men and women show several marked differences by the time their physical growth is completed. These changes may occur slowly and extend over a period of more than ten years, or appear suddenly and be completed within one or two years.

Male secondary sexual characteristics

The first body changes during puberty are growth of the testicles, the appearance of pubic hair at the base of the penis, and an enlargement of the penis.

The body grows rapidly in size. The shoulders become wider than the hips, the chest enlarges, and the muscles in the arms, legs, and shoulders grow stronger and more obvious.

Body hair and pubic hair grows. Facial hair also develops.

The larynx (voice box or ‘Adam’s apple’) enlarges. As a result, men generally have deeper voices than women.

Female secondary sexual characteristics

First, the breasts begin to enlarge. Pubic hair and body hair begin to develop. During puberty, the body grows in height, and the hips become wider than the shoulders. Fatty tissue is laid down in and around the breasts, shoulders, hips and buttocks.

The first menstruation (also known as menarche) indicates the approach of sexual maturity. In the beginning, the menstrual cycles are irregular. A woman usually gains her full reproductive capacity one or two years after her first menstruation.
1. 1.1 Explain why puberty is necessary in humans. (3)
1.2 Name the physiological changes that occur during puberty. (4)
1.3 Name five physical changes that occur during puberty in boys and girls. (5)

2. The graph below shows the results of an investigation on the average height of boy and girls from birth to 19 years of age.

EXAM TIP
Make sure you can interpret information from a graph.

2.1 What is the independent variable in this investigation? (1)
2.2 What is the dependent variable in this investigation? (1)
2.3 At what age(s) is the average height of the boys and girls the same? (2)
2.4 Give the average height of a 16-year-old boy. (1)
2.5 Give the average height of an 18-year-old girl. (1)

3. The male sex hormone is responsible for causing the development of secondary sexual characteristics in boys during puberty.
3.1 Name this male sex hormone. (1)
3.2 Name the structure in which this hormone is produced. (1)
3.3 List any five male secondary sexual characteristics. (5)

[Total marks: 25]
Gametogenesis

The production of gametes

- The production of gametes is known as **gametogenesis**. This is the process by which germ cells undergo cell division and differentiation to form mature haploid gametes.
- Gametogenesis occurs by meiosis in animals. It occurs in the gonads (sex organs).
  - The mechanism by which male gametes, sperm cells, are formed is called **spermatogenesis**.
  - The mechanism by which female gametes, ova, are formed is called **oogenesis**.

Spermatogenesis

- **Spermatogenesis** is the process by which male germ cells develop to become mature sperm cells that are capable of fertilising an ovum.
  - It occurs in the testes and epididymis.
  - It starts at puberty and usually continues uninterrupted until death.
- The process of spermatogenesis from germinal cell to mature sperm cell takes 74 days.
- The testes produce 200 to 300 million sperm daily.

![Figure 4.7 The structure of a sperm cell](image-url)

The process of spermatogenesis

- Germinal epithelial cells lining the seminiferous tubules in the testes undergo meiosis.
- Each cell to form in the seminiferous tubules of the testes undergoes meiosis. Four haploid spermatids are formed.
- Each spermatid matures to form a haploid spermatozoa.
Oogenesis

- Oogenesis is the process by which female germ cells develop to become mature ova.
- Germinal epithelial cells undergo mitosis to form many follicles.
- Follicles will not develop further until after puberty.
- One follicle enlarges and undergoes meiosis.
- Of the four haploid cells that are formed, three break up.
- Of the four haploid nuclei that are produced, only one survives to become a mature haploid ovum. See Figure 4.8.

![Figure 4.8 Structure of an ovum](image)

Test yourself

1. Briefly outline the process of spermatogenesis in humans.
2. Briefly outline the process of oogenesis in humans.
3. Name the structure(s) in the human reproductive system in which each of these processes occurs:
   - 3.1 production of ova
   - 3.2 meiosis
   - 3.3 production of sperm
   - 3.4 addition of liquid to sperm to form semen.
4. Draw a fully labelled diagram of a human sperm cell.

(Answers on pages 186)

EXAM TIP

Read the questions carefully and follow the instructions. When questions say 'name' or 'give', you can answer with one word.

[Total marks: 35]
The menstrual cycle

The menstrual cycle refers to the changes that occur in a uterus and ovary for the purpose of sexual reproduction. It is essential for the production of ova (eggs) and for the preparation of the uterus for pregnancy. Typically each cycle lasts about 28 days.

The menstrual cycle starts to happen at puberty and lasts until menopause.

The changes that occur in the endometrial lining of the uterus are known as the uterine cycle. This cycle is responsible for the thickening and breakdown of the endometrium.

The changes that occur in the follicles of the ovary are known as the ovarian cycle. This cycle is responsible for the maturation of an ovum in one of the ovaries each cycle.

The menstrual cycle is controlled by the endocrine system. The following hormones play an important role in the control of the menstrual cycle:

- Oestrogen
- Progesterone
- FSH (follicle stimulating hormone)
- LH (luteinising hormone).

The hormonal control of the menstrual cycle

The changes that occur in the ovaries (the ovarian cycle) are controlled by the hormones:

- Follicle-stimulating hormone (FSH)
- Luteinising hormone (LH)

These hormones are secreted by the pituitary gland, or hypophysis.

The changes that occur in the uterus (the uterine cycle) are controlled by the hormones:

- Oestrogen
- Progesterone.

These hormones are secreted by the ovaries.

The level of each hormone rises and falls during the stages of a menstrual cycle.

The mechanism of the hormonal control of menstruation

The pituitary gland secretes FSH, which stimulates the maturation of a follicle in one of the ovaries.

This follicle releases oestrogen as it develops into a fully mature Graafian follicle.

The increasing oestrogen level stimulates the pituitary gland to release LH.

A spike in the LH level triggers ovulation (the release of an ovum) on about day 14 of the cycle.

After ovulation, the Graafian follicle develops into the corpus luteum. This is the tissue that is left behind in the ovary after the release of the egg, and it remains in the ovary.

The corpus luteum secretes progesterone. Progesterone inhibits the release of FSH and LH by the pituitary gland. This is a negative feedback mechanism.

The corpus luteum degenerates, the progesterone level decreases, causing the endometrium to break down. This tissue is released from the body via the vagina as a bloody discharge during menstruation.

The lack of progesterone, means that FSH and LH are no longer inhibited. They are therefore produced by the pituitary gland, and the cycle begins again.
EXAM TIP
Make sure you can understand the graph and that you can read information from it.

EXAM TIP
Hormones:
Pituitary gland = FSH
= LH
ovary = oestrogen
= progesterone

Menstruation is the beginning of the menstrual cycle.

Figure 4.9 The relationship between the changing levels of the hormones that control the menstrual cycle and the uterine and ovarian parts of the cycle

The fate of the corpus luteum

- If fertilisation does not occur:
  - The pituitary gland produces LH (luteinising hormone).
  - The LH stimulates the corpus luteum to produce progesterone.
  - The ovum degenerates.
  - The progesterone level rises, causing negative feedback to the pituitary gland.
  - The corpus luteum degenerates.
  - Menstruation occurs.

- If fertilisation does occur:
  - The pituitary gland produces LH (luteinising hormone).
  - The LH stimulates the corpus luteum to produce progesterone.
  - The corpus luteum continues to produce progesterone and oestrogen until the placenta develops.
  - The placenta starts to secrete progesterone and oestrogen.
  - Only then does the corpus luteum degenerate.
1. Explain how FSH and LH play a role in a woman’s fertility.

2. Study the diagram, which shows the changes that occur in an ovary during the development of an ovum. Then answer the questions.

2.1 Name the process that is represented by the parts labelled A to H. (1)

2.2 Name the hormone that is responsible for controlling the process referred to in 2.1. (1)

2.3 Name the gland that secretes the hormone referred to in 2.2. (1)

2.4 Name the structures labelled A to E. (5)

2.5 Name the process that enables the part labelled E to be released. (1)

2.6 How frequently does the process referred to in 2.5 occur? (1)

2.7 Name the structure responsible for secreting the hormone oestrogen. (1)

2.8 List the functions of oestrogen. (3)

2.9 Name the hormone that is produced by the part labelled D. (1)

2.10 List the functions of this hormone. (3)

2.11 Name the hormone that is responsible for the development of the structure labelled D. (1)

3. Write an essay explaining how the hormonal changes of the ovarian cycle affect the uterine cycle, causing menstruation.
Unit 5  Gestation

- **Gestation** is the period of development of an embryo/foetus inside the uterus of a female. This is known as the prenatal stage.
- The length of time that a pregnancy lasts is called the gestation period.
- The beginning of gestation is usually dated from the beginning of the previous menstrual period.
- In humans, the average length of the gestation period is 38-40 weeks or 9-9.5 months.
- Early development lasts from **fertilisation** until the end of the eighth week (second month) of pregnancy.
- Late development lasts from the ninth week (third month) of pregnancy until birth. This is the foetal development stage.

**Test yourself**

1. Study the graph below. It shows the change in relative amounts of three hormones in a woman's bloodstream during gestation.

![Graph showing changes in hormone levels during pregnancy](image)

**Key**

A. Human chorionic gonadotropin  
B. Oestrogen  
C. Progesterone

**EXAM TIP**

Look at the heading of the graph and the labels of the axes. Also read the key. Then answer the questions.

1.1 Where is each hormone shown in the graph produced? (4)  
1.2 Describe the function of each hormone in the graph. (5)  
1.3 What happens to progesterone levels during pregnancy? Explain your answer. (4)  
1.4 What will happen to oestrogen levels when the woman starts to menstruate again after her pregnancy? (1)  
1.5 Miscarriages often occur at 12-14 weeks in pregnancy. Use evidence from the graph to explain how this may occur. (6)  

**EXAM TIP**

Write a paragraph to explain this answer. [20]

[Total marks: 20]
Unit 6

Fertilisation, blastocyst implantation and embryo development

Fertilisation and development of the zygote to blastocyst

**Fertilisation**
- During ovulation the ovum, surrounded by follicle cells, is drawn into the Fallopian tube.
- Once semen has been deposited in the vagina, the sperm swim through the cervix, uterus and into the Fallopian tubes.
- Fertilisation occurs in the Fallopian tube as follows:
  - Thousands of sperm cells surround the ovum and the follicle cells.
  - Sperm cells secrete enzymes that break down the follicle cells.
  - Only one sperm cell penetrates the cell membrane of the ovum.
  - The nuclei of the sperm cell and the ovum fuse to form a diploid zygote.

**Development of the zygote to blastocyst**
- Although the zygote is growing and developing, the woman is not pregnant at this stage.
- The movement of the developing embryo along the Fallopian tube is due to a combination of:
  - peristaltic waves of contraction moving along the Fallopian tube towards the uterus
  - the rhythmical beating of the cilia in the Fallopian tube towards the uterus.
- The following changes occur as the developing embryo moves along the Fallopian tube towards the uterus:
  - The zygote immediately starts to divide to form two cells.
  - Each cell divides by mitosis again and again, forming four cells, then eight cells, and so on.
  - This cell division continues and a solid ball of cells, the morula, is formed.
  - The morula develops into a hollow, fluid-filled ball of cells called the blastocyst.
- The development to the blastocyst stage takes about five days from fertilisation.

Refer to Figure 4.10 for development of zygote to blastocyst.

**Figure 4.10 Development of the blastocyst and its implantation**
Implantation of the blastocyst

- The blastocyst attaches to the uterine wall in a process called implantation. This occurs about 10 days after fertilisation as follows:
  - The outer cells of the blastocyst secrete enzymes that break down a small portion of the thickened uterine wall, causing it to soften.
  - The blastocyst sinks into this area.
  - The blastocyst/embryo releases a hormone (human chorionic gonadotropin, hCG), that stimulates the corpus luteum to continue to produce oestrogen and progesterone.
  - These hormones prevent menstruation from happening and ensure that the endometrium stays intact.
- The outer cell layers of the blastocyst, called the trophoblast develop into two extra-embryonic membranes:
  - chorion
  - amnion.
- The chorion then sends finger-like outgrowths, called chorionic villi, into the endometrium.
- These villi form part of the placenta. They anchor the embryo during its early stages of development and absorb nutrients from the mother’s blood.

Test yourself

1. Name the cells of the blastocyst that develop into the extra-embryonic membranes. (1)
2. Name and give the functions of each extra-embryonic membrane. (9)

[Total marks: 10]

Development of the embryo after implantation

- Once implantation has occurred and the placenta starts to develop, the embryo continues to develop. See Figure 4.11.
- The amnion and yolk sac develop. The amnion is a cavity that is filled with amniotic fluid.

Figure 4.11 Development of the embryo, measured in weeks
• The foetus continues to develop until 38–40 weeks, when the foetus is full term. See Figure 4.12.

Figure 4.12 Development of a foetus, measured in weeks

The role/function of the placenta
• The placenta is a temporary, disc-like organ attached to the uterus by tiny finger-like outgrowths, the villi. See Figure 4.13.
• The placenta performs vital functions during pregnancy.
  • It allows the diffusion of oxygen, water, and dissolved food from the mother’s blood into the foetal blood for cellular respiration and nutrition for the foetus.
  • The waste products carbon dioxide and urea are removed from the foetal blood and excreted from the mother’s body by her lungs and kidneys.

EXAM TIP
Know the labels and functions of the parts of the placenta.

Figure 4.13 The structure of the placenta and umbilical cord
The placenta acts as a filter, preventing most infectious diseases, pathogens and toxins from passing into the foetus. Some viruses, for example, rubella (German measles) and HIV, can enter the foetus via the placenta.

Small molecules and compounds such as nicotine, alcohol and heroin are not filtered. They pass through the placenta and harm the foetus.

Maternal antibodies pass into the foetus and provide passive natural immunity that lasts for a few months after birth.

From 12 weeks after ovulation, the placenta produces hormones. It takes over the functions of the corpus luteum of producing progesterone after implantation occurs. Progesterone prevents further ovulation and menstruation and, therefore, prevents the loss of the foetus.

The role/function of the umbilical cord

The umbilical cord develops during the fourth week of pregnancy. It contains two umbilical arteries and an umbilical vein embedded in connective tissue.

- The umbilical arteries carry carbon dioxide, nitrogenous waste products (such as urea, uric acid) and other metabolic wastes from the embryo to the placenta.
- The umbilical vein carries oxygen, nutrients, water and all other useful substances from the placenta to the embryo.

EXAM TIP
The arteries leave foetus, to mother, therefore carry waste to mother.
The vein goes to foetus, therefore carry useful substances to foetus.

The role/function of the amnion and amniotic fluid

The amnion is a thin, strong extra-embryonic membrane that grows around the embryo/foetus.

- The amnion secretes the amniotic fluid around the foetus.

Functions of the amniotic fluid

- The amniotic fluid:
  - enables the foetus to move freely, preventing malformation due to gravity or pressure
  - maintains a constant temperature around the foetus
  - acts as a shock absorber to cushion and protect the foetus against external mechanical shock
  - prevents dehydration of the foetus
  - provides a medium in which the foetus can practise swallowing and breathing movements.
1. Study the diagram below that represents a developing human embryo. Then answer the questions.
   1.1 Provide the labels for the parts numbered 1 to 10.

   ![Diagram of a developing human embryo]

   1.2 Give the functions of the parts labelled 1, 5, 8 and 10.
   1.3 Based on the information provided in this question, give an approximate age for this embryo.

2. Write an essay describing the specialised structures and functions of the placenta that allow it to act as an exchange surface. Include in your answer the umbilical cord as a transport system.

   Contents (17)
   Synthesis (3)

3. Study the table below, which shows the growth of a foetus. Then answer the questions.

<table>
<thead>
<tr>
<th>Gestational age (weeks)</th>
<th>8</th>
<th>12</th>
<th>16</th>
<th>20</th>
<th>24</th>
<th>28</th>
<th>32</th>
<th>36</th>
<th>40</th>
</tr>
</thead>
<tbody>
<tr>
<td>Length of foetus (cm)</td>
<td>1,6</td>
<td>5,4</td>
<td>11,6</td>
<td>16,4</td>
<td>30,0</td>
<td>37,6</td>
<td>42,4</td>
<td>47,4</td>
<td>51,2</td>
</tr>
<tr>
<td>Mass of foetus (g)</td>
<td>1</td>
<td>14</td>
<td>100</td>
<td>300</td>
<td>600</td>
<td>1 005</td>
<td>1 702</td>
<td>2 622</td>
<td>3 462</td>
</tr>
</tbody>
</table>

3.1 Draw a line graph to represent each set of data shown in the table on the same set of axes.
3.2 Between which weeks did the length of the foetus increase by just slightly more than 100%?
3.3 Between which weeks did the mass of the foetus double?
3.4 Between which weeks did the foetus increase in length the most?
3.5 Between which weeks did the foetus increase in mass the most?

**EXAM TIP**
Make sure that you know how to draw a graph. Start by drawing the axes, labelling them and giving them a scale. Give your graph a heading and then plot your points.

[Total marks: 60]
Birth

- Birth happens at the end of a pregnancy period when one or more newborn infants are expelled from a woman's uterus through the vagina or birth canal.
- If a birth cannot happen naturally, the foetus is taken out of the mother's uterus by a doctor. This surgical procedure is called a caesarean section.
- A woman knows she is going into labour when she experiences regular contractions of her uterus.
- This is known as pre-labour and can last for hours or days, especially in women giving birth to their first child.
- There are three stages of natural birth, they are:
  - labour
  - expulsion of baby
  - release of afterbirth.

Birth control and contraception

- Birth control and contraception are the prevention of conception by artificial or natural means. See Figure 4.14.
- Artificial methods include:
  - preventing the sperm cells from reaching an ovum (for example, using condoms, using diaphragms)
  - inhibiting ovulation (using oral contraceptive pills, injection)
  - preventing implantation (using intrauterine devices)
  - killing the sperm cells (using spermicides)
  - preventing the sperm cells from entering the seminal fluid (by vasectomy).
- Natural methods include:
  - the rhythm method
  - withdrawal.

Natural methods are not reliable, but are used by people who prefer not to use artificial methods for religious reasons.

Figure 4.14 Various methods of contraception

Contraceptive methods

Table 4.1 a) to d) on the next page summarises various contraceptive methods.
### Table 4.1   a) to d) Various contraceptive methods

<table>
<thead>
<tr>
<th>a) Chemical methods</th>
<th>Combination pill</th>
<th>Contraceptive injection</th>
<th>Spermicides</th>
</tr>
</thead>
<tbody>
<tr>
<td>How it works</td>
<td>Contains oestrogen and progesterone. This prevents ovulation, prevents implantation of ovum, and thickens cervical mucus.</td>
<td>Single injection of progesterone (thickens cervical mucus, inhibits ovulation), lasts three months</td>
<td>Contains a chemical substance that immobilises and kills the sperm before they are able to swim into the uterus. Best used in conjunction with a barrier method of contraception</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>b) Barrier methods</th>
<th>Female condom</th>
<th>Male condom</th>
<th>IUD (Intrauterine device) or coil</th>
<th>Diaphragm</th>
</tr>
</thead>
<tbody>
<tr>
<td>How it works</td>
<td>Polyurethane pouch fitted into vagina before sex</td>
<td>Latex sheath covering penis</td>
<td>Small ‘T’-shaped device, containing either copper or progesterone, is inserted into the uterus</td>
<td>A cervical barrier-type of birth control. It is a soft latex or silicone dome.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>c) Surgical methods (surgical methods)</th>
<th>Vasectomy</th>
<th>Tubal ligation</th>
</tr>
</thead>
<tbody>
<tr>
<td>How it works</td>
<td>During a minor operation, the vas deferens (sperm ducts) are cut, blocked or sealed. This prevents sperm from reaching the seminal fluid (semen). No sperm will be in the semen.</td>
<td>The Fallopian tubes are cut, tied or blocked to permanently prevent pregnancy. It prevents sperm from travelling up the Fallopian tubes to the egg. Fertilisation cannot occur.</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>d) Natural methods</th>
<th>Withdrawal</th>
<th>Rhythm</th>
</tr>
</thead>
<tbody>
<tr>
<td>How it works</td>
<td>This is the practice of withdrawing the penis from the vagina and away from a woman’s external genitalia before ejaculation to prevent pregnancy.</td>
<td>Abstain from sex during the time when the woman is fertile</td>
</tr>
</tbody>
</table>

### Test yourself

1. What is the most suitable method of contraception for:
   1.1 A couple who have had all the children they planned
   1.2 A young unmarried couple
   1.3 A couple with one child who would like to have another child.

2. Study the results of a survey to determine the most commonly used method of contraception in sexually mature couples. 100 couples participated in the survey.

   Condoms: 23; Contraceptive pill: 30; Withdrawal: 3; Rhythm: 1;
   Female sterilisation: 6; Vasectomy: 3; IUD: 16; Injection: 13; Other: 5

   2.1 Tabulate the above results.
   2.2 Name the least commonly used method of contraception.
   2.3 Give the most likely reason for your answer to 2.2.
   2.4 Name the most commonly used method of contraception.
   2.5 Give the most likely reason for your answer to 2.4.
   2.6 Apart from preventing pregnancy, give an advantage that the use of condoms provide, which the other named methods do not provide.
   2.7 Name two methods of contraception that would be included under ‘other’.

   (Answers on pages 188–189)

   [EXAM TIP]
   - Question 2 requires that you apply your knowledge of contraception.
   - Tabulate means draw a table, label the columns and rows.
# Topic Test yourself

(Answers on page 189)

1. Choose an item from Column B that matches a description in Column A. Write only the letter next to the corresponding question number.

<table>
<thead>
<tr>
<th>Column A</th>
<th>Column B</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1 Ring of muscle separating uterus and vagina</td>
<td>A</td>
</tr>
<tr>
<td>1.2 Male gamete</td>
<td>B</td>
</tr>
<tr>
<td>1.3 Consists of seminal fluid and sperm</td>
<td>C</td>
</tr>
<tr>
<td>1.4 Area where the blastocyst implants and the embryo grows</td>
<td>D</td>
</tr>
<tr>
<td>1.5 Nourishes and activates sperm cells</td>
<td>E</td>
</tr>
<tr>
<td>1.6 Tube that ovum enters after being released from ovary</td>
<td>F</td>
</tr>
<tr>
<td>1.7 Pocket of skin that contains the testes</td>
<td>G</td>
</tr>
<tr>
<td>1.8 Organs that make sperm cells</td>
<td>H</td>
</tr>
<tr>
<td>1.9 Coiled tube where sperm cells are stored</td>
<td>I</td>
</tr>
<tr>
<td>1.10 Process of releasing an ovum once a month</td>
<td>J</td>
</tr>
<tr>
<td>1.11 Female gamete</td>
<td>K</td>
</tr>
<tr>
<td>1.12 Passage for menstrual flow and birth of baby</td>
<td>L</td>
</tr>
<tr>
<td>1.13 Tube that can transport both urine and semen</td>
<td>M</td>
</tr>
<tr>
<td>1.14 Female gonad that produces ova</td>
<td>N</td>
</tr>
<tr>
<td>3.1.1 ovulation</td>
<td></td>
</tr>
<tr>
<td>3.1.3 implantation</td>
<td></td>
</tr>
<tr>
<td>3.1.5 urination</td>
<td></td>
</tr>
<tr>
<td>3.1.7 birth contractions</td>
<td></td>
</tr>
<tr>
<td>3.1.2 fertilisation</td>
<td></td>
</tr>
<tr>
<td>3.1.4 ejaculation</td>
<td></td>
</tr>
<tr>
<td>3.1.6 menstruation</td>
<td></td>
</tr>
<tr>
<td>3.2.1 the coil</td>
<td></td>
</tr>
<tr>
<td>3.2.3 the Pill</td>
<td></td>
</tr>
<tr>
<td>3.2.5 spermicide</td>
<td></td>
</tr>
</tbody>
</table>

2. Draw a flow diagram to show the path followed by a single sperm cell from the time it is formed until it meets an ovum.

3. Study the diagrams of reproductive systems below and answer the questions.

- **EXAM TIP** A flow diagram has boxes with information and arrows between the boxes to show relationships.

3.1 Write down the letter labelling the part involved in:

- 3.1.1 ovulation
- 3.1.3 implantation
- 3.1.5 urination
- 3.1.7 birth contractions
- 3.1.2 fertilisation
- 3.1.4 ejaculation
- 3.1.6 menstruation

3.2 Give the label of the part involved in each method of contraception:

- 3.2.1 the coil
- 3.2.3 the Pill
- 3.2.5 spermicide.
- 3.2.2 the diaphragm
- 3.2.4 sterilisation

[Total marks: 35]