LIFE SCIENCES

Grade 12 Teacher's Guide

basic education
Department:
Basic Education
REPUBLIC OF SOUTH AFRICA

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Life Sciences Teachers' Guide: An Introduction

The purpose of this textbook and teachers' guide series is to equip you, the teacher, with the necessary tools to effectively teach life sciences within the FET phase. All the materials have been designed with the aim of *covering all the content required for CAPS* but at the same time *effectively communicating the broader value of Life Sciences to your students and classes* in a way that is *easy to read*. We hope that you find this book to be a helpful resource as you teach and engage with your students, and may it facilitate an even greater appreciation within you of the subject. Since January 2012 the teaching in all schools was adapted to meet the standards laid out in the National Curriculum and Assessment Policy Statements (CAPS) document. It is highly recommended that you be familiar with this document.

Overview of the National Curriculum

(a) The *knowledge, skills and values* deemed most important for South African learners is clearly set out in the National Curriculum and Assessment Policy Statement for Life Sciences. The content is adapted to the unique environment and context of South Africa, but at the same time provides an awareness of important global trends.

(b) The National Curriculum Statement Grades R - 12 undertakes to:

- equip all learners, irrespective of their backgrounds, race, gender or ability, with the *knowledge, skills and values* necessary to reach their goals and be functioning members of society.
- facilitate access to higher education.
- smooth the transition of learners into to the workplace.
- provide employers with a profile of a learner's competencies.

(c) The key principles of the National Curriculum Statement for Grades R - 12 are:

- *social transformation*: working to alleviate the educational differences of the past and providing *equal educational opportunities* to all.
- *active and critical learning*: encouraging learners to think about and understand what they are learning and not merely emphasising the rote-memory of facts.
- *high knowledge and high skills*: specified minimum standards of knowledge and skills are set to be achieved at each grade.
- *progression*: both the content and the context of subjects will be expanded as one progresses through the grades.
- *Social awareness*: being sensitive to issues such as poverty, inequality, race, gender, language, age, disability and other factors.
- Valuing *human rights, inclusivity and environmental and social justice*.

- *Valuing indigenous knowledge systems*: acknowledging the rich history and heritage of this country.
- *Credibility, quality and efficiency*: providing an education that is comparable in quality, breadth and depth to those of other countries.

(d) The aims as listed in the National Curriculum Statement Grades R - 12 interpret the kind of citizen the education systems tries to develop. It aims to produce learners that are able to:
- identify and solve problems and make decisions using *critical and creative thinking.*
- *work effectively as individuals and with others* as members of a team.
- organise and *manage themselve*s and their activities responsibly and effectively.
- collect, analyse, organise and *critically evaluate information*.
- *communicate effectively* both visually, symbolically and with language.
- *use science and technology effectively* and critically, showing responsibility towards the environment and the health of others.
- demonstrate an *understanding of the world as a set of related systems* by recognising that problem solving contexts do not exist in isolation.

(e) Inclusivity is one of the key principles of the National Curriculum Statement Grades R - 12 and should be a central part of the organisation, planning and teaching at each school. Educators need to:
- have a sound understanding of how to *recognise* barriers to learning and address them in the classroom.
- know how to *plan for diversity* .
- use various curriculum differentiation strategies (Consult the Department of Basic Education's Guidelines for Inclusive Teaching and Learning, 2010)
- address barriers to learning using the support structures within the community, District-Based Support Teams, Institutional-Level Support Teams, parents and Special Schools as Resource Centres.

What is Life Science?

The term 'Life Sciences' indicates clearly the two ideas held together in this subject. Life refers to all living things- from the most basic of molecules through to the interactions of organisms with one another and their environments. Science indicates it is necessary to use certain methods in our study of the subject. The two broad aims of any science are to *increase existing knowledge* and *discover new things*. We approach this using a careful method that can be copied by others. The methods include proposing hypotheses and carrying out investigations and experiments to test these hypotheses. Scientific knowledge changes over time as more is

discovered and understood about our world; as such, Life Sciences is a constantly growing subject.

Life Sciences Strands for Grade 11 and 12

Everything within grade 11 and 12 will fit under one of these four broad strands. These knowledge pathways grow over the three years of FET. Within each knowledge strand, ideas should not be studied separately; you goal as a teacher should be to encourage the students to rather seek to discover the links between related topics so that they grow in their understanding of the inter- connectedness of life. As you teach each section or chapter, highlight to them the broad strokes that place it under one of these strands:

- Knowledge Strand 1: Life at the Molecular, Cellular and Tissue Level
- Knowledge Strand 2: Life Processes in Plants and Animals
- Knowledge Strand 3: Environmental Studies
- Knowledge Strand 4: Diversity, Change and Continuity.

Although there is some flexibility in the order in which the knowledge strands are covered, it is important to remember that Knowledge Strand 1 must be taught before Knowledge Strand 2, and that Knowledge Strand 3 must come before Knowledge Strand 4. It is up to you to decide whether to start the school year with Knowledge Strand 1 or Knowledge Strand 3.

The purpose of studying Life Sciences

There are three broad purposes, which will be expanded upon as we continue:

- Aim 1 – acquiring the knowledge of Life Sciences
- Aim 2 – doing practical work and investigations
- Aim 3 – understanding the applications of Life Sciences in society- both present society (indigenous and western) and within the context of history.

Specific Aim 1: Acquiring knowledge of Life Sciences

Learners are expected to develop an understanding of Life Science concepts, processes, phenomena, mechanisms, principles, theories and models. The specific skills you are wanting to equip them with, is to be able to:

1. *Acquire and recall knowledge*
    - Access information
    - Select key ideas
    - Recall facts
    - Describe concepts, processes and theories

Verbs that can be used in testing this skill: **State, name, label, list, define, describe.**

2. *Understand, comprehend and make connections between ideas and concepts*
   - Write summaries
   - Develop flow charts, diagrams and mind maps
   - Recognise patterns and trends

   Verbs that can be used in testing this skill: **explain, compare, rearrange, give an example, illustrate, calculate, interpret, suggest, make a generalisation, predict, select, differentiate.**

3. *Apply knowledge in new and unfamiliar contexts*
   - Use information in a new way
   - Construct meaning from new data using pre-acquired knowledge

   Verbs that can be used when testing this skill: **demonstrate, interpret, predict, compare, differentiate, illustrate, solve, select.**

4. *Analyse, evaluate, and synthesise scientific knowledge, concepts and ideas*
   - Analyse information and data
   - Recognise relationships between existing knowledge and new ideas
   - Critically evaluate scientific information
   - Identify assumptions
   - Categorise information

   Verbs that can be used when testing this skill: **Appraise, argue, judge, select, evaluate, defend, compare, contrast, criticise, differentiate, distinguish.**

Specific Aim 2: Investigating phenomena in Life Sciences

Practical investigations involve a specific range of skills, which can be summarised as follows:

1. *Follow Instructions*
   - Students must be able to adhere to instructions that they are given
   - Adhering to safety rules

2. *Handle Equipment/apparatus*
   - Knowledge of apparatus (naming, handling and what it is used for)
   - How to use chemicals and taking necessary precautions when handling them
   - Using equipment appropriately and safely

3. *Make Observations*
    - Drawings
    - Descriptions
    - Grouping of materials (similarities and/or differences)
    - Measurements
    - Comparing materials before and after treatment
    - Observing results of an experimental investigation and recording information in the appropriate manner
    - Counting

4. *Record Information or data*
    - Simple tables
    - Drawings
    - Descriptions
    - Constructing a pie chart
    - Line graph
    - Histogram or bar chart as suited to the data and choosing suitable axes and scales

5. *Measure*
    - Reading linear and two-dimensional scales
    - Scaling by choosing a headings for axes
    - Measuring quantities
    - Making valid measurements of variables, repeating measurements to obtain an average where necessary in all quantitative work
    - Recognising, or supplying the correct units for common measurements
    - Counting systematically

6. *Interpret*
    - Convert information into an appropriate graph, table etc. and extract data
    - Apply knowledge
    - Analyse and recognise patterns or trends
    - Acknowledge limitations of experimental procedures
    - Make deductions based on evidence to reach a conclusion

7. *Design/plan investigations or experiments*
    - Identifying a problem and formulate a question that will guide the investigation
    - The aim of the investigation
    - The Hypothesis
    - Selecting the correct apparatus or equipment and/or materials and chemicals
    - Identifying variables

- Adhere to laboratory safety procedures

Specific Aim 3: Appreciating and understanding the importance of Life Sciences in society (present and past)

- Understanding the history and relevance of discoveries
- The history of scientific discoveries is the context of our learning.

- Being aware of the value indigenous knowledge systems give to Life Sciences
- Understand the different cultures in which indigenous knowledge systems developed
- Link specific cultures directly to the areas in Life Science that they have influenced

- Know the value and application of Life Sciences knowledge in industry, careers and everyday life
- Analyse the applications of biotechnology
- Summarise and understand the positive and negative effects of biotechnology on the environment
- Have a knowledge of the different career paths in Life Sciences

- Develop language skills
- Improve writing skills
- Grown in the ability to read and understand scientific text and produce essays, summaries etc.

Time Allocation

The time allocation for Life Sciences in Grade 11 and 12 is 4 hours per week.
The curriculum for Grade 11 has been designed to be completed within 32 weeks out of 40 weeks in the school year. The Grade 12 curriculum is designed to be completed within 27 ½ weeks out of the 40 weeks. The extra weeks are designed to allow for school-based activities that may disrupt teaching.

Syllabus

For the detailed syllabus descriptions applicable to Life Sciences for grade 11 and 12 please consult your CAPS document or access it online here (insert link)

Assessment

Assessment can be defined as the *planned process of gathering and interpreting data on the performance of students* in your class.

Assessment serves a purpose to both students and teachers. It allows students to gauge their own progress and test their understanding and skills. For you as a teacher, it will help you identify weak areas and intervene where needed to reinforce concepts.
The four steps of assessment would be to *generate and collect the evidence* of progress, *evaluate* it, *record* the results and *use your findings* to make adjustments (in teaching and learning) where needed.

Using your findings entails

- Making judgements about a specific student's progress
- Informing the students about their strengths, weaknesses and progress
- Using your findings to assist other teachers and the parents, in making the best decisions possible for the student.

In both formal and informal assessments, always consider the content, concepts and skills and the aims specified for Life Sciences. It is important to ensure that over the year, *all of the subject content is covered*, the *full range of skills is included* and *different forms of assessment* are used.

Types of assessments

Assessments should be both *on* learning (formal) and *for* learning (informal).
Informal or daily assessments
The aim of informal assessments is to provide consistent feedback to the learner of their progress that can be used to improve their learning. Informal assessment occurs daily. This is done through observations, discussions, practical demonstrations, learner-teacher conferences and informal classroom interactions. It should be seen as a part of the learning activities taking place in the classroom.

- There should be a minimum of three informal assessments done per week. These can be marked by you or the students.
- There should be a consolidation task at the end of each topic.
- Practical skills should be taught in a way that integrates them into the theory being taught.
- The assessments should vary in their difficulty and cognitive levels so that collectively all the degrees are covered.

Formal Assessments

The aim of these assessments is to provide you a systematic way to evaluate how your students are progressing. Examples of formal assessments include tests, exams, tasks, projects, assignments, demonstrations and orals.

These are the assessments that are marked by you, and those results recorded formally for progression and certification purposes. For grade 11 and 12, these assessments are broken up in the following way:

- 25 % school-based formal assessments (incudes June exam, as well as trials for grade 12)
- 75% end of year examination

Degrees of difficulty for test/exam questions

Each question set will fall into one of the following levels:

Level 1: **easy** for the average student to answer

Level 2: **moderately** challenging for the average learner to answer

Level 3: **difficult** for the average learner to answer

Level 4: **very difficult**. The skills and knowledge required to answer these questions allows for the level 7/high-achieving students to be discriminated from the other high-ability learners.

Factors that influence the cognitive demand of questions

Content difficulty: A question that asks a student to recall an **abstract theory** or fact, or complex content, is harder than once that asks for recall of a **simple fact**.
Writing difficulty: It is generally easier to recall a sequence of events in a **few sentences** or point form, compared to being asked to answer in an **essay form**.

Reading difficulty: Different sources may be more **complicated to comprehend** and interpret. For example a magazine article is in a **simpler format** than a classical work like an excerpt from a textbook. The difference in content, vocabulary and structure, and the way abstract ideas are presented will influence the student's ability to extract information.

It is important as an examiner to make sure that you are able to identify the *type of cognitive demand* that a question will place on the learner, as well as *the degree of difficulty of the question* or task. Combining these two features together we can consider the question against a framework for question difficulty. It is important to do this so that a paper is neither too difficult nor too easy. These are the other factors that influence the difficulty level of a question

Content/concept difficulty: This refers to the difficulty of the subject matter, topic or knowledge assessed and required. In this judgement, difficulty is present in the academic and conceptual demands a questions makes, as well as the grade level limits of the specific element being questioned.

Stimulus difficulty: This refers to the difficulty of the language (linguistic complexity) and the challenge presented to the learner when they try to read and understand the language of both the question and any source material provided as part of it.

Task difficulty: This refers to the challenge the learner faces when trying to formulate or produce an answer.

Expected response difficulty: This refers to the difficulty imposed by examiners in the mark scheme and memorandum. This is largely applicable to constructed response questions and less to selected response questions (multiple choice, true/false, matching columns)

Weighting of cognitive levels for Grade 11 and 12

Knowing Science 40%

- State or name
- List
- Label
- Define
- Describe

Understanding Science 25%

- Communicate understanding
- Interpret
- Exemplify and classify
- Summarise
- Classify
- Infer
- Compare
- Explain

Applying scientific knowledge 20%

- Perform a basic or routine procedure or rule or method
- Apply an understanding of learned concepts or facts from a known to an unfamiliar context.
- Demonstrate
- Solve

Evaluating, analysing and synthesising scientific knowledge 15%

- Analyse complex information and adapt *appropriate strategies to solve non-routine*/complex/open ended questions.
- *Evaluate or make a critical judgement*, for example on the quality of results, the probability or desirability of an outcome.

- To create a new product by *integrating concepts*/ ideas/ information and *make connections* between different ideas or the overall purpose or structure of a system.
- To *differentiate or suggest a reason*.

School based assessments for Grade 12

TERM	Task	Weighting (% of SBA)	% of reporting mark per term
1	Practical Minimum 30 marks	10	25
	Test Minimum 50 marks	10	75
2	Practical Minimum 30 marks	10	25
	Mid-year Exam One paper - 150 marks Duration: 2½ hours	20	75
3	Assignment (50 marks) Duration: 1 - 1½ hours	15	25
	Trial Exam Two papers - 150 marks each Duration: 2½ hours each	35	75
	Total	**100**	

The different tasks of the Formal Assessment Programme

Tests and Examinations

- Minimum 50 marks
- It must cover the work taught in that specific term
- The mid-year exam must cover Term 1 and Term 2
- For grade 12, the trial exams must cover Terms 1-3
- The degree of difficulty must be considered and the assessment must be balanced in terms of cognitive levels and topics.
- They must follow the NSC exam in design, rigor and format
- One minute must be allocated per mark
- Each test/exam must cover all three specific aims with at least 20% of the weighting going to specific aim two.
- Remedial and intervention strategies must be in place where needed

Practical Tasks

- One task must involve manipulation of apparatus or data collection
- All seven skills must be covered over the practicals for the year
- Each practical must assess at least 3 of the 7 skills
- Minimum 30 marks

Research Project

- All three specific aims must be covered
- The marks for this must be recorded in the third term, no matter when the project was completed
- It must be 50 marks
- The task is long-term (more than three weeks non-contact time)
- It must be investigative
- Sub-skills to be included are *formulating questions and hypotheses*, *gathering information* and being able to *manipulate and process* it. *Patterns must be identified* and the *data evaluated*. Valid *conclusions must be drawn* and the *findings communicated* effectively.

Assignment

- It must be skills based and not heavily weighted towards content recall
- All three specific aims must be covered
- The mark for the assignment must be recorded in the third term, no matter when the assignment was completed.
- It must be 50 marks
- Short term task (1-1 ½ hours)
- Completed individually, at school, under controlled conditions.
- No resources may be used while completing the task
- It must include a short source-based essay (10-15 marks)
- As many of the following as possible must be covered: *analysing and interpreting data*, *making drawings* and *plotting graphs*, drawing *tables*, *performing calculations* and *justifying conclusions*.

Assessment Tools

The purpose of these tools is to assist you to record information gathered during assessments. They allow your marking to be systematic, and they enable you do check the quality and content of your assessments. It makes any analysis of a student's achievements more objective.

Types of assessment tools: These can be checklists, rubrics, an observation notebook, recordings, written descriptions, portfolios and more.

Before assessment it is important for the students to know: How and when they will be assessed, the format for the response and the consequences of the assessment.

Questions to be answered after the assessment

Were the criteria used appropriate?
Has feedback been given to the learners?
Have any learning disabilities been identified?
What follow-up action is needed?
How will the assessment further the purpose of teaching and learning?

Rubrics for assessment (rubrics from Siyavula, Life Sciences Grade 10)

Assessment Rubric 1: Practical activity

- To be used for any practical task where learners are required to follow instructions to complete the task.

Assessment criteria	0	1	2	Comments
Following instructions	Unable to follow instructions	Instructions followed with guidance	Able to work independently	
Observing safety precautions	Unable to observe safety precautions	Sometimes does not follow safety precautions	Able to follow safety precautions completely	
Ability to work tidily	Cannot work tidily	Can work tidily		
Cleans up afterwards	Does so once reminded	Does so without reminding		
Organisation	Disorganised	Fairly organised	Organised and efficient	
Use of apparatus, equipment and materials	Always used incorrectly and materials wasted	Sometimes used correctly and aware of material usage	Apparatus and materials used correctly and efficiently	
Results or final product	No result or final product	Partially correct results or product	Results or product correct	
Answers to questions based on activity	No answers provided or most are incorrect	Can answer questions and at least 60% are correct	Can answer application and questions correctly	

Assessment Rubric 2: Investigation

- To be used for an investigation, especially where learners have to write their own experimental report or design the investigation themselves.

Assessment criteria	0	1	2	3	Comments
Aim	Not stated or incorrect	Not clearly stated	Clearly stated		
Hypothesis or prediction	Not able to hypothesize	Able to hypothesize, but not clearly	Clearly hypothesizes		
Materials and apparatus	Not listed or incorrect	Partially correct	Correct		
Method	None	Confused, not in order or incorrect	Partially correct	Clearly and correctly stated	
Results and observations (recorded either as a graph, table or observations)	No results recorded or incorrectly recorded	Partially correctly recorded	accurately recorded but not in the most appropriate or specified way	Correctly and accurately recorded in the most appropriate or specified way	
Analysis or discussion	No under-standing of the investigation	Some under-standing of the investigation	Understands the investigation	Insightful understanding of the investigation	
Evaluation	No attempt	Partially correct	Correct, but superficial	Critical evaluation with suggestions	
Neatness of report	Untidy	Tidy			
Logical presentation of report	Not logical	Some of report is logically presented	Report is logically presented		

Assessment Rubric 3: Graph

- To be used for any graph or translation task you would like to assess, either on its own or within another activity.

Assessment criteria	0	1	2	Comments
Correct type of graph	Not correct	Correct		
Appropriate heading, describing both variables	Not present	Present, but incomplete	Complete	
Independent variable on x-axis	Not present or incorrect	Present		
Dependent variable on y-axis	Not present or incorrect	Present		
Appropriate scale on x-axis	Incorrect	Correct		
Appropriate scale on y-axis	Incorrect	Correct		
Appropriate heading for x-axis	Not present or incorrect	Correct		
Appropriate heading for y-axis	Not present or incorrect	Correct		
Units for independent variable on x-axis	Not present or incorrect	Correct		
Units for dependent variable on y-axis	Not present or incorrect	Correct		
Plotting points	All incorrect	Mostly or partially correct	All correct	
Neatness	Untidy	Tidy		
Graph size	Too small	Large		

Assessment Rubric 4: Table

- To be used when learners have to draw their own table and you would like to assess it.

Assessment criteria	0	1	2	Comments
Appropriate heading, describing both variables	Not present	Present, but incomplete	Complete	
Appropriate column headings	Not present or incorrect	Mostly correct	Correct and descriptive	
Appropriate row headings	Not present or incorrect	At least half correct	All correct	
Units in headings and not in body of table	None present	Present but in the body	Present and in the headings	
Layout of table	No horizontal or vertical lines	Some lines drawn	All vertical and horizontal lines drawn	
Data entered in table	Not correct	Partially correct	All correct	

Assessment Rubric 5: Scientific drawing

- To be used when learners have to do a drawing, particularly in Life and Living.

Assessment criteria	0	1	2	Comments
Appropriate, descriptive heading	Not present	Present, but incomplete	Complete	
Appropriate size of drawing (sufficiently large on page)	Incorrect (too small)	Correct		
Accuracy of drawing (correct shape and proportion of parts)	Incorrect	Somewhat correct	Correct	
Structures or parts placed correctly in relation to each other	Mostly incorrect	Mostly correct, but some misplaced	All correct	
Diagram lines are neat, straight and done with a sharp pencil	Not clear or neat or blunt pencil	Clear and neat		
Label lines do not cross over each other	Incorrect	Correct	All correct	
Parts are labelled	Mostly incorrect	Mostly correct with some missing or incorrectly labelled	All correct and labelled	

Assessment Rubric 6: Research assignment or project

- To be used when learners have to do a research assignment or project, either outside of class or in class time, and either individually or in groups.

Assessment criteria	0	1	2	Comments
Group work (if applicable)	Conflict between members or some did not participate	Some conflict and some members did not always participate	Worked efficiently as a group	
Project layout	No clear or logical organisation	Some parts are clear and logical, while others are not	Clear and logical layout and organisation	
Accuracy	Many errors in content	A few errors in content	Content is accurate	
Resources used (material or media)	No resources used	Some or limited resources used	A range of resources used	
Standard	Poor standard	Satisfactory	Of a high standard	
Use of time	Did not work efficiently and ran out of time	Worked fairly efficiently	Worked efficiently and finished in time	

Assessment Rubric 7: Model

- To be used when learners have to design and build their own scientific models.

Assessment criteria	0	1	2	Comments
Scientifically accurate	Model inaccurate or incomplete	Mostly accurate, but with some parts missing or incorrect	Accurate, complete and correct.	
Size and scale	Too big or too small, parts not in proportion to each other	Correct size, but some parts too big or too small	Correct size and proportional scale	
Use of colour or contrast	Dull, with little use of contrast	Somewhat colourful	Creative and good use of colour and contrast	
Use of materials	Inappropriate use or only expensive materials used	Satisfactory use of appropriate materials and recyclables where possible	Excellent use of materials and recyclables where appropriate	
Use of a key or explanation	Not present	Present but incomplete or vague	Clear and accurate	

Assessment Rubric 8: Poster

- To be used when learners have to make a poster, either individually or in a group.

Assessment criteria	0	1	2	Comments
Title	Absent	Present, but not sufficiently descriptive	Complete title	
Main points	Not relevant	Some points relevant	All points relevant	
Accuracy of facts	Many incorrect	Mostly correct, but some errors	All correct	
Language and spelling	Many errors	Some errors	No errors	
Organisation and layout	Disorganised and no logic	Organisation partially clear and logical	Excellent, logical layout	
Use of colour	No colour or only one colour	Some use of colour	Effective colour	
Size of text	Text very small	Some text too small	Text appropriate size	
Use of diagrams and pictures	Absent or irrelevant	Present but sometimes irrelevant	Present, relevant and appealing	
Accuracy of diagrams or pictures	Inaccurate	Mostly accurate	Completely accurate	
Impact of poster	Does not make an impact	Makes somewhat of an impact	Eye catching and makes a lasting impact	
Creativeness	Nothing new or original	Some signs of creativity and independent thought	Original and very creative	

Assessment Rubric 9: Oral presentation

- To be used when learners have to give an oral presentation to the class on a selected topic.

Assessment criteria	0	1	2	3	Comments
Introducing the topic	Did not do	Present, but with no clear link to content	Present, clear links to content being covered	Interesting and catching introduction	
Speed of presentation	Too fast or too slow	Started off too fast or too slow but reaches optimal pace	Good speed throughout		
Pitch and clearness of voice	Too soft or unclear	Started off unclear or too soft, but improved	Speaks clearly and optimal pitch throughout		
Capturing audience's attention and originality	Did not make an impact or no attempt to capture interest	Interesting at times	Sustained interest and stimulating	Sustained interest throughout with originality	
Organisation of content during presentation	Illogical or unclear	Clear and mostly logical	Clear and logical throughout		
Factual content	Many errors in content	Some errors in content	All correct		
Concluding remarks	No conclusion or inappropriate	Make a satisfactory conclusion	Insightful or thought-provoking conclusion		
Answers to the educator and class's questions	Was not able to answer or gave incorrect answers	Was able to answer recall questions only	Was able to answer recall and application questions		

Assessment Rubric 10: Group work

- To be used to assess any work where learners are required to complete the task as a group. This rubric is designed to assess the group as a whole.

Assessment criteria	0	1	2	3	Comments
Member participation	Very few members participated	Only some members participated	At start, only some, but then full participation	Full participation throughout	
Discipline within the group	Lack of discipline	Some members disciplined	Most members disciplined	All members disciplined	
Group motivation	Unmotivated or lack focus	Some members motivated but others lack focus	Most members motivated and focused	All members focused and motivated	
Respect for each other	Show disrespect to each other	Some members show disrespect	All members are respectful		
Conflict within group	Considerable conflict and disagreements which were unresolved	Some conflict which was either resolved or unresolved	No conflict or issues were resolved maturely		
Time management	Disorganised and unable to stick to time frames	Mostly able to work within the given time	Effective use of time to complete the tasks		

Recording and Reporting

Recording is the process of documenting the level of a student's performance in an assessment or task. It shows their progress towards achieving the knowledge and skills within the Curriculum and Assessment Policy Statements. Records of the students' performance should show evidence of their *progression within a grade* and their *readiness to move to the next grade*. Records of performance are also a useful tool to show the progress made by the teachers in the learning process.

Reporting is a process of communicating the performance to the students, their parents, schools, and other stakeholders. It can be communicated through *reports, parents' meetings, school open days, parent-teacher conferences, phone calls, letters, newsletters*, etc. All reporting is done in percentages.

The various achievement levels and their corresponding percentage bands are as shown in the table below. The seven point scale should have descriptions that give sufficient information for each level and this should be contained within the report for efficient communication to parents and other stakeholders.

Codes and Percentages for Reporting in Grades R – 12:

Rating Code	Description of Competence	Percentage
7	Outstanding Achievement	80 - 100
6	Meritorious Achievement	70- 79
5	Substantial Achievement	60 - 69
4	Adequate Achievement	50 - 59
3	Moderate Achievement	40- 49
2	Elementary Achievement	30- 39
1	Not Achieved	0 - 29

Schools are required to provide *quarterly feedback to parents* on the Programme of Assessment using a formal tool such as a report. The report should indicate the *overall level of performance* of a student.

CHAPTER 1: DNA – THE CODE OF LIFE

Overview

Time Allocation**:** 2 ½ Weeks (10 Hours)

This chapter consists of:

1. Introduction
2. Key concepts
3. Revision on cellular structure
4. The structure of nucleic acids
5. Deoxyribonucleic acid (DNA)
6. Ribonucleic acid (RNA)
7. Comparison between DNA and RNA
8. DNA replication
9. DNA fingerprinting
10. Protein synthesis
11. Summary
12. End of topic exercises

Introduction

All living organisms contain both DNA (deoxyribonucleic acid) and RNA (ribonucleic acid) – we focus on their location, structure and function.

We explore the discovery of DNA, its role in the human body and how it replicates.

Protein synthesis is vital for life – we examine how proteins are formed by both DNA and RNA.

Key concepts

- Cellular structure was studied in grade 10. The nucleus, ribosomes and cytoplasm are essential parts of the cell when studying DNA and RNA.
- There are two types of nucleic acid: DNA and RNA.

- Nucleic acids are composed of nucleotides. Nucleotides consist of a sugar, a phosphate and a nitrogenous base.
- DNA makes up the genes of chromosomes (nuclear DNA) and is found in the mitochondria (mitochondrial DNA).
- Watson and Crick are credited for the DNA molecular theory.
- DNA contains four nitrogenous bases (thymine) and is a long chain which twists to form a double helix.
- DNA replication is important to produce identical daughter cells which contain the same number and type of chromosomes.
- DNA profiling can be used for paternity testing and in criminal investigations.
- There are three types of RNA found in the nucleus and cytoplasm of cells.
- RNA contains four nitrogenous bases (uracil), is short and single stranded.
- RNA plays an important role in the synthesis of proteins, using transcription and translation.

Revision on Cellular Structure

Learners need to revise the structure and functioning of cytoplasm, ribosomes and the various parts of the nucleus.

The Structure of Nucleic Acids

Key terminology

nucleic acid	a type of organic compound
monomer	a building block
nucleotide	the monomer which forms DNA and RNA

There are two nucleic acids in the human body – DNA (deoxyribonucleic acid) and RNA (ribonucleic acid). Together these form the basis of all life of earth. They consist of monomers (building blocks) called nucleotides.

Learners are required to know that monomers of nucleic acids are nucleotides composed of a sugar, phosphate and nitrogenous base.

Deoxyribonucleic Acid (DNA)

Key terminology

DNA	• deoxyribonucleic acid is made up of nucleotides • nitrogenous bases adenine, thymine, guanine and cytosine • carries the genetic code for protein synthesis
nuclear DNA	DNA found in the nucleus
extra- nuclear DNA	DNA found outside of the nucleus: mitochondrial and chloroplastic DNA.
double helix	the shape of DNA consists of two strands joined together and twisted spirally
hereditary	genetic information passed on from parent to offspring

Learners must know the location, structure and function of DNA. It is important to point out that thymine is only found in DNA as a nitrogenous base. Learners must have an understanding of the complementary bases i.e. adenine bonds with thymine and guanine bonds with cytosine.

For assessment purposes learners must apply their knowledge of structure and include deoxyribose sugar as the sugar in the nucleotides forming DNA.

Learners are required to know Watson and Crick are credited for the formulation of the DNA molecular theory.

Learners should be able to perform a basic investigation to extract DNA. Examples of this can be found in many textbooks, one is included below for your use:

Extraction of chromosomal DNA from bananas

Materials:

- ¼ of a banana
- masher or a fork
- 50 mL water
- pinch of salt
- filter paper
- 2 clear plastic beakers
- dishwashing liquid
- 5 mL pineapple juice
- 300 mL surgical spirits or rubbing alcohol
- tooth picks
- funnel

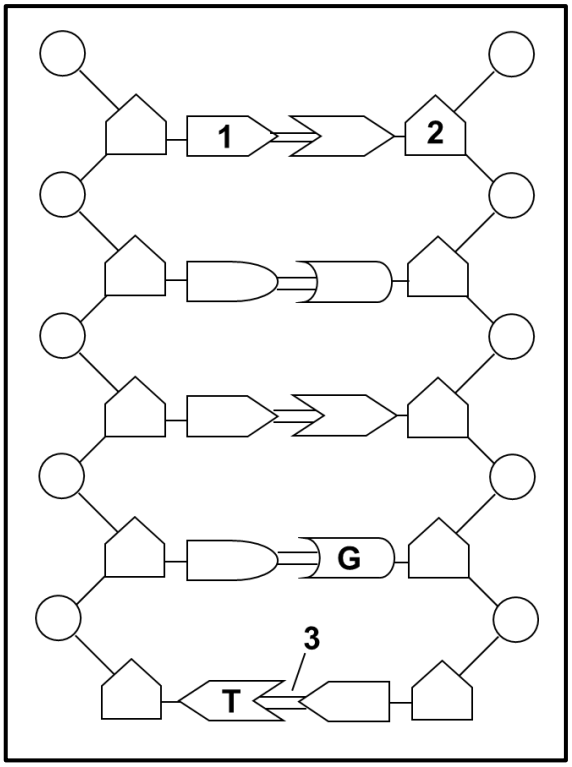
Method:

1. Dissolve the salt in 50 mL water to make a salt solution in one beaker.
2. Mash the banana in the salt solution. Make sure that the banana is thoroughly mashed.
3. Pour the banana ‘soup’ through the filter paper into the second cup. Use the funnel.

4. Add a few drops of dishwashing liquid to the filtrate formed, and swirl the mixture gently. Do not shake it!
5. Let the mixture rest for about 5 to 10 minutes.
6. Add 1 to 2 mL of pineapple juice to the mixture.
7. Slowly add the surgical spirits. Add enough to double the volume of your mixture.
8. Remove the DNA from the mixture, by winding it onto a toothpick.
9. Congratulations! You are holding the stuff of life itself!

Activity 1: DNA

The diagram shows part of a DNA molecule



1. Label parts 1, 2 and 3 (3)

   1 – adenine ✓,

   2 – deoxyribose sugar ✓

   3 – hydrogen bonds ✓

2. Give the number of nucleotides shown in the diagram (1)

   10 ✓

3. Name two places in an animal cell where this nucleic acid may be found. (2)

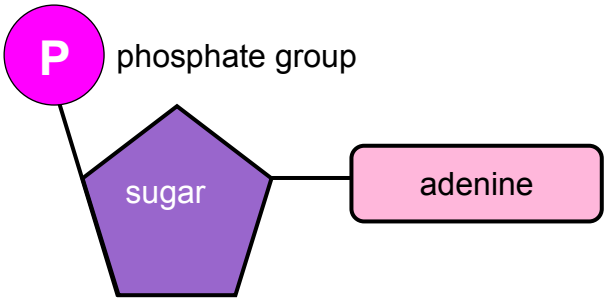
   Nucleus ✓ and mitochondria ✓

4. What is the natural shape of this molecule? (1)

   Double helix ✓

5. Draw a nucleotide with the nitrogenous base adenine. (4)

   ✓ for structure, ✓ - for each correct label



(11)

Ribonucleic Acid (RNA)

Key terminology

RNA	RNA consists of nucleotides linked to the nitrogenous bases adenine, uracil, guanine and thymine
messenger RNA	mRNA carries the code for protein synthesis from DNA to the ribosome
ribosomal RNA	rRNA forms ribosomes which are the site of protein synthesis
transfer RNA	tRNA brings amino acids to the ribosome to form the protein

Learners must know the location, structure and function of RNA. It is important to point out that uracil (rather than thymine) is only found in RNA as a nitrogenous base.

For assessment purposes learners must apply their knowledge of structure and include ribose sugar as the sugar in the nucleotides forming RNA.

It is important to know that there are three types of RNA and each plays a different role during protein synthesis.

Comparison between DNA and RNA

Learners must be able to tabulate differences and list similarities between the nucleic acids. If given a diagram learners should able to identify which molecule it is based on observable differences.

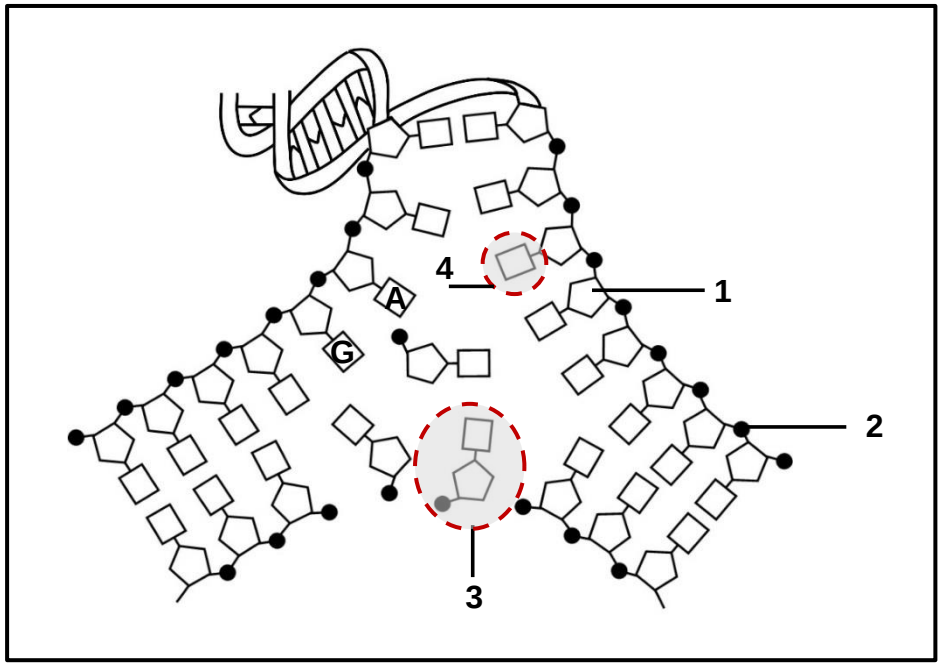
DNA Replication

Learners need to know the process and application of DNA replication for assessment purposes. In most cases, a diagram will be provided and learners must be able to interpret and apply knowledge to the scenario given.

Learners often confuse DNA replication and protein synthesis, so teachers should ensure that a clear distinction is made between the two processes.

Activity 2: DNA replication

Study the diagram below and answer the questions that follow.



1. Name the process illustrated in the diagram above. (1)

   DNA replication ✓

2. State the significance of the process mentioned in question 1. (1)

   DNA replication ensures that identical cells, with the same number and type of chromosomes, can be produced during cell division. ✓

3. Identify the parts labelled as 1, 2, 3 and 4. (4)

   1 – deoxyribose sugar ✓, 2 – phosphate ✓, 3 – nucleotide ✓, 4 – thymine ✓

4. Describe how this process takes place. (6)

   The process of DNA replication

   - Double helix DNA unwinds as the weak hydrogen bonds between the nitrogenous bases break ✓
   - The two DNA strands separate from each other (DNA unzips) and each original DNA strand serves as a template to form a new strand ✓
   - Free DNA nucleotides from the nucleoplasm attach to the original strand ✓
   - The nucleotides attach to their complementary bases (A to T and G to C) ✓
   - Each DNA molecule now consists of one original strand and one new strand ✓
   - The result is two genetically identical DNA molecules; the entire process is controlled by enzymes ✓

5. Give one location of extra-nuclear DNA. (1)

   Mitochondrial DNA in mitochondria or chloroplastic DNA in chloroplasts ✓

(13)

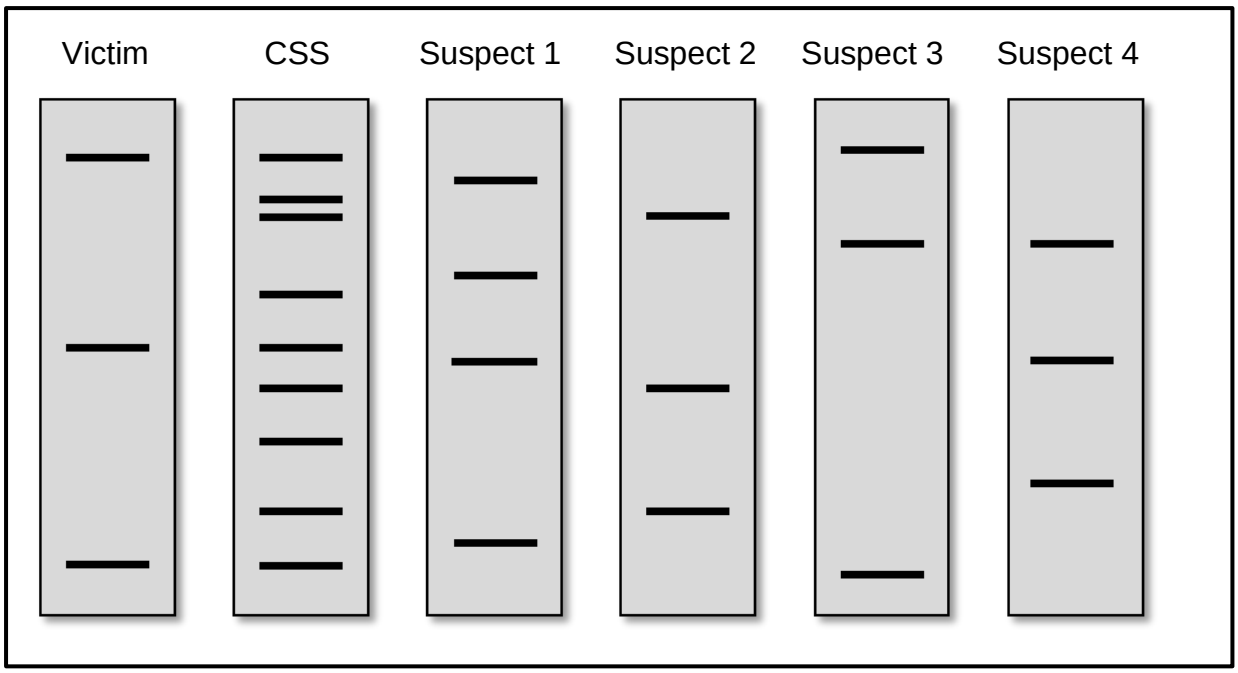
DNA Profiling

Learners are not required to know this in detail or the methods entailed to produce a DNA fingerprint. They need to understand and apply knowledge with regards to comparing profiles to make deductions about individuals.

Learners are required to know the uses of DNA profiling as well as the arguments against its use.

Activity 3: DNA profiling

In a fight involving a number of people, one person was seriously injured. Police took blood samples from the victim, the crime scene (CSS – crime scene sample) and four suspects. The DNA was then extracted from each sample. The results are shown in the DNA profiles below.



1. Which suspect probably injured the victim? (1)

   Suspect 2 ✓

2. Give a reason for your answer to the previous question. (1)

   3 of the DNA bands match the evidence from the crime scene while none of the other suspects match. ✓

3. List one application of DNA profiling other than for solving crime. (1)

   Any one of … ✓

   - identification of relatives such as paternity testing or tracing siblings
   - testing for genetic disorders

- to determine matching tissues for organ transplants
- research into variation in populations

4. Give two reasons why DNA profiling may sometimes be challenged. (2)

Any two of …. ✓✓

- DNA samples may be planted or a person could be framed with the use of false evidence
- Human error can lead to false results
- Only a small amount of DNA is analysed so it may not be unique to one individual
- Testing standards may not be followed in various private labs
- Invasion of privacy and revealing personal information

(5)

Protein Synthesis

Key terminology

amino acids	monomers forming proteins
base triplet	three nitrogenous bases one after the other on DNA
transcription	1st stage of protein synthesis – mRNA formed carrying code for the protein to be made
translation	2nd stage of protein synthesis – amino acids combine to form protein
codon	three nitrogenous bases one after the other on mRNA – these are opposite to the triplet on DNA
anti-codon	three nitrogenous bases one after the other on tRNA – these are opposite to the codon on mRNA

Learners find this process quite challenging and teachers should ensure that a solid understanding is obtained of both transcription and translation. Learners should be able to identify the different stages using diagrams and be able to explain the various structures involved as well as the process taking place.

This section is often asked as an application type question during assessments. Learners are not required to learn the names of the amino acids but must know how to apply knowledge when given their names. This type of question can be seen in the activity provided.

Learners must understand the difference between the triplets, codons and anti-codons and know how to apply this knowledge by being able to form complementary

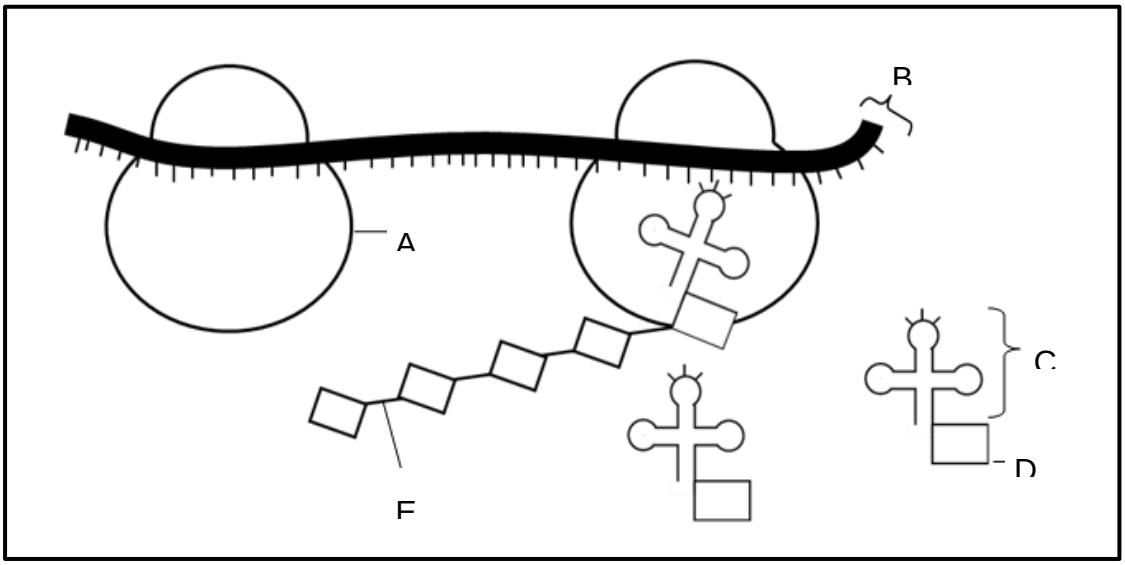
bases from one to the other in the formation of proteins i.e. Triplet to codon to anticodon.

This can be shown in the table below:

Molecule	3 adjacent bases is called:	Example
DNA	Triplet	AGC
mRNA	Codon	UCG
tRNA	Anti-codon	AGC
Amino Acid		Alanine

Activity 4: Protein synthesis

The diagram below represents a process that occurs during protein synthesis.



1. Identify the process above. (1)

   Translation of protein synthesis ✓

2. Name …

   a) organelle A (1)

      ribosome ✓

   b) molecule B (1)

      mRNA ✓

   c) the bond at E (1)

      peptide ✓

3. Provide the letter and name of the molecule that …

   a) carries the amino acid (1)

C – tRNA ✓

b) is the monomer of protein (1)

D – amino acid ✓

4. Name and describe the process occurring in the nucleus which results in the formation of the mRNA molecule. (6)

Transcription ✓

- section of DNA double helix unwinds as the weak hydrogen bonds between the nitrogenous bases of DNA break
- DNA unzips (in this section of DNA), and one strand acts as a template
- This DNA template is used to form a complementary strand of messenger RNA (mRNA) ✓
- This is done using free RNA nucleotides in the nucleoplasm ✓
- The mRNA now contains the code for the protein which will be formed ✓
- Three adjacent nitrogenous bases on the mRNA are known as codons. These code for a particular amino acid. ✓
- mRNA moves out of the nucleus through a nuclear pore into the cytoplasm, where it attaches onto a ribosome. ✓

Activity 5: Codons and amino acids

The sequence of amino acids in a protein molecule is coded for by DNA and RNA. The table below shows some mRNA codons and the corresponding amino acids.

mRNA codons	amino acid
AGC	serine
GAU	aspartate
CUA	leucine
UAU	tyrosine
UUC	phenylalanine
AGU	serine
GAC	aspartate
UUU	phenylalanine
CUC	leucine
GAG	glutamic acid

1. According to the table, how many codons code for phenylalanine? (1)

   2 ✓

2. What is the anti-codon for glutamic acid? (1)

   CUC ✓

3. A section of mRNA has the following base sequence and is read from left to right:

   GAU CUC GAC AGC AUG ACC

   Give the …

   a) DNA base triplet for the last codon on this section of mRNA (1)

      TGG ✓

   b) 1st amino acid coded for by this section of mRNA (1)

      aspartate ✓

   (4)

Summary

- There are two types of nucleic acids which are both made up of nucleotides. A nucleotide is made up of a sugar, a phosphate and a nitrogenous base.
- DNA's structure is based on a theory put forward by Watson and Crick. Their theory states that DNA has a three dimensional, double helix shape.
- DNA is mainly found inside of the nucleus (nuclear DNA) and in the mitochondria and chloroplasts of animal and plant cells (extra-nuclear DNA).
- DNA is made up of nucleotides containing deoxyribose sugar and the nitrogenous bases Adenine: Thymine and Guanine: Cytosine which are complementary. It is double helix and the two strands of DNA are held together by joining the bases using weak hydrogen bonds.
- DNA functions to control all metabolic processes and carries the hereditary information of an individual.
- RNA is found in the nucleus and cytoplasm of cells. It contains ribose sugar as well as the nitrogenous bases Adenine: Uracil and Guanine: Cytosine which are complementary. It is single stranded.
- DNA replication is the process by which DNA makes an identical copy of itself during interphase of the cell cycle. This is important for ensuring that identical daughter cells are formed with the same number and type of chromosomes.

- DNA profiling involves producing a pattern of lines with various lengths and thicknesses. These are unique (except for identical twins) and are used to determine biological parents and in criminal cases.
- Protein synthesis is the process by which proteins are formed. It uses both DNA which codes for the protein being made and RNA which forms the protein. This process involves two stages: transcription and translation.

End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A- D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 A molecule of RNA is copied from DNA by the process of

A **transcription** ✓✓
B mitosis.
C mutation.
D translation.

1.1.2 In a DNA molecule

A guanine pairs with adenine.
B **adenine pairs with thymine**. ✓✓
C cytosine pairs with adenine.
D Guanine pairs with thymine.

1.1.3 A codon is a sequence of three nucleotides on a molecule of

A rRNA.
B **mRNA**. ✓✓
C tRNA.
D DNA.

1.1.4 DNA was analysed and found to contain 14% T (thymine). What percentage of the molecule is cytosine?

A 14%
B 28%
C **36%** ✓✓
D 72%

1.1.5 A gene in a bacterium codes for a protein that has 120 amino acids. How many mRNA nucleotides code for this protein?

A 30
B 40
C **360** ✓✓
D 480 (5 × 2 = 10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 Proteins that form part of the chromosomes.
Histones ✓

1.2.2 Which type of RNA travels from the nucleoplasm to the cytoplasm.
mRNA / messenger RNA ✓

1.2.3 The nitrogenous base found in RNA but not in DNA.
Uracil ✓

1.2.4 A sugar that is a component of DNA.
Deoxyribose ✓

1.2.5 A sudden change in the sequence / order of the nitrogenous bases of a nucleic acid.
Mutation ✓

1.2.6 The name of the bond that forms between amino acids in a protein molecule.
Peptide ✓

1.2.7 The type of nucleic acid that carries a specific amino acid.
tRNA / transfer RNA ✓

1.2.8 A segment of DNA coding for a particular characteristic.
Gene ✓

1.2.9 The bonds that form between nitrogenous bases in a DNA.
Hydrogen bond ✓

1.2.10 The organelle in the cytoplasm on which protein synthesis occurs.
Ribosome ✓

(10 x 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

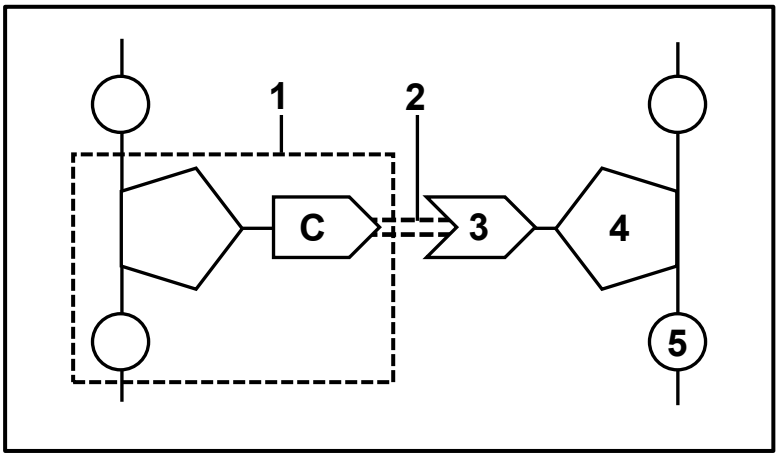
Column I	Column II
1.3.1 Contains ribose sugar	A: DNA B: RNA
1.3.2 Discovery of DNA	A: Mendel B: Darwin

1.3.3 Location of DNA.	A: nucleus B: mitochondria
1.3.4 The process where one DNA molecule produces two identical DNA molecules.	A: replication B: reproduction
1.3.5 Pairing of nitrogenous bases	A: DNA B: RNA

(5 x 2) = (10)

1.3.1 **B only ✓✓**
1.3.2 **None ✓✓**
1.3.3 **Both ✓✓**
1.3.4 **A only ✓✓**
1.3.5 **A only ✓✓**

1.4 The diagram below represents a portion of a nucleic acid.



1.4.1 Name the nucleic acid. (1)

DNA ✓ / Deoxyribonucleic acid

1.4.2 Name two places in animal cells where this nucleic acid may be found. (2)

Nucleus ✓ / chromosome

Mitochondria ✓ (mark first 2 only)

1.4.3 Identify

a) portion 1 (1)

Nucleotide ✓

b) nitrogenous base 3 (1)

Guanine ✓

c) molecule 5 (1)

Phosphate ✓

d) bond 2 (1)

hydrogen bond ✓

1.4.4 What is the natural shape of this molecule? (2)

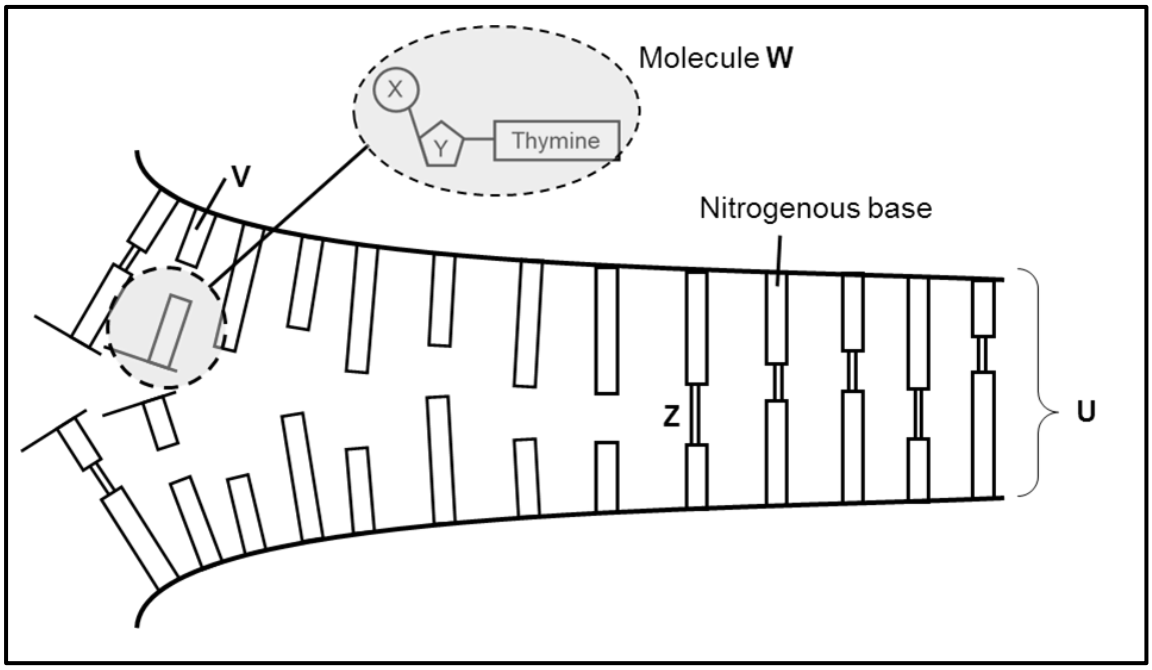
Double ✓ helix ✓

1.4.5 Name the process in which this molecules make a copy of itself? (1)

DNA replication ✓

(10)

1.5 The diagram below represents DNA replication.



1.5.1 Identify the following:

a) molecules **W** and **U** (2)

W – nucleotide ✓, U – DNA ✓

b) parts of molecule W labelled X and Y (2)

X – phosphate ✓, Y – deoxyribose sugar ✓

c) bond Z (1)

hydrogen bond ✓

d) nitrogenous base V (1)

adenine ✓

1.5.2 Where in the cell does this process take place? (1)

Nucleus ✓

1.5.3 Name the phase of the cell cycle where replication takes place. (1)

Interphase ✓

1.5.4 What is the purpose of DNA replication? (2)

For DNA to make an exact copy of itself ✓ so that each daughter cell will receive exactly the same DNA. ✓

(10)

Section A: [50]

Section B

Question 2

2.1 The following sequence represents a part of the nitrogenous base sequence on a DNA molecule.

TAC	TCT	CCA
Triplet 1	Triplet 2	Triplet 3

2.1.1. Write down the base sequence of the anticodon of triplet 1 shown above. (1)

UAC ✓

2.1.2. The table below shows the amino acids that correspond with different mRNA codons.

mRNA codon	**Amino Acid**
AGA	arginine
AUG	methionine
GGU	glycine
AUC	isoleucine

a) Give the correct sequence of amino acids for DNA triplets 1 to 3. (2)

Methionine- Arginine- Glycine ✓✓

b) During DNA replication a mutation occurred on triplet 1 resulting in C being replaced by G. Describe how this mutation will affect the structure of the protein formed. (3)

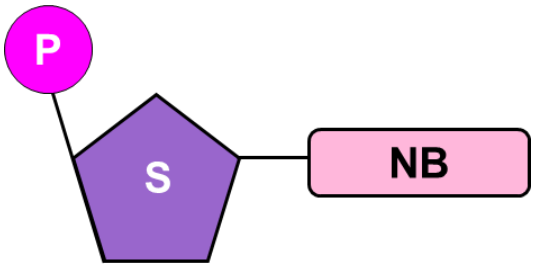
- the corresponding mRNA codon will be AUC ✓
- resulting in isoleucine being picked up tRNA ✓
- resulting in a different protein ✓

2.1.3. Name and describe the process occurring in the nucleus which results in the formation of an mRNA molecule. (6)

- The process is **transcription** ✓ - **Compulsory mark**
- The double helix DNA molecule unwinds ✓
- When the hydrogen bonds break ✓
- the DNA molecule unzips ✓ / two DNA strands separate
- One strand is used as the template ✓ to form mRNA
- using free RNA nucleotides ✓ from the nucleoplasm
- The mRNA is complementary to the DNA ✓ / A-U, C-G
- The process is controlled by enzymes ✓

(**Compulsory mark + Any 5)**

2.1.4. Draw a RNA nucleotide with a complementary base to adenine. (2)



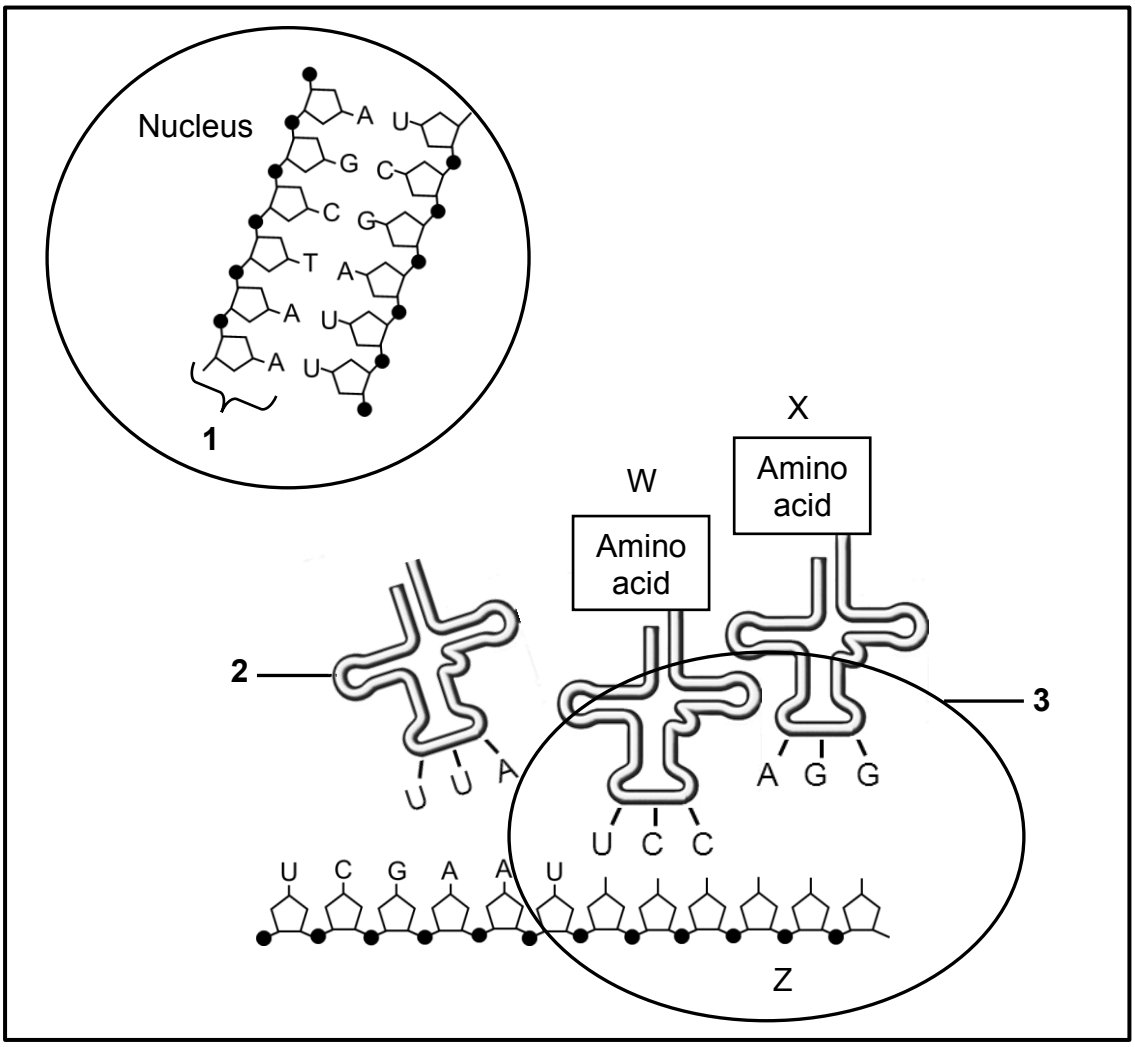
S: ribose sugar
P: phosphate
NB: uracil

Guidelines for assessing diagram

Correct Structure (Phosphate, Sugar, Nitrogenous base)	✓
Uracil	✓

(14)

2.2 The diagrams below represent the process of protein synthesis. Study them and answer the questions that follow.



2.2.1 Identify the structures labelled **1,2** and **3**. (3)

1 – DNA template ✓, 2 – tRNA ✓, 3 – ribosome ✓

2.2.2 Name and describe the stage of protein synthesis taking place at **Z** (5)

- The stage of protein synthesis taking place at Z is **translation** ✓ - compulsory mark
- According to the codons of mRNA ✓
- tRNA molecules with complementary anticodons ✓
- bring the required amino acids to the ribosome ✓
- the amino acids link by peptide bonds ✓
- to form the required protein ✓

(Compulsory mark + ANY 4)

2.2.3 Using the table below, work out the names of the amino acids labelled **W** and **X**. (4)

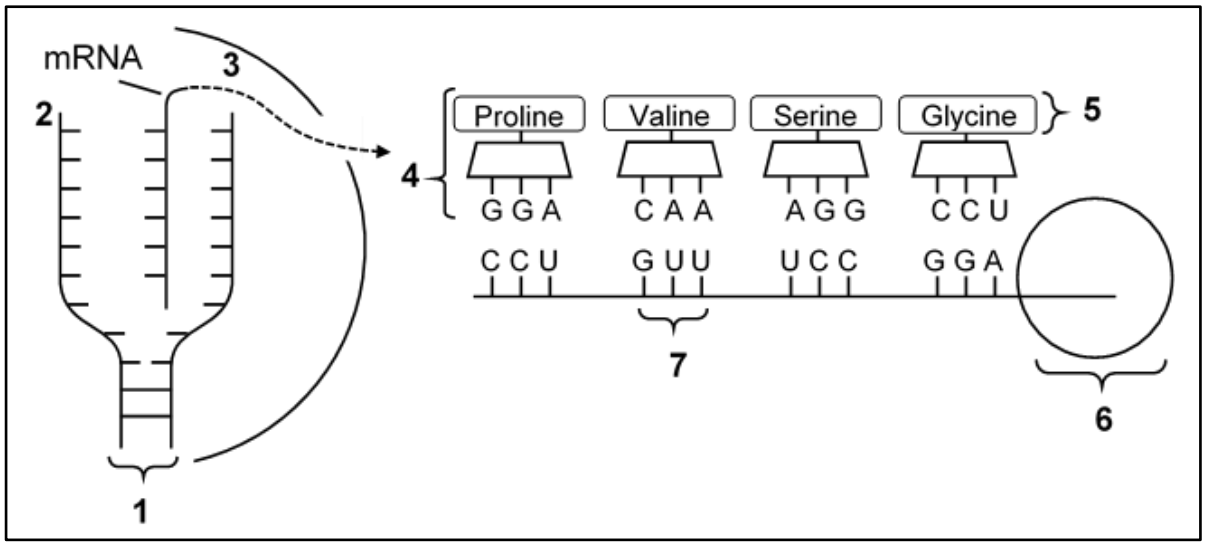
Base Triplet on mRNA coding for the amino acid	Amino acid coded for
GAG	glutamate
CAG	histidine
AGG	arginine
CUG	leucine
UCC	proline
GUG	valine

W – arginine ✓✓, X – proline ✓✓

(12)
[26]

Question 3

3.1 The diagram below represents two stages of protein synthesis.



3.1.1 Provide labels for:

a) molecule **1** (1)

DNA ✓

b) organelle **6** (1)

ribosomes ✓

3.1.2 Give only the number of the part which represents a:

a) DNA template strand (1)

2 ✓

b) monomer of proteins (1)

5 ✓

c) codon (1)

7 ✓

3.1.3 Describe *translation* as it occurs in organelle **6**. (4)

- The mRNA attaches to the ribosome ✓
- When each codon ✓ of the mRNA
- matches with the anticodon ✓ on the tRNA
- the tRNA brings the required amino acid to the ribosome ✓
- When the different amino acids are brought in sequence ✓
- adjacent amino acids are linked by peptide bonds ✓
- to form the required protein ✓ / polypeptide

3.1.4 Provide the:

a) DNA sequence that codes for glycine (2)

CCT ✓✓

b) codon for proline (2)

CCU ✓✓

3.1.5 State two differences between a ***DNA*** nucleotide and an ***RNA*** nucleotide. (4)

DNA	**RNA**
Has deoxyribose sugar ✓	Has ribose ✓ sugar
Has nitrogen base thymine ✓ (T) / A, G, C and T	Has nitrogen base uracil ✓ (U) / A, G, C and U

Mark first two only; table not required

(17)

3.2 The first 7 triplets of nitrogenous bases that form part of the gene coding for one chain of the haemoglobin protein that makes up red blood corpuscles in humans is shown below. Study the table and answer the questions that follow.

DNA Template	CAC	GTG	GAC	TGA	GGA	CTC	CTC
Base triplet number	1	2	3	4	5	6	7

3.2.1 How many of the following are coded for in the DNA template sequence above?

a) Nitrogenous bases (1)

21 ✓

b) Different types of tRNA molecules that are required to form the polypeptide from this piece of DNA. (1)

6 ✓

3.2.2 Write down the mRNA sequence for the triplets numbered **4** and **6** in the above table. (2)

4 – ACU ✓, 6 – GAG ✓

3.2.3 Using the table below, determine the amino acid sequence coded for by triplet numbers **4** and **6.** (2)

Anticodons on tRNA coding for the amino acid	**Amino acid coded for**
CUC	glutamate
GUC	histidine
GGA	proline
GAC	leucine
UGA	threonine
CAC	valine

4 – threonine ✓, 6 – glutamate ✓

3.2.4. If the T in the 6th base triplet changed to A in the DNA template above, write down the new amino acid (using the table above) that this 6th triplet now codes for. (1)

Valine ✓

(7)

[24]

Section B: [50]

Total Marks: [100]

Cognitive level distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1	✓				2
1.1.2	✓				2
1.1.3	✓				2
1.1.4				✓	2
1.1.5			✓		2
					10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
					10
1.3.1		✓			2
1.3.2		✓			2
1.3.3		✓			2
1.3.4		✓			2
1.3.5		✓			2
					10
1.4.1	✓				1
1.4.2	✓				2
1.4.3 a - d	✓				4
1.4.4	✓				2
1.4.5	✓				1
					10
1.5.1 a - d	✓				6

1.5.2	✓				1
1.5.3	✓				1
1.5.4		✓			2
					10
2.1.1	✓				1
2.1.2 a - b			✓		5
2.1.3			✓		6
2.1.4		✓			2
					14
2.2.1	✓				3
2.2.2			✓		5
2.2.3			✓		4
					12
3.1.1 a - b	✓				2
3.1.2 a - c		✓			3
3.1.3		✓			4
3.1.4 a - b		✓			4
3.1.5			✓		4
					17
3.2.1 a - b		✓	✓		(1+1)
3.2.2		✓			2
3.2.3		✓			2
3.2.4		✓			1
					7
	40	37	21	2	100

CHAPTER 2: MEIOSIS

Overview

Time allocation: 2 weeks (8 hours)

This chapter consists of the following sections:

1. Introduction
2. Key concepts and terminology
3. Genetic code and chromosomes
4. The process of meiosis
5. The importance of meiosis
6. Abnormal meiosis
7. Summary
8. End of topic exercises

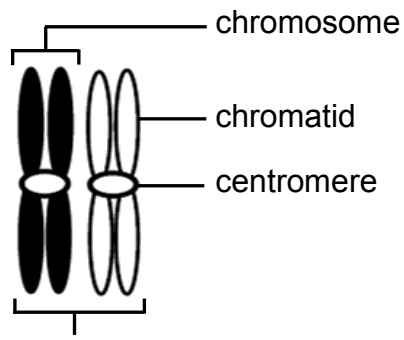
Introduction

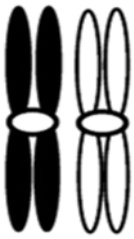
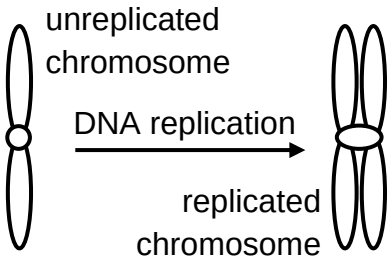
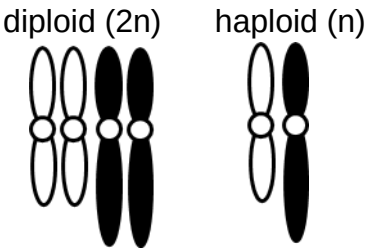
In this section we discuss how meiosis takes place and why it is vital for sexual reproduction. We will also cover what happens if meiosis goes wrong.

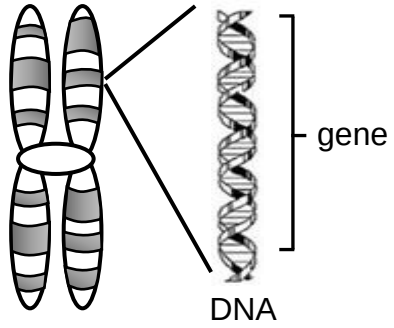
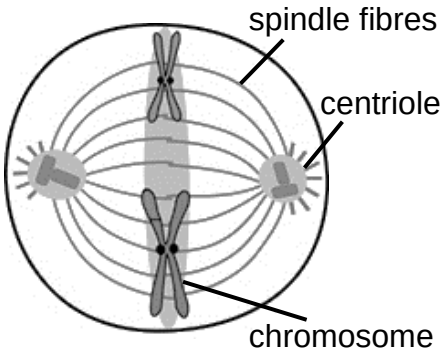
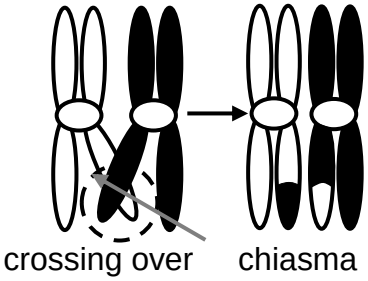
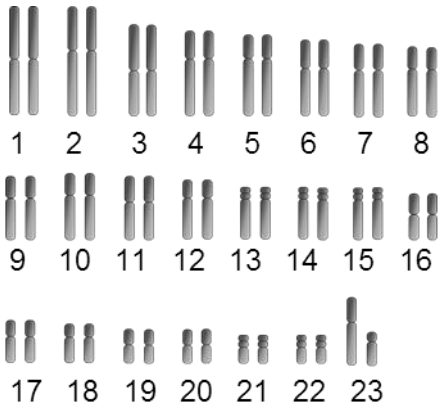
Key concepts and terminology

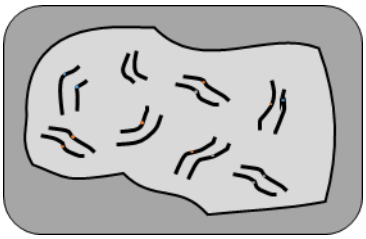
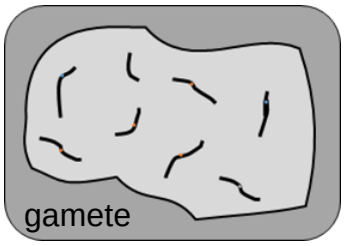
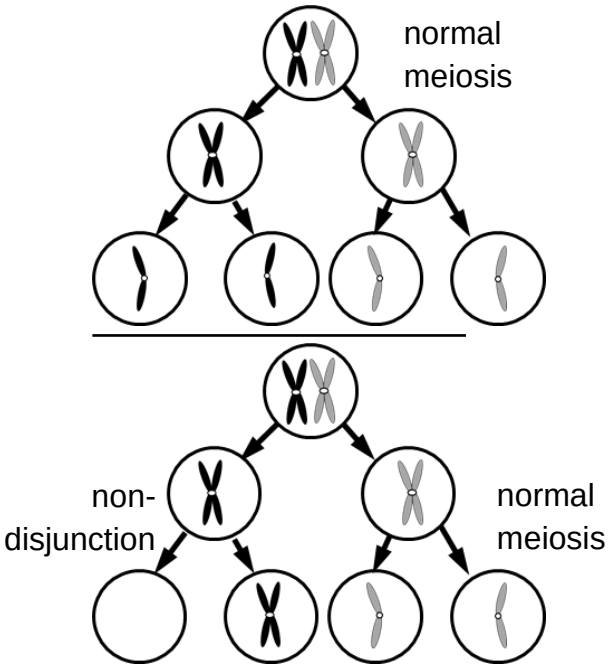
- Meiosis is divided into two divisions (Meiosis I and Meiosis II).
- Each division is divided into four phases which are Prophase, Metaphase, Anaphase and Telophase.
- The importance of meiosis is that it produces haploid daughter cells and variation.
- Differences and similarities of mitosis and meiosis.
- Abnormal meiosis will be discussed. When meiosis goes wrong syndromes result e.g., Down syndrome.

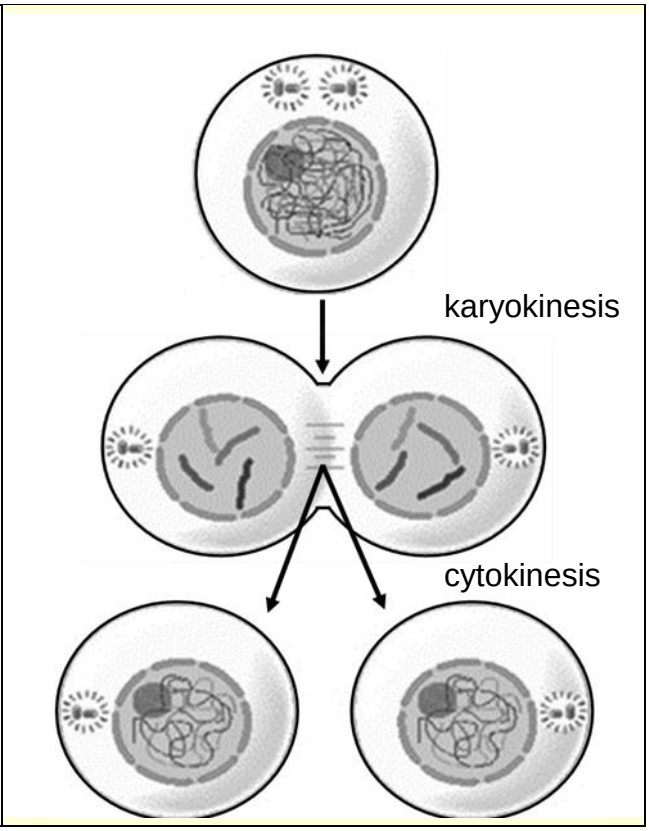
Key terminology

<table>
<tr><td>chromosome</td><td>a threadlike structure made up of DNA and protein found in the nucleus of most living cells, carrying genetic information in the form of genes</td><td rowspan="4"> 

homologous chromosomes – one from the mother and one from the father</td></tr>
<tr><td>chromatid</td><td>one of the two identical strands of a replicated chromosome</td></tr>
<tr><td>centromere</td><td>region where the two chromatids of a chromosome are held together</td></tr>
<tr><td>homologous chromosomes</td><td>a pair of chromosomes of the same shape, size and having similar genes for each characteristic occupying the same position</td></tr>
<tr><td>bivalent</td><td>a pair of homologous chromosomes which lie next to each other and are physically in contact with each other at a point where crossing over will occur</td><td>  </td></tr>
<tr><td>unreplicated chromosomes</td><td>an unreplicated "chromosome" has a single double-stranded DNA molecule</td><td rowspan="2"> 
</td></tr>
<tr><td>replicated chromosomes</td><td>a replicated "chromosome" has two identical double-stranded DNA molecules</td></tr>
<tr><td>interphase</td><td>the phase in the cell cycle when DNA replication occurs</td><td></td></tr>
<tr><td>diploid (2n)</td><td>two complete set of chromosomes in a cell</td><td rowspan="2"> 
</td></tr>
<tr><td>haploid (n)</td><td>one complete sets of chromosomes in a cell</td></tr>
</table>

gene	a segment of DNA in a chromosome that contains the code for a particular characteristic	
centrosome	organelle (containing two centrioles) found only in animal cells	
centriole	structures formed when the centrosome divides into two; they move to opposite ends of the cell during cell division	
crossing over	Overlapping of homologous chromosomes resulting in the exchange of genetic material during Prophase I	
chiasma	point where two chromatids overlap during crossing over	
karyotype	a representation of the number, shape and arrangement of a full set of chromosomes in the nucleus of a somatic cell	
autosome	the first 22 pairs of chromosomes which control the appearance, structure and functioning of the body	
gonosomes (sex chromo-somes)	the pair of chromosomes (XX or XY) responsible for sex determination	

somatic cells (body cells)	Any cells in an organism excluding male and female gametes – they are diploid (have 2 sets of chromosomes) and are produced through mitosis	 somatic cell – chromosomes are in homologous pairs
sex cells (gametes)	specialized cells called gametes (sperm cell and egg cell). They have a haploid number of chromosomes and are produced through meiosis	 single unpaired chromosomes
non-disjunction	when homologous chromosome pairs fail to separate in meiosis	
karyokinesis	Karyo means “nucleus” and kinesis means “synthesis or division.” Karyokinesis is the process of division of the nucleus of a cell	

cytokinesis	Cyto means "cytoplasm," and kinesis mean "synthesis or division." Cytokinesis is the process of division during which the cytoplasm of a single cell divides into two daughter cells.	

Genetic code and chromosomes

In this section, start by revising mitosis and its role in **somatic** cells. Emphasize the fact that mitosis always makes two identical copies of the mother cell. Then explain that if two somatic cells fuse during fertilisation, the chromosome number of the zygote will be double the normal number. This could lead to developmental problems in the offspring. So a "special" type of cell division called meiosis, is essential.

By producing haploid **gametes** the characteristic chromosome number will be maintained. Meiosis halves the chromosome number (haploid) so that after fertilisation, it will return to normal (diploid). Meiosis, therefore, only occurs in sex organs (**gonads** in animals, **anther** and **ovule** in flowering plants) to produce gametes in animals and spores in flowering plants.

The other important function of meiosis is to bring about genetic **variation** so that the offspring have a unique combination of genes from the mother and father. Emphasise that if this new combination results in a better adapted organism, this is an advantage in terms of survival. If these genes are passed on over many generations, it could lead to evolution.

The process of meiosis

Learners usually pick up the various phases quite easily as it is similar to mitosis, but it is VITAL that they distinguish between Meiosis I and Meiosis II. The number MUST be written after the name of the phase or else they will lose the mark in the exam.

Learners need to know the names of the phases for each division and be able to identify each from diagrams. They must be able to describe the fundamental fact(s) that defines each phase. For example, Telophase I produces two haploid daughter cells whereas Telophase II produces FOUR daughter cells.

Explain that Meiosis I is a reduction phase whereby the diploid number of chromosomes is reduced to haploid. It is also where variation is brought about due to a "shuffling" of genes during crossing over so that each daughter cell will be slightly different genetically. It is important to stress that homologous chromosomes pair up to form bivalents. This is important because when crossing over occurs, similar genes are exchanged so no genes are doubled up or lost.

Explain that Meiosis II has to occur because the chromosomes present in the daughter cells at the end of Meiosis I are made up of TWO **chromatids**. This is due to the fact that DNA replication occurs before meiosis as well as mitosis. So during Prophase I each chromosome is made up of two **identical chromatids**. These chromatids are NOT separated during Anaphase I as the whole chromosome moves to a pole. Consequently, each chromosome must go through a division like mitosis so that the chromatids are separated during Anaphase II resulting in each daughter cell having daughter chromosomes made up of ONE **chromatid** only.

Due to the fact that there are TWO divisions, there will be FOUR daughter cells formed at the end of meiosis, each with a haploid number of chromosomes.

Importance of meiosis

Reducing the diploid number of chromosomes to haploid is one function. Bringing about genetic variation is the other important role of meiosis. This is brought about during Prophase I and Metaphase I and II.

The "shuffling" of genes during Prophase I has been mentioned previously.

The way in which the chromosomes arrange themselves on the equator during Metaphase I and II is called **random arrangement** and is purely due to chance. When the chromosomes or chromatids move apart and move to the poles, it is called **random assortment**.

Independent assortment is often confused with this. However, independent assortment refers to the genes (not the chromosomes) that are separated into the four gametes (one gene on each of the four chromatids in the two chromosomes of the bivalent). Independent assortment is crucial in genetics and is the basis for the formation of gametes in the genetic diagram. This will be discussed in the Genetics chapter.

Activity 1: Meiosis I and Meiosis II

1. Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1 Which one of the following correctly describes the daughter cells produced by meiosis?

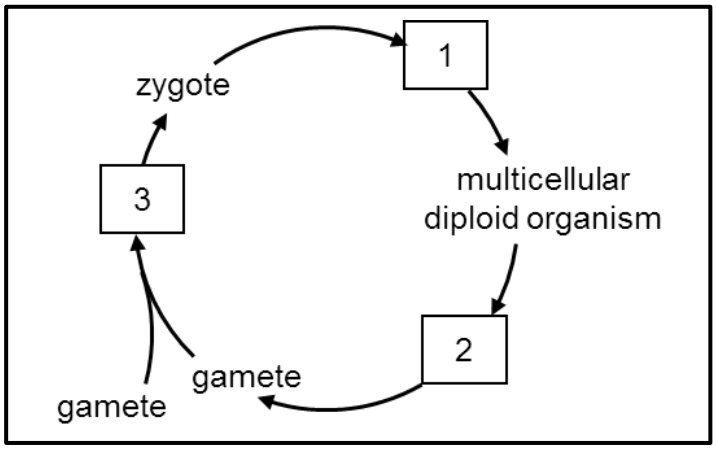
Cells produced by meiosis

	Chromosome number	Genetic composition
A	**haploid**	**different ✓✓**
B	diploid	identical
C	diploid	different
D	haploid	identical

1.2 If there are 38 chromosomes in the body cell of a donkey. How many of these chromosomes are autosomes?

A 38 B 19 C **36 ✓✓** D 44

1.3 Use the sketch below to identify processes 1, 2 and 3.



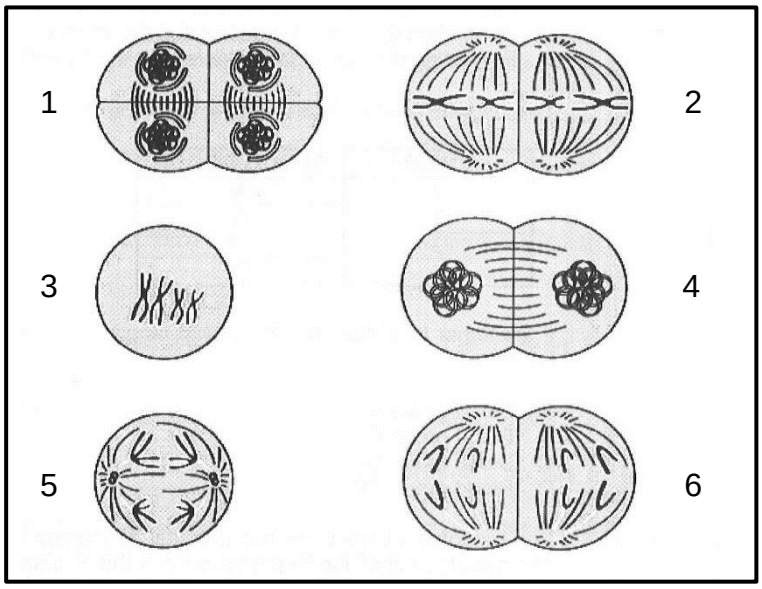
	1	2	3
A	meiosis	fertilisation	mitosis

B	fertilisation	mitosis	meiosis
C	**mitosis**	**meiosis**	**fertilisation** ✓✓
D	fertilisation	meiosis	mitosis

1.4 Cytokinesis is a term that describes …

A nuclear division
B **cytoplasmic division** ✓✓
C reduction of the chromosome number
D doubling the chromosome number

1.5 The diagrams below represent six different phases of meiosis taking place in a particular cell.



1.5.1 The diploid number of chromosomes in this cell is …

A 2 B **4** ✓✓ C 8 D 46

1.5.2 The correct sequence from the start of meiosis till the end is …

A 1, 2, 3, 4, 5, 6
B 6, 2, 5, 4, 1, 3
C **3, 5, 4, 2, 6, 1** ✓✓
D 3, 4, 5, 6, 1, 2

1.6 Interphase is the stage during which …

A nothing happens in the cell.
B a dividing cell forms a spindle.
C cytokinesis occurs.
D **a cell grows and duplicates its DNA**. ✓✓ (7 × 2) = (14)

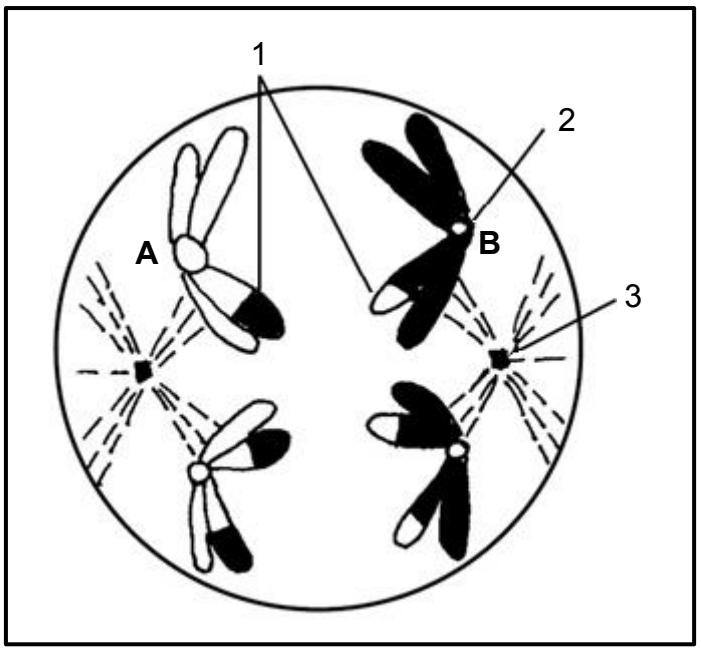
2. Each of the following questions consist of a statement in Column I and two items in Column II. Decide which item(s) relate(s) to the statement. Write **A only**, **B only**, **Both A and B** or **None** next to the question number.

	Column I	Column II
2.1	Chromosome number changes from diploid to haploid	A: Meiosis B: Mitosis
2.2	Takes place to form sex cells	A: Mitosis B: Meiosis
2.3	Replication of DNA takes place	A: before mitosis B: before meiosis
2.4	Crossing over takes place	A: Prophase in mitosis B: Prophase I in meiosis
2.5	Chromosomes are pulled to opposite poles	A: Anaphase in mitosis B: Anaphase I in meiosis
2.6	Results in genetic variation	A: crossing over B: random arrangement
2.7	Chromosomes lengthen to form a chromatin network	A: Metaphase B: Anaphase

(7 × 2) = (14)

2.1 **A only ✓✓**
2.2 **B only ✓✓**
2.3 **Both A and B ✓✓**
2.4 **B only ✓✓**
2.5 **B only ✓✓**
2.6 **Both A and B ✓✓**
2.7 **None ✓✓**

3. Study the diagram.



3.1 What type of cell division is occurring? (1)

Meiosis ✓

3.2 What phase is depicted? (1)

Anaphase I ✓

3.3 Provide labels for parts labelled 2 and 3. (2)

2 – centromere ✓ , 3 – centriole ✓

3.4 What process resulted in the exchange of segments labelled 1? (1)

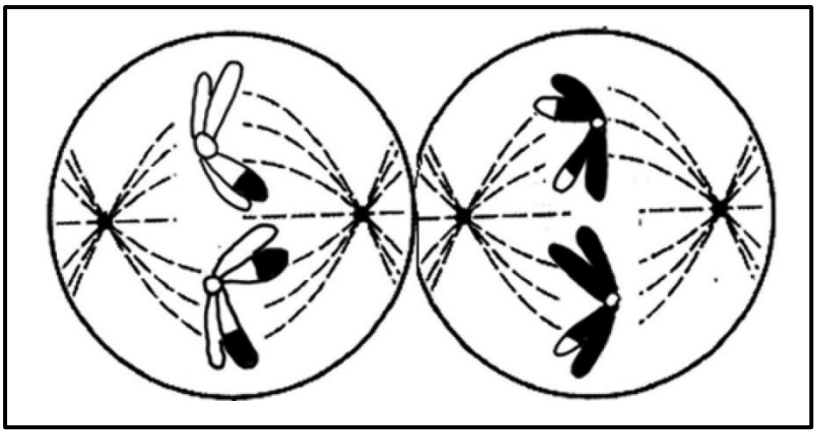
crossing over ✓

3.5 Explain why the process mentioned in 3.4 is important. (1)

Results from the swopping of genetic material during Prophase I which brings about genetic variation ✓

(6)

4. Refer to the diagram below which shows two cells dividing by meiosis.



4.1 Which phase of meiosis is depicted? (1)

Metaphase II ✓

4.2 Give two visible reasons for your answer to 4.1. (2)

Single chromosomes are lined up at the equator ✓ in two cells ✓

4.3 Why do some of the chromatids have two different colours? (1)

Crossing over between the maternal and paternal chromosomes results in genetic variation (different gene combinations) ✓

4.4 Do you think that these cells were taken from a human? No ✓ (1)

4.5 Give a reason for your answer to 4.4. (1)

Only 2 chromosomes – in humans, there would be 23 ✓

4.6 If these cells were taken from an angiosperm, name the two parts of the flower where this type of division would occur. (2)

Anther ✓ and ovule ✓

(8)

5. Explain why meiosis is important for the survival of a human. (8)

Meiosis ✓ is vital so that sexual reproduction ✓ can occur. This is due to the fact that the chromosome number is halved ✓ (diploid to haploid ✓). This allows haploid male and female gametes to fuse ✓ to form a diploid zygote which has the correct ✓ diploid number. It also allows genetic variation ✓ so that the offspring has a unique genetic makeup. In this way a better adapted ✓ offspring could be formed which could lead to evolution.

(50)

Abnormal Meiosis

Problems can arise if crossing over does not occur equally resulting in one chromosomes having extra genes and the other missing genes. This is not part of the syllabus, but is happening more often nowadays so you need to be aware of this in case a learner asks about it.

Problems occurring during Anaphase I and II are in the syllabus. Incorrect separation of chromosomes is called **non-disjunction**. If only ONE PAIR of chromosomes fails to separate it is called aneuploidy and if ALL the chromosomes do not separate (i.e. one daughter cell has none and the other has the diploid number) it is called polyploidy.

Down syndrome is an example of aneuploidy, and polyploidy in plants is important for genetically modified crops.

Summary

Genetic code and chromosomes

- At the start of meiosis the chromatin network condenses to form a characteristic number of chromosomes (46 in humans).
- Each chromosome is made of two chromatids joined by a centromere, due to DNA replication during interphase.
- The full set of chromosomes is called the karyotype and is inherited from both parents – a haploid set from the mother (maternal) and a haploid set from the father (paternal).
- In humans: there are 44 autosomes and 2 gonosomes.

Meiosis – the process

- Meiosis takes place in two divisions each going through four phases: Prophase, Metaphase, Anaphase and Telophase.
- **Meiosis I** can be summarised as follows:

  Prophase I - chromosomes pair up (bivalents are formed); crossing over takes place to exchange genetic material.

  Metaphase I - chromosomes move to middle (equator) but stay in pairs, randomly arranged above and below the equator.

  Anaphase I - chromosomes move apart to the poles without centromere splitting.

  Telophase I - terminal phase where daughter cells are formed consisting of a haploid number of chromosomes, each made of two chromatids and genetically different.
- **Meiosis II** takes place in both daughter cells as follows:

  Prophase II - chromosomes do not pair up.

  Metaphase II - chromosomes are randomly arranged on the equator, not in pairs.

  Anaphase II - centromere splits and chromatids move to opposite poles.

  Telophase II - four haploid, non-identical daughter cells are formed.

Importance of Meiosis

- Haploid daughter cells are formed. Gametes (sex cells) can be formed which can fuse during sexual reproduction without doubling the chromosome number.
- Genetic variation is brought about by crossing over and the random arrangement of chromosomes during Metaphase I and chromatids during Metaphase II. These changes could lead to evolution.

Abnormal Meiosis

- If the chromosomes fail to separate properly during Anaphase I it is called non-disjunction.
- If this only involves one pair of chromosomes, it is called aneuploidy, e.g. Down syndrome.
- If this involves the full set of chromosomes, it is called polyploidy which is an advantage to agriculture.

End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 During which phase of meiosis do homologous chromosome pairs separate?

A Metaphase I
B **Anaphase I ✓✓**
C Anaphase II
D Telophase II

1.1.2 Which of the following distinguishes Prophase I of meiosis from Prophase of mitosis?

A **Homologous chromosomes pair up ✓✓**
B Spindle forms
C Nuclear membrane breaks down
D Chromosome becomes visible

1.1.3 Which ONE of the following events occurs during Metaphase I of meiosis?

A **Homologous chromosomes arrange themselves at the equator**. ✓✓
B Centrioles move to the opposite poles.
C Chromosomes arrange themselves singly at the equator.
D The cytoplasm is split.

1.1.4 Which one of the following combinations results in genetic variation in organisms?

A Mitosis; sexual reproduction; mutations.
B Meiosis; asexual reproduction; mutations.
C Mitosis; meiosis; sexual reproduction.
D **Meiosis; sexual reproduction; mutations**. ✓✓

1.1.5 In bees, females are diploid and males are haploid. Females and males produce haploid gametes. This means that

A females produce gametes by mitosis.
B males produce gametes by meiosis.
C **males produce gametes by mitosis**. ✓✓
D Females have half the number of chromosomes that males have.

(5 × 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The division of the cytoplasm after a cell nucleus has divided.
Cytokinesis ✓

1.2.2 The point of crossing over between two adjacent chromosomes.
Chiasma ✓

1.2.3 The name of the process when homologous chromosome pairs fail to separate during meiosis.
Non-disjunction ✓

1.2.4 Region where the two chromatids of a chromosome are held together.
Centromere ✓

1.2.5 Chromosome condition describing the presence of a single set of chromosomes in a cell.
Haploid ✓

1.2.6 The structure responsible for pulling chromosomes to the poles of an animal cell during cell division.
Spindle fibres / spindle threads / spindle ✓

1.2.7 The DNA in a nucleus of a non-dividing cell.
Chromatin network ✓

1.2.8 The structure that is made up of two chromatids joined at the centromere.
Chromosome ✓

1.2.9 A phase in the cell cycle that occurs before cell division.
Interphase ✓

1.2.10 A source of genetic variation that arises during Metaphase I.
Random arrangement ✓of homologous chromosomes

(10 × 1) = (10)

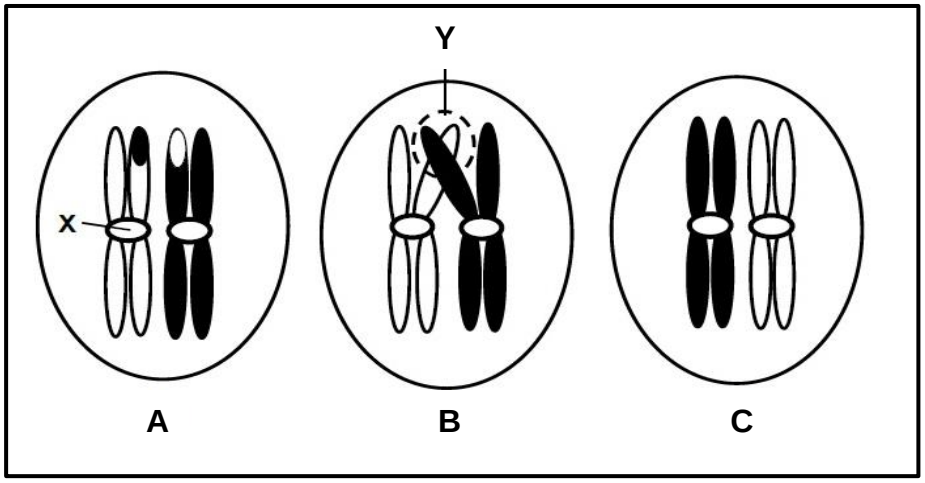
1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 Chromosomes align at equator	A: Metaphase I B: Metaphase II
1.3.2 Occurs during Telophase of meiosis I	A: division of the cytoplasm B: centrioles move to the opposite poles
1.3.3 Phase during which chromatids are pulled to opposite poles	A: Anaphase I B: Anaphase II
1.3.4 Contributes to each gamete receiving DNA segments from each parent.	A: Prophase I B: Prophase II
1.3.5 The structure that moves chromosomes / chromatids to the poles during cell division.	A: centrosomes B: spindle fibres

(5 × 2) = 10

1.3.1 **Both A and B** ✓✓
1.3.2 **A only** ✓✓
1.3.3 **B only** ✓✓
1.3.4 **A only** ✓✓
1.3.5 **B only** ✓✓

1.4 The diagrams below represent a chromosome pair in a female human cell. The cells (**A**, **B** and **C**) show different events in a phase of meiosis, which are not necessarily in the correct sequence.



1.4.1 How many pairs of chromosomes occur in a normal human cell? (1)
23 ✓

1.4.2 Give labels for:

a) region **X** centromere ✓ (1)

b) area **Y** chiasma ✓ (1)

1.4.3 Name the organ in the human female where meiosis occurs. (1)

Ovary ✓

1.4.4 Name the

a) process occurring in diagram **B**. (1)

crossing over ✓

b) phase represented by the diagrams above. (1)

Prophase I ✓

c) type of cell that would result from meiosis of this cell. (1)

Ovum ✓ / female gamete

1.4.5 Arrange letters **A**, **B** and **C** to show the correct sequence of the events. (1)

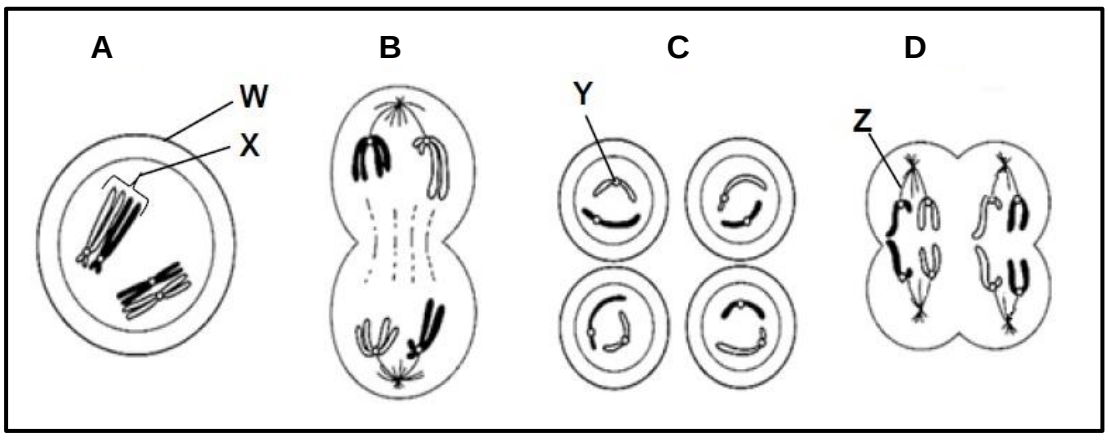
C → B → A ✓

1.4.6 What is the biological importance of meiosis? (2)

- Leads to the formation of haploid gametes ✓ in some organisms and haploid spores in 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 ✓ (Mark any 2 × 1)

(10)

1.5 The diagrams below show different phases in meiosis. Study the diagrams and answer the questions that follow.



1.5.1 Label structures **W** and **X**. (2)

W – cell membrane / plasmalemma ✓

X - bivalent/homologous chromosomes ✓

1.5.2 How many chromosomes are present in each cell:

a) phase **A** 4 ✓ (1)

b) phase **C** 2 ✓ (1)

1.5.3 Give the letter of the diagram that represents Anaphase II. D ✓ (1)

1.5.4 State the name and function of region **Y** and structure **Z**. (4)

Y – centromere✓: holds sister chromatids together ✓

Z – spindle fibres✓: pulls chromosomes/chromatids to poles ✓

1.5.5 Which phase precedes (occurs before) phase **A**? (1)

Interphase ✓

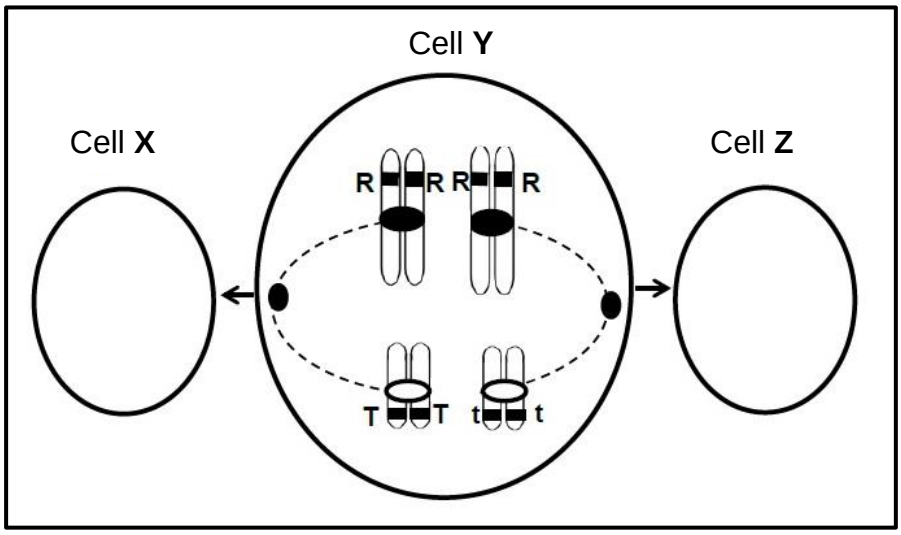
(10)

Section A: [50]

Section B

Question 2

2.1 The diagram below represents a phase in meiosis. Cell **Y** undergoes division to give rise to cells **X** and **Z**. Some alleles are indicated by letters.



2.1.1 Explain why cell **Y** does NOT belong to a human. (2)

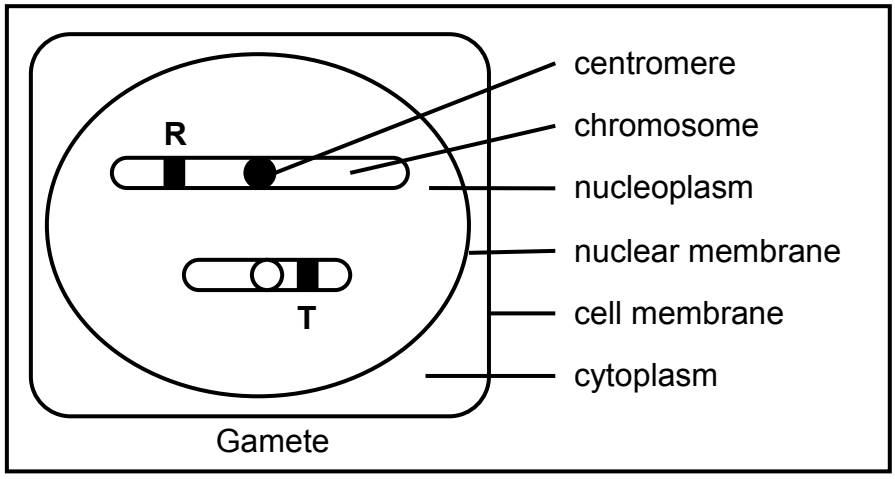
Human somatic cells have 23 ✓ pairs of chromosomes / 46 chromosomes and this cell only has 2 pairs ✓ / 4 chromosome

2.1.2 How many chromosomes would be present in:

a) cell **X** at the end of Telophase **I**. 2 ✓ (1)

b) the daughter cells produced by cell **Z** after meiosis **II**. 2 ✓ (1)

2.1.3 Draw a labelled diagram of a gamete that will result from cell **Y**. (5)



Guidelines for marking diagram:

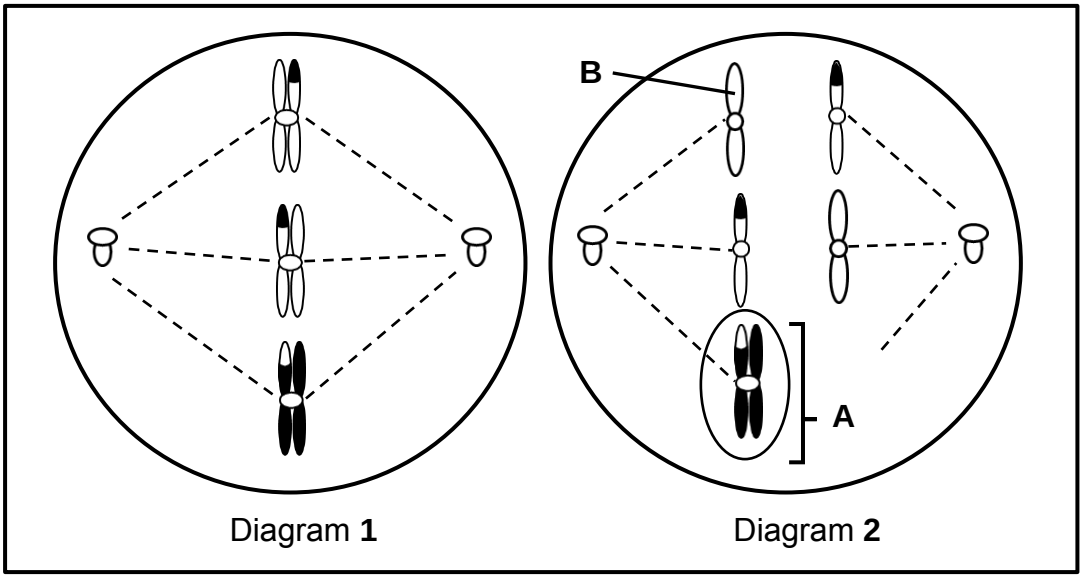
Criteria	Mark
Single cell is drawn	✓
Only 2 unreplicated chromosomes in drawing	✓
Short unreplicated chromosome indicating T	✓
Long unreplicated chromosome indicating R	✓
Any one correct label	✓

2.1.4 Describe the events of Anaphase II. (3)

- the spindle fibres contract ✓
- the centromere of each chromosome splits into two ✓
- the chromatids move to opposite poles ✓

(12)

2.2 Study the diagrams below representing two phases of meiosis and answer the questions that follow.



2.2.1 Identify the phase represented by:

a) Diagram **1** Metaphase II ✓ (1)

b) Diagram **2** Anaphase II ✓ (1)

2.2.2 Name the part labelled **B**. chromatid ✓ (1)

2.2.3 Describe what happens during the phase illustrated in Diagram **1**. (2)

Chromosomes arranged singly/randomly along the equator ✓
Chromosomes attached to spindle fibres ✓

2.2.4 In Diagram **2** the part circled, and labelled **A** is an abnormality during the process of meiosis.

a) Name this abnormality. Non-disjunction (1)

b) What genetic disorder would result in humans if this abnormality occurred in chromosome pair no. 21? (1)

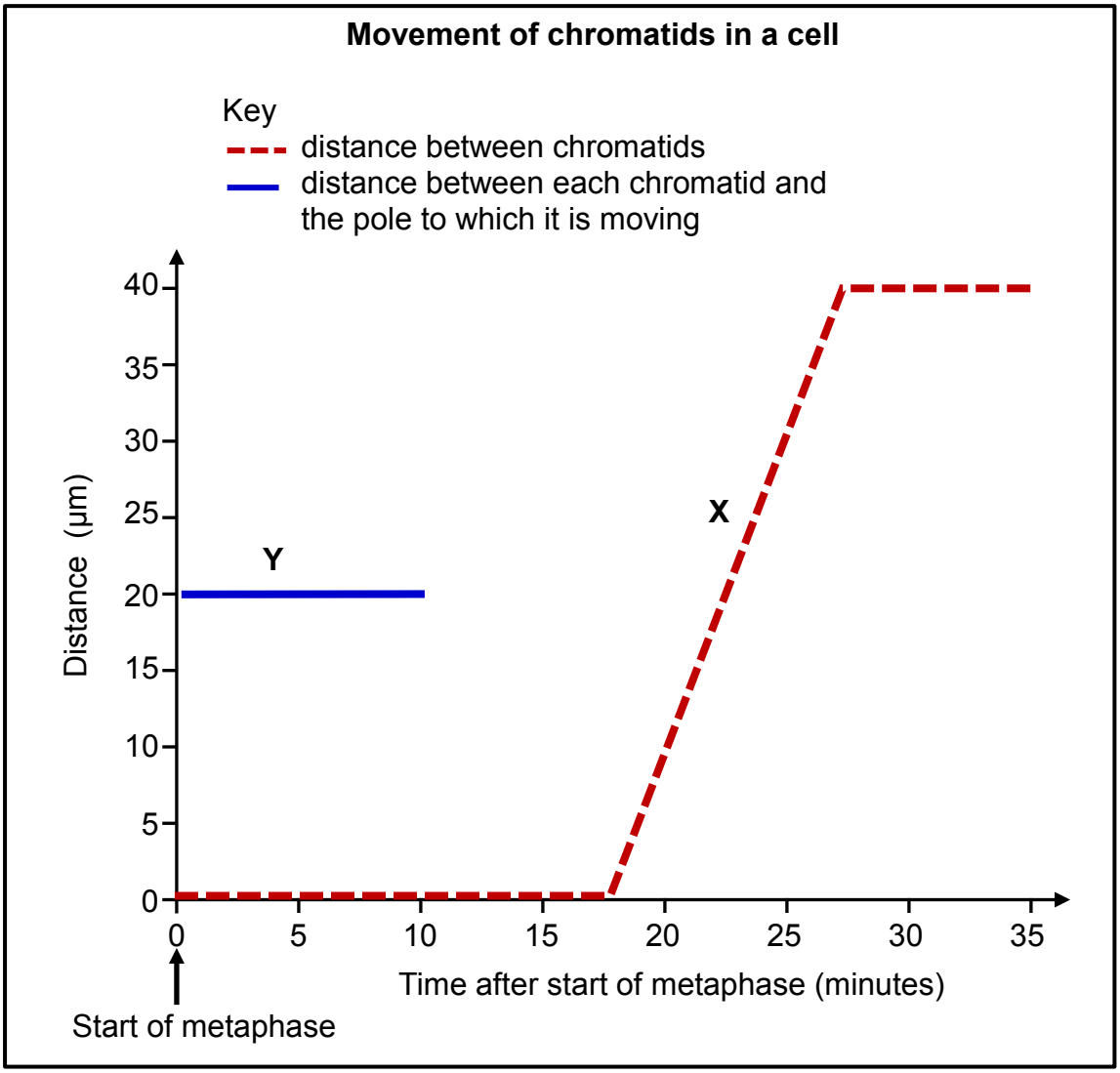
Down Syndrome ✓

c) Give one symptom of the genetic abnormality mentioned in question 2.2.4 (b). (1)

Mental retardation ✓
Heart defects ✓
Upwardly slanting eyes ✓
Abnormal ear shape ✓
Small nose ✓
Hearing loss ✓
Decreased muscle tone ✓
Small mouth ✓
Depressed nasal bridge ✓
(Mark first one only)

(8)

2.3 The graph shows information about the movement of chromatids in a cell that has just started Metaphase II.



2.3.1 Name one difference between Metaphase I and Metaphase II. (2)

Metaphase I – chromosomes come as homologous pairs to the equator ✓

Metaphase II – individual chromosomes move to equator ✓

2.3.2 What is the duration of Metaphase II in this cell? (1)

18 minutes ✓

2.3.3 Use line X to calculate the duration of Anaphase II in this cell. (2)

(28 min – 18 min) ✓ = 10 minutes ✓

(5)
[25]

QUESTION 3

3.1 Describe the behaviour of the chromosomes during the process of meiosis I by referring to the following phases:

3.1.1 Prophase I (6)

- Each chromosome shortens and becomes visible ✓
- as two chromatids ✓ joined at the a centromere
- Homologous chromosomes come lie next to each other ✓
- Chromatids from each homologous chromosome overlap / crossing over occurs ✓ at the chiasma/chiasmata ✓
- and genetic material is exchanged ✓

3.1.2 Metaphase I (3)

- The homologous chromosome pairs ✓ line up along the equator randomly ✓
- and are attached to spindle fibres ✓ / spindle threads

3.1.3 Anaphase I (2)

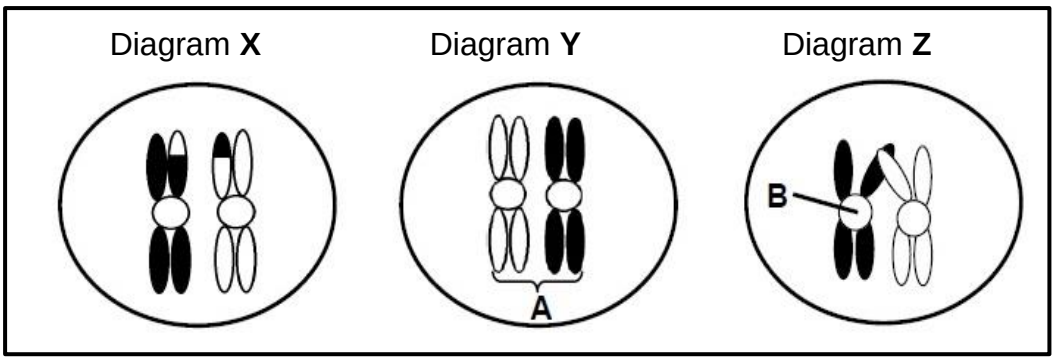
- Spindle fibres shorten ✓ / contract
- Chromosomes of each homologous pair are pulled to the opposite poles✓

3.1.4 Telophase I (3)

- The cytoplasm divides to form two new cells ✓
- with genetically different nuclei ✓
- Each nucleus has half the number of chromosomes of the original cell. ✓

(14)

3.2 The diagram below shows chromosome pair 21 in the nucleus of a cell of the ovary of a woman. The chromosomes are involved in a process that takes place in a phase of meiosis.



3.2.1 Give labels for **A** and **B**. (2)

A – bivalent / homologous chromosomes ✓
B – centromere ✓

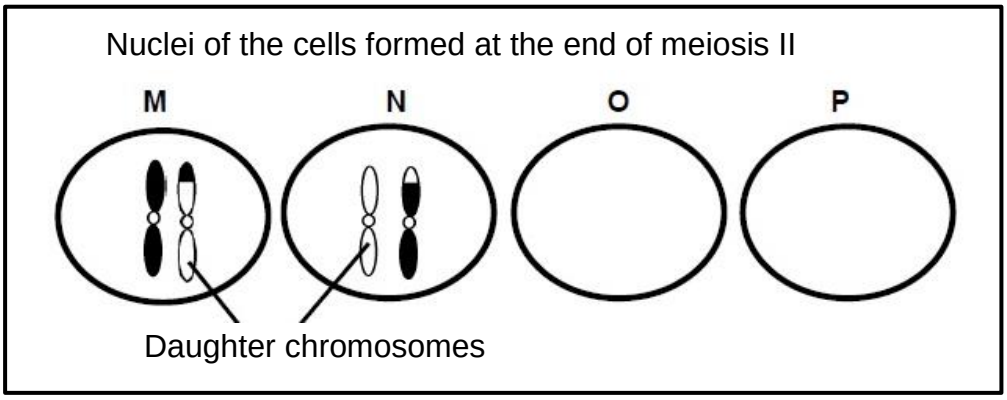
3.2.2 Rearrange the letters **X**, **Y** and **Z** to show the correct sequence in which the events take place in this phase. (1)

Y → Z→ X ✓

3.2.3 Explain why chromosomes in Diagram X and Diagram Y are different in appearance. (3)

Genetic material was exchanged ✓ between the chromosomes in diagram X due to crossing over ✓ whereas the chromosomes in diagram Y did not undergo crossing over✓

3.2.4 The diagram below shows the nuclei of the four cells that resulted from meiosis involving chromosomes in Diagram **X** above.



a) Explain why nuclei **O** and **P** do NOT have chromosomes. (2)

- During meiosis the chromosome pair does not separate ✓ / there is non-disjunction.
- Two gametes (M and N) will have an extra copy of chromosome ✓ number 21 and therefore the other gametes (O and P) do not have a copy of chromosome 21.

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

- Down Syndrome ✓
- If the gamete fuses with a normal sperm having one copy of chromosome 21 ✓
- The resulting zygote will have 3 copies ✓ of chromosome number 21 / 47 chromosomes

(11)

[25]

Section B: [50]

Total Marks: [100]

Cognitive levels distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1	✓				2
1.1.2		✓			2
1.1.3		✓			2
1.1.4	✓				2
1.1.5				✓	2
	4	4		2	10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	10				10
1.3.1		✓			2
1.3.2		✓			2
1.3.3		✓			2
1.3.4		✓			2
1.3.5		✓			2
		10			10
1.4.1	✓				1
1.4.2 a - b	✓✓				1+1
1.4.3	✓				1
1.4.4 a - c		✓✓✓			1+1+1
1.4.5		✓			1
1.4.6		✓			2
	4	6			10

1.5.1	✓				2
1.5.2 a - b	✓✓				1+1
1.5.3		✓			1
1.5.4	✓				4
1.5.5	✓				1
	9	1			10
2.1.1			✓		2
2.1.2 a - b			✓✓		1+1
2.1.3		✓			5
2.1.4	✓				3
	3	5	4		12
2.2.1 a - b	✓✓				2
2.2.2	✓				1
2.2.3		✓			2
2.2.4 a - c	✓(c)	✓(a) ✓(b)			1+1+1
	4	4			8
2.3.1		✓			2
2.3.2			✓		1
2.3.3		✓			2
		4	1		5
3.1.1		✓			6
3.1.2		✓			3
3.1.3		✓			2
3.1.4		✓			3
		14			14
3.2.1	✓				2
3.2.2		✓			1
3.2.3		✓			3
3.2.4 a- bb		✓✓			5
	2	9			11
	36	57	5	2	100

CHAPTER 3: REPRODUCTIVE STRATEGIES IN VERTEBRATES

Overview

Time allocation: ½ week (2 hours)

This chapter consists of the following sections

1. Introduction
2. Key concepts and terminology
3. External and internal fertilisation
4. Ovipary, ovovivipary, vivipary
5. The amniotic egg
6. Precocial and altricial development
7. Parental care
8. Summary

Learners are exposed to the reproductive strategies used by vertebrates to maximise their reproductive success. All five vertebrate classes (Amphibians; Fish; Aves; Reptiles and Mammals) with relevant examples of each must be discussed.

Introduction

There is a great deal of variety of reproductive strategies in the Kingdom Animalia and it is recommended to acquaint your learners with as many examples as possible (time dependent). CAPS allocates half a week or two hours to this topic.

Key concepts and terminology

- Differences between internal and external fertilisation.
- The organisation of vertebrate classes according to the presence of internal or external fertilisation.
- Definitions of ovipary, ovovivipary and vivipary.
- Labelling and descriptions of the parts of an amniotic egg.
- Differentiate between precocial and altricial development, including examples of animals born precocial or altricial.

- Descriptions of the effects of parental care, or the lack of it, on the survival of offspring.
- Examples of parental care.

Key terminology

reproductive strategy	structural, functional and behavioural adaptations that improve the chances of fertilisation and the survival of offspring.
external fertilisation	fertilisation that takes place outside the female's body, usually in water
internal fertilisation	fertilisation that occurs inside the female's body where the male has deposited its sperm
ovipary	eggs are laid; the embryo develops outside the mother's body
ovovivipary	young develop from eggs fertilised internally and retained within the mother's body after fertilisation until they hatch
vivipary	the young develop inside the uterus of mother after eggs are fertilised internally; young are nourished through the placenta
amniotic egg	the embryo inside the egg is protected by a hard shell; the egg consists of many extra-embryonic membranes that serve different functions
extra-embryonic membranes	membranes that surround the developing embryo inside the amniotic egg or uterus.
amnion	produces amniotic fluid which cushions embryo and protects it from mechanical injury, temperature changes, dehydration
allantois	collects the embryo's nitrogenous waste and assists in the exchange of gases
chorion	allows for gaseous exchange in the amniotic egg and forms the placenta in mammals
yolk sac	contains the food reserves for the developing embryo
precocial development	when hatchlings are well developed as they hatch, able to move and feed themselves, with eyes open – limited parental care
altricial development	when hatchlings are underdeveloped as they hatch, unable to move or feed or fend for themselves – young require more parental care
parental care	includes the building of nests, protection, teaching of young and feeding – the care, or lack thereof, directly influences the survival of the young

External and internal fertilisation

Differences between internal and external fertilisation and the organisation of vertebrate classes according to the presence of internal or external fertilisation occurring are to be stressed.

Ovipary, ovovivipary; vivipary

Important definitions

ovipary	ovi / pary egg + bearing	Eggs are laid, and development occurs outside the female's body.
ovovivipary	ovo / vivi / pary egg + live + bearing	Eggs develop and hatch within the female's body and young are born live.
vivipary	vivi / pary live + bearing	No eggs are present, young develop from the placenta and are born live.

Have a good reading knowledge on different examples of vertebrate reproductive strategies (at least two per class). Exposure to the sources that you can read for your learners is also vital. This can be in the form of a summary table, with two examples per vertebrate class, under the following headings:

- Vertebrate class
- Internal / external fertilisation
- Oviparous / ovoviviparous / viviparous
- Precocial / altricial young
- Amount of parental care provided

Lastly, remember that entire vertebrate classes do not fall under 'one-label' only. For example, it is incorrect to say that snakes are only oviparous and that amphibians show no parental care. Use the following trend table as a guide:

	external / internal fertilisation	**oviparous / ovoviviparous / viviparous**	**precocial / altricial young**	**parental care**
fish	mostly external	oviparous	highly precocial	mostly none
amphibia	external	oviparous	precocial	none / little
reptiles	internal	oviparous or ovoviviparous	precocial	mostly none

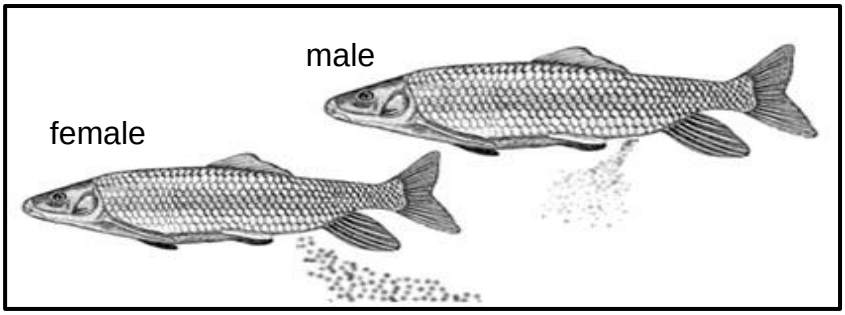
aves	internal	oviparous	precocial or altricial	none / little / high
mammals	internal	oviparous (monotremes) but mostly viviparous	altricial	high

To avoid confusion about the above, remind learners that in most questions an image will be given of the vertebrate class. From this image it will be easier to identify the specific reproductive strategy.

Present the topic using images, charts (life cycles of vertebrates), multi-media clips or documentaries. Only go through to this extent IF time is available. Use the end of chapter activity to gauge where your learners' understanding of content lies.

Activity 1: Fertilisation

The diagram below shows a certain species of fish mating.



1. Identify the type of fertilisation displayed by the fish species. (1)

   External fertilisation ✓

2. State two visible ways in which the chances of fertilisation in these fish are increased. (2)

   The fish are close to each other when they release their gametes ✓. Many egg and sperm cells are released to maximise the chances of fertilisation ✓

3. Name the reproductive strategy used by these fish that involves the production of eggs. (1)

   Oviparous / Ovipary ✓

4. Give two reasons why there is no need for the eggs of these fish to be covered by a hard or leathery shell. (2)

   The eggs are already in water ✓, no desiccation drying-out will occur ✓.

5. Explain the challenge that external fertilisation poses and how organisms with external fertilisation overcome this challenge. (4)

   The chances of fertilisation are reduced as gametes have to meet in water ✓

. To overcome this challenge, many gametes are produced and released shortly after each other and while the parents are close to each other to maximise the chances of fertilisation ✓ .

Offspring do not have a large degree of protection from the external environment and are easily predated upon ✓ . To overcome this challenge, parents can offer parental care and defend eggs and juveniles. Offspring are also precocially developed and well-suited for their environment meaning that they can fend for themselves ✓ .

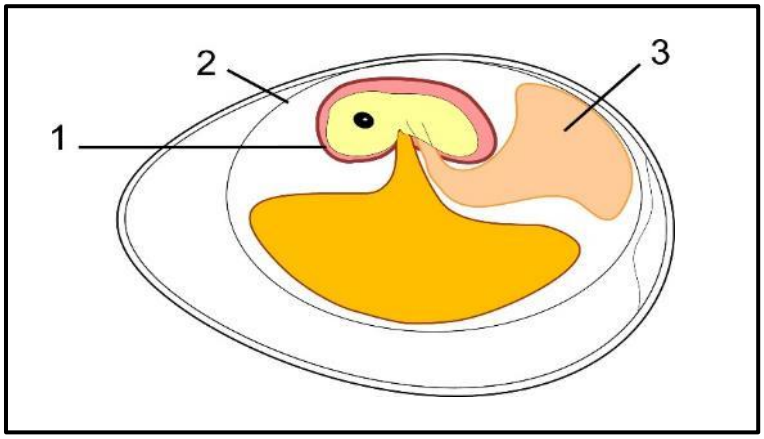
(10)

The amniotic egg

In discussing the amniotic egg, pay particular attention to the naming and description of the various parts as given in the learner text.

Activity 2: Amniotic egg

Study the diagram and answer the questions that follow.



1. Identify the membrane numbered 1 and 2. (2)

   1 – Amnion ✓ ; 2 – chorion ✓

2. Describe any two functions of the fluid found in part 1. (2)

   Temperature regulation; limits mechanical injury; prevents dehydration of the embryo ✓✓ - any two

3. Identify the organ that will replace the function of membrane 3 in the adult organism. (1)

   The bladder ✓

4. Explain why the allantois and yolk sac are non-functional in a human foetus.

   The foetus is directly connected to the mother via the umbilical cord to the

placenta. Through these structures, the foetus can receive nourishment (replacing the function of yolk sac) ✓ and release nitrogenous waste to the mother's body (replacing the function of the allantois) ✓ (2)

5. Briefly explain how the amniotic egg allowed life to evolve onto land. (5)

The outer shell is porous to allow gaseous exchange but prevents the desiccation of the embryo as it limits water loss ✓ . The chorion allows gaseous exchange to take place through the porous egg shell ✓ . The amnion cushions the developing embryo from mechanical injury ✓ and helps regulate temperature ✓ and prevents dehydration ✓ .

(12)

Precocial and altricial development

Differentiate between precocial and altricial development, including examples of animals born precocial or altricial. Learners must be able to identify whether or not a offspring is precocial or altricial based on images.

Parental care

Descriptions of the effects of parental care, or the lack of it, on the survival of offspring. Examples of parental care. Know the major vertebrate classes and their respective degrees of parental care.

Activity 3: Development and care

Study the diagrams below showing different forms of development

A

B

C

D

1. Write down the letters of the organisms which show

a) altricial development B ✓ & D ✓ (2)

b) precocial development A ✓ & C ✓ (2)

2. Ovoviviparous animals can display either precocial or altricial development. Explain how these development approaches differ in respect to

a) the degree of parental care offered (4)

Parental care for precocially developed young would be less intensive as these young are already mobile at birth and can feed and fend for themselves ✓ .

Parental care for altricial young however would require a greater degree of parental care as these young cannot feed themselves ✓ as their bodies are still under-developed ✓ . Parents would need to feed and protect these young until they reach a more developed state ✓ .

b) how well young are developed at birth (2)

The bodies of precocial young are well developed. Precocially developed young's eyes are open, they have down feathers or fur and can move soon after birth ✓ . The bodies of altricially developed young however are not as well developed as their eyes are closed, bodies are naked and have very limited movement ✓ .

c) the amount of yolk present in eggs (2)

In precocial ovoviviparous species' eggs, more yolk is found to assist in the development of a well-developed body. This also sustains the young for a longer incubatory period ✓ . In altricial ovoviviparous species' eggs, less yolk is found and the offspring are born sooner, thus being under-developed ✓ .

3. Tabulate three differences between precocial and altricial development. (7)

	precocial developm.	**altricial developm.**
development of the body	well developed	under developed
eyes after birth	open	closed
presence of fur / feathers	have fur / feathers	usually naked
parental care required	low degree of parental care required	high degree of parental care required
mobility	young can move soon after birth.	young usually have limited capability to move freely
yolk amount in egg	greater quantity	lower quantity

✓ - for tabulating answer; ✓ - 2 marks per correct development – one for precocial, and one for altricial development

(19)

Summary

- Reproduction ensures the continued existence of a species.
- During reproduction, energy is invested in the young in various forms, e.g. amount of energy in pre-natal (yolk per egg; incubation, etc.) and post-natal parental care (protecting young, feeding, teaching, etc.).
- Fertilisation of egg cells could either be external or internal.
- Ovipary, Ovovivipary and Vivipary are reproductive strategies that tell us where the embryo develops, how it feeds and whether a shell is present or not.
- The amniotic egg is an adaptation for reproduction on land. It contains the embryo surrounded by three extra-embryonic membranes, the yolk sac, albumen and a hard-calcareous shell that assist in the embryo's development and protection.
- Precocial and altricial development differ in the respective amounts of pre-natal and post-natal energy input and how well developed the young are at birth.
- Parental care as a reproductive strategy ensures the survival of young until they can fend for themselves.

Enrichment

Courtship behaviours: https://youtu.be/SFwgCh1hh4U

Monotremes: https://youtu.be/NGuIezLFidY

Vertebrate reproduction: https://youtu.be/ce3M1Xwhsas

There are no **End of topic** exercises for this short chapter.

CHAPTER 4: HUMAN REPRODUCTION

Overview

Time Allocation: 3 weeks (12 Hours)

This chapter consists of the following sections:

1. Introduction
2. The male reproductive system
3. The female reproductive system
4. Puberty
5. Gametogenesis
6. The menstrual cycle
7. Fertilisation and development of zygote to blastocyst
8. Implantation of the blastocyst and gestation
9. Summary
10. End of topic exercises

Introduction

In this chapter we will be studying human reproduction. All organisms must reproduce to ensure the survival of the species. We will be looking at the structure of the male and female reproductive systems, how they produce gametes and in particular menstruation and the hormonal control of females. We will also briefly study puberty and gestation, including the processes leading to gestation and birth.

Key concepts and terminology

- The male reproductive system consists of the main sex organ, various ducts and tubules, accessory glands and the external genitalia. Each of these plays a vital role in sperm cell production.

- The female reproductive system consists of the main sex organ, the fallopian tubes, the accessory organs and the external genitalia. Each of these plays a vital role in ova production.
- The sperm cells and ova are known as gametes, and these are fused during fertilisation to form offspring.
- Puberty begins between the ages of 11 and 15 in both girls and boys and prepares their bodies for sexual reproduction in various ways.
- The process of forming gametes begins at puberty and is known as gametogenesis.
- Gametogenesis takes place through different processes in males and females, which is spermatogenesis and oogenesis respectively.
- Females go through a 28 day cycle known as menstruation, this occurs to prepare both the ovum and uterus for possible pregnancy.
- There are four important hormones which control the changes that take place during menstruation namely follicle stimulating hormone, oestrogen, luteinizing hormone and progesterone.
- If fertilisation takes place a zygote is formed and will go through developmental changes to form a blastocyst. The blastocyst will implant and continue to develop throughout gestation first as an embryo and later on as a foetus.
- The formation of the placenta and umbilical cord ensures that the foetus receives nourishment and oxygen, while removing waste products.

Key terminology

gamete	an egg or sperm cell with half the number of chromosomes
gametogenesis	the process in which gametes are produced in the testes and ovaries through meiosis
oogenesis	the process that occurs when egg cells are made in the ovary through meiosis
spermatogenesis	the process that takes place when sperm cells are made in the testes through meiosis
germinal epithelium	cuboidal epithelium found on the surface of the testes and ovaries which gives rise to the cells which mature to form sperm cells and egg cells respectively

The male reproductive system

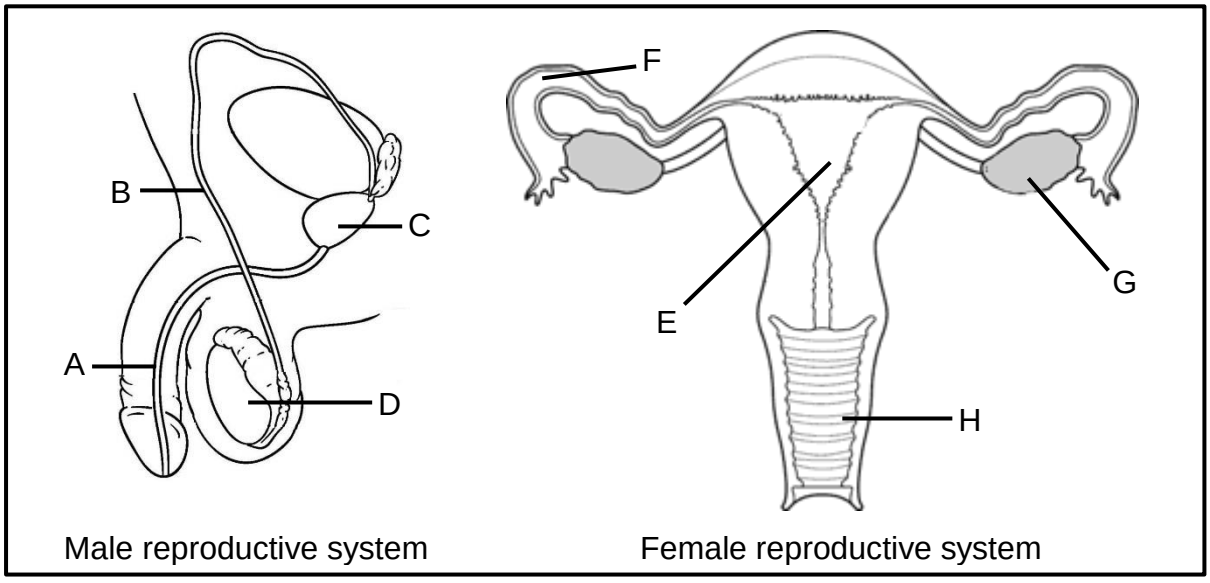
Learners must be able to identify structures in the diagrams by providing labels as well as the functions of these parts. They should be able to discuss the key structures in detail.

The female reproductive system

Learners must be able to identify structures in the diagrams by providing labels as well as the functions of these parts. They should be able to discuss the key structures in detail.

Activity 1: Reproductive systems

Study the diagrams below showing the male and female reproductive systems.



1. Identify the parts labelled A – H. (8)

   A – urethra ✓, B – vas deferens ✓, C – prostate gland ✓, D – testes ✓, E – uterus ✓, F – fallopian tube ✓, G - ovary ✓, H – vagina ✓

2. State one function of the each of the following:

   a) The fluid produced by C. (1)

   Protects the sperm cell from the acidic environment of the vagina or provides a fluid medium in which sperm cells can swim / increases mobility of sperm ✓

   b) Part E (1)

   place for the foetus to develop ✓; maintains pregnancy ✓; assists in child birth✓; implantation of the blastocyst ✓; protects the foetus ✓; passage for sperm cells ✓ (any one)

3. Provide two functions of part H. (2)

   serves as a birth canal ✓; allows for passage of blood ✓ / endometrial lining / amniotic fluid / placenta; facilitates sexual intercourse ✓ / receives semen; secretes acid which prevents infections ✓ (any two)

4. Explain why it is necessary for part D to be 'outside' the human body in males. (2)

   to keep the testes at a temperature that is lower than body temperature ✓, optimum temperature for sperm production which is necessary for the production of healthy sperm and so that healthy sperm can survive. ✓

(14)

Puberty

Puberty is covered in many learning areas so learners should be aware of the changes that take place during puberty. Here, key changes with regards to hormones are emphasized however there are many changes which occur and can be discussed with learners.

Gametogenesis

Learners are not required to know the individual names of the stages of spermatogenesis and oogenesis. This section is not often asked in the form of a diagram but rather as shorter questions. Diagrams depicting spermatogenesis and oogenesis might require some explanation from the teacher.

Diagrams are available on the internet but these are too detailed for what the learners are required to know. For example, in spermatogenesis learners do not need to learn about the spermatogonium becoming the primary spermatocyte and then changing into a secondary spermatocyte. They are required to know spermatid and spermatozoa which are sperm cells. The same applies to oogenesis.

Activity 2: Gametogenesis

1. Name the organ where meiosis takes place in the male and female reproductive systems respectively. (2)

   In males meiosis occurs in the testes ✓ and in females meiosis occurs in the ovaries ✓.

2. Define gametogenesis. (1)

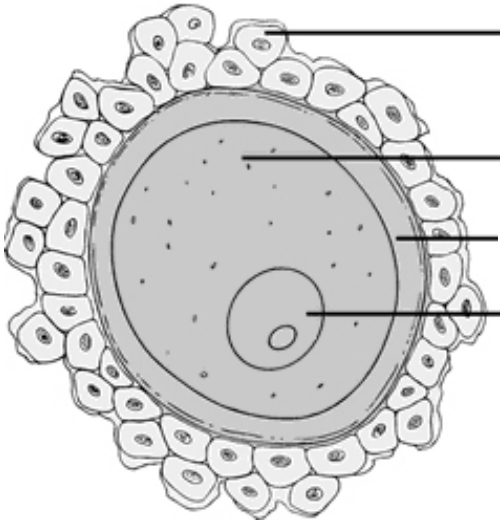
Gametogenesis is the process in which cells undergo meiosis to form gametes ✓

3. Name the type of gametogenesis that takes place in the male and female reproductive systems respectively. (2)

Gametogenesis in males is called spermatogenesis ✓ and in females it is known as oogenesis ✓

4. Draw a fully labelled diagram of an ovum. (5)

Structure of ovum ✓



1 mark for title, one for actual drawing, 3 marks for any 3 correct labels.

5. Discuss the functions of the four main parts of a sperm cell. (8)

- acrosome ✓ – contains enzymes to penetrate the ovum ✓
- head ✓ – contains the nucleus with the male genetic information ✓
- middle portion ✓ – contains many mitochondria to provide energy for the sperm cell to swim ✓
- tail ✓ – propels the sperm cell forward / allows the sperm to swim ✓

(18)

The menstrual cycle

Key terminology

Graafian follicle	fluid filled vesicle in which the egg cell grows
ovulation	the release of an egg from the Graafian follicle of the ovaries
endometrium	the lining of the uterus wall
menstruation	the monthly loss of blood and tissue as a result of changes that occur in the lining of the uterus
menopause	stage in the life of a woman when she stops ovulating and menstruating; usually occurs between the ages of 45 and 55

fertilisation	the fusion of the haploid sperm cell nucleus and the haploid egg cell nucleus to form a diploid nucleus and zygote
implantation	the attachment of the embryo to the endometrium lining the uterus

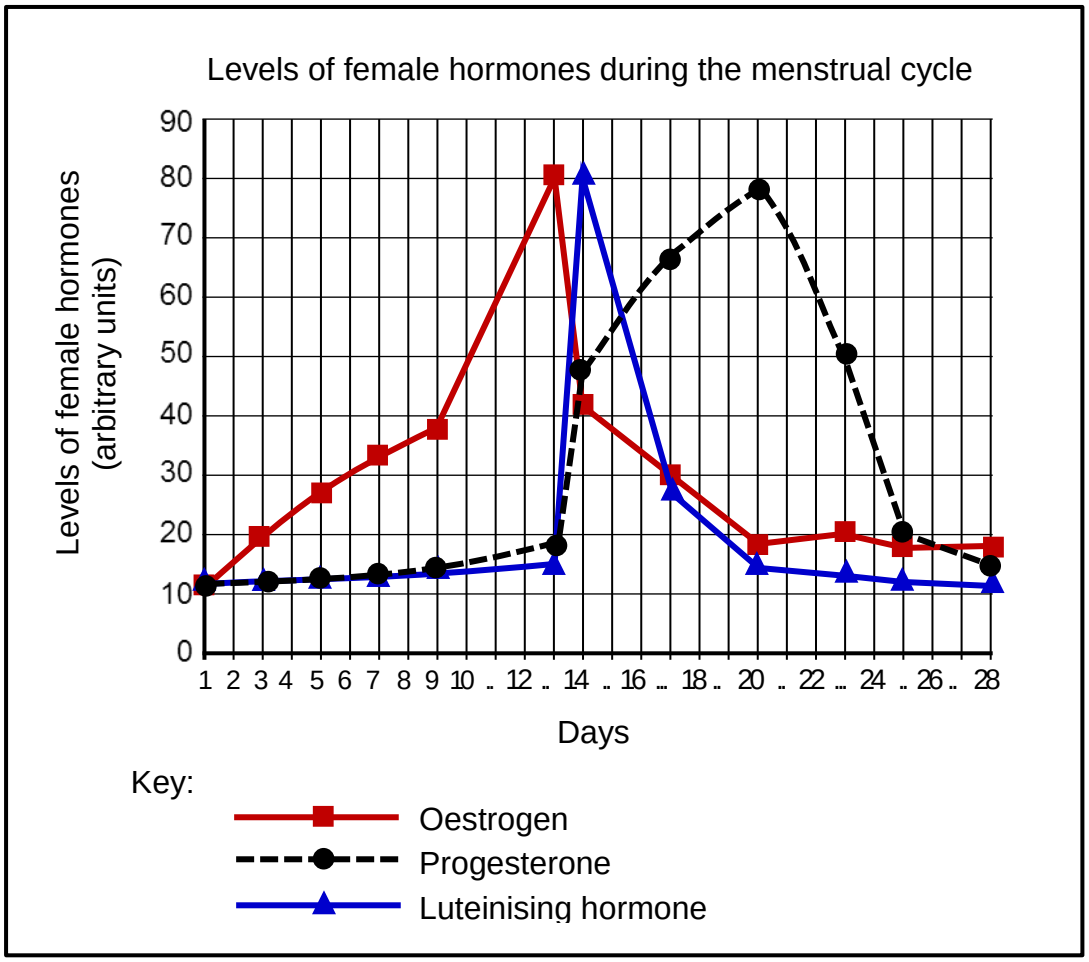
The menstrual cycle occurs in two parts of the reproductive system but at the same time. Learners often struggle to understand this concept. Learners must be able to discuss what is happening in both of these cycles with regards to the development of the ova and the endometrium under hormonal control.

The hormones (follicle stimulating hormone, oestrogen, luteinising hormone and progesterone) are important not only in the development of the ova and endometrium but also with regards to their negative feedback mechanism.

Learners must be able to interpret and provide information as to what is happening in the graph provided in this section.

Activity 3: Hormones

Study the graphs below, then answer the questions that follow.



1. On which day did ovulation occur? (1)

   Day 14 (13 or 15 is accepted) ✓

2. Give one reason for your answer to question 1 that can be seen on the graph. (1)

   The level of oestrogen decreases sharply or the level of luteinising hormone increases ✓

3. Which structure in the ovary produces the following hormones?

   a) Oestrogen (1)

      Graafian follicle ✓

   b) Progesterone (1)

      corpus luteum ✓

4. Explain why there is a sharp increase in the production of …

   a) oestrogen from day 9 to 13. (2)

      The follicles have developed into the Graafian follicle secreting more oestrogen ✓ to make the endometrial wall thicker / more vascular

   b) luteinising hormone from day 13 to 14. (2)

      Increased levels of oestrogen stimulate the pituitary gland to release more LH ✓ so that ovulation can occur ✓

5. What conclusion can be drawn if the level of progesterone …

   a) Remains high from day 20 to 28? (1)

      pregnancy has resulted or the woman is pregnant ✓

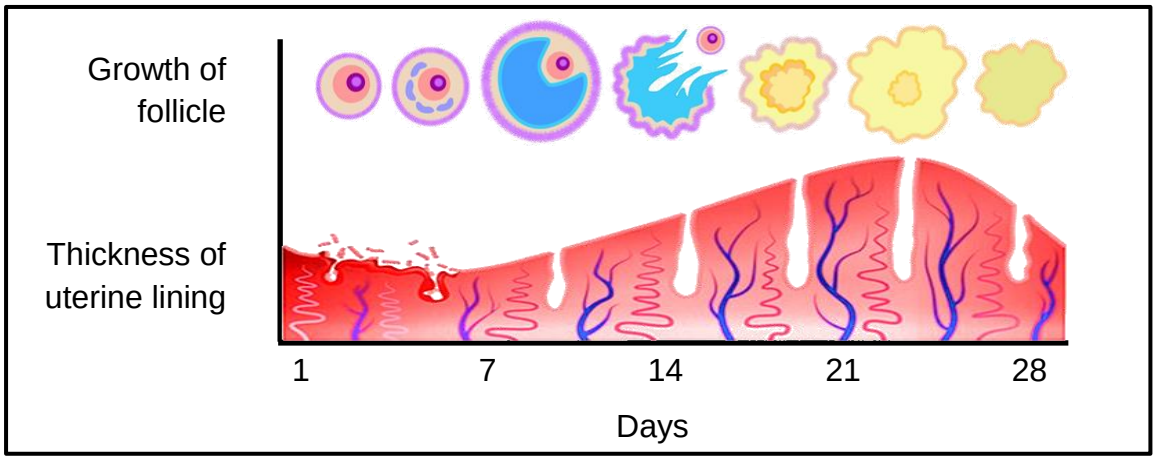
   b) Drops as shown in the graph above? (1)

      no pregnancy or leads to menstruation ✓

(10)

Activity 4: Menstrual cycle

The diagram shows some changes that may take place during the menstrual cycle.



1. The menstrual cycle is controlled by hormones. Name one hormone that will increase in level between days 2 and 10. (1)

   oestrogen / follicle stimulating hormone ✓

2. Give one observable reason for your answer to question 1. (2)

   the lining of the endometrium thickens during this period stimulated by the increased level of oestrogen OR the follicle develops during this period stimulated by increased levels of FSH (✓✓)

3. Explain what evidence there is in the diagram to indicate that no fertilisation took place? (3)

   corpus luteum has not disintegrated, it continues to secrete progesterone so the endometrial lining remains thickened (✓✓✓)

   (6)

Fertilisation & development of zygote to blastocyst

Learners must know how, where and when fertilization takes place. Learners are required to know the transformation of the zygote to becoming a blastocyst.

The concept of diploid and haploid should be revised with learners, and they should know that the chromosome number is returned to diploid from the fusion of the haploid gamete nuclei.

Implantation of the blastocyst and gestation

After implantation the blastocyst becomes known as the embryo and after 12 weeks of development it is then called the foetus.

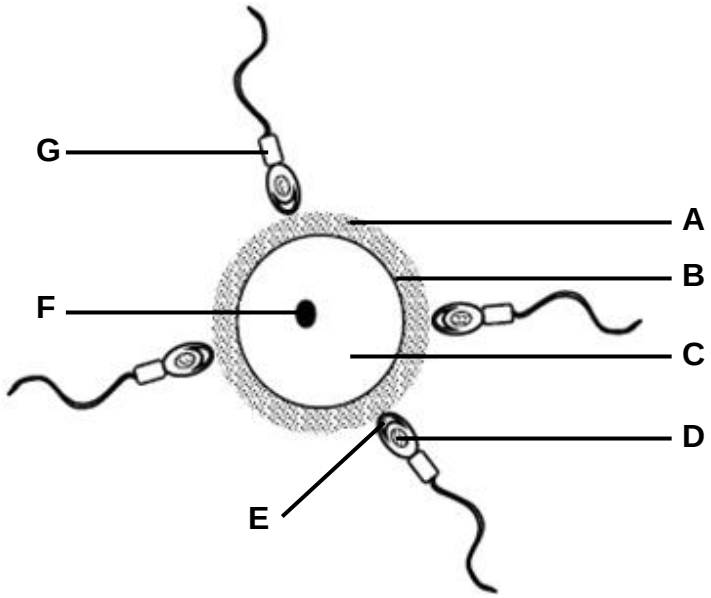
Learners must know the various extra-embryonic membranes involved in foetal development. The placenta is vitally important and learners should be able to provide its functions as well as the implications of the placenta not functioning correctly.

Learners should be able to identify the parts and structures involved during foetal development and be able to provide their functions. These can be seen on the diagram provided.

Learners only need to know what is meant by the term gestation, they are not required to know the week by week development of the foetus.

Activity 5: Fertilisation

The diagram below shows a human ovum about to be fertilised



1. Identify the parts labelled A – G. (7)

   A – jelly coating ✓, B – cell membrane ✓, C – cytoplasm ✓, D – head ✓, E – acrosome ✓, F – nucleus ✓, G – middle part (neck) ✓

2. Give the letter of the part that …

   a) contains the mitochondria. G ✓ (1)

   b) contains enzymes required to penetrate the ovum. E ✓ (1)

   c) will enter the ovum during fertilization. D ✓ (1)

3. Describe the developmental changes in the fertilised ovum until implantation occurs in the uterus. (5)

   The zygote undergoes mitosis ✓ until a ball of cells is formed called the morula ✓. The morula continues to divide and forms a mass of cells with a hollow cavity ✓ called a blastocyst ✓. The outer membrane of the blastocyst forms the chorionic villi which attaches it to the endometrium ✓

4. Define gestation. (1)

   Gestation is the period of development inside the uterus between fertilisation and birth ✓

(16)

Summary

- The male reproductive system consists of: the testes, seminiferous tubules, epididymis, vas deferens, urethra, prostate gland, Cowper's gland, seminal vesicles and the penis.

- The female reproductive system consists of: the ovaries, fallopian tubes, uterus, vagina and the vulva.
- Puberty is when sexual maturity occurs. There are many primary and secondary sexual characteristics that develop.
- Gametogenesis is the process by which gametes are formed. In males this is referred to as spermatogenesis and the process occurs in the testes to produce sperm cells. In females this is referred to as oogenesis and the process occurs in the ovaries to produce ova.
- In females, menstruation begins shortly after the onset of puberty.
- The menstrual cycle is composed of two separate cycles. The ovarian cycle describes the development of follicles within the ovary to produce ova. The uterine cycle describes the changes that take place in the endometrium of the uterus. These changes are controlled by four hormones which are follicle stimulating hormone, oestrogen, luteinizing hormone and progesterone.
- Progesterone and follicle stimulating hormone function together in a negative feedback mechanism to maintain optimal conditions within the uterus for implantation and pregnancy.
- During copulation sperm cells are released and swim towards the ovum so that fertilisation can occur. The nucleus of the sperm cell and ovum fuse to form a zygote.
- The zygote divides by mitosis forming a blastocyst which will implant itself in the endometrium. This process is known as implantation and the female is pregnant.
- Pregnancy otherwise known as gestation lasts for approximately 40 weeks.
- The important structures to ensure the development and survival of the foetus are: placenta, umbilical cord, chorion and amnion.

End of topic exercises

Section A
Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D.

1.1.1 The following statements describe the functions of the placenta:

i. Serves as an attachment of the embryo to the mother
ii. Allows for the diffusion of dissolved nutrients from the mother to the foetus.
iii. Allows for diffusion of excretory wastes from the mother to the foetus
iv. Allows for diffusion of oxygen from the mother to the foetus.

Which one of the following combinations correctly describe the functions of the placenta?

A (i), (ii), and (iii)
B (ii) only
C **(i), (ii) and (iv)** ✓✓
D (ii) and (iii)

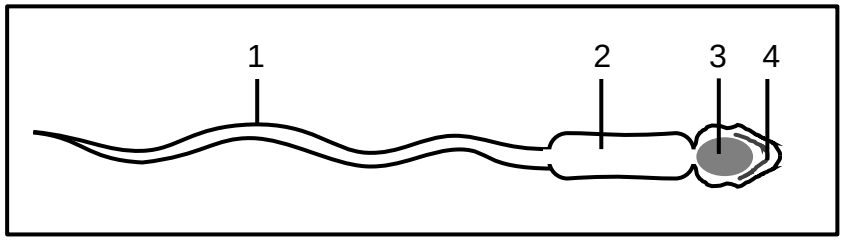
1.1.2 Contraceptive pills which prevent pregnancy are likely to contain…

A high levels of FSH and progesterone.
B high levels of LH and oestrogen.
C high levels of only FSH.
D **high levels of only progesterone**. ✓✓

1.1.3 Before copulation the male sperm is stored temporarily in the…

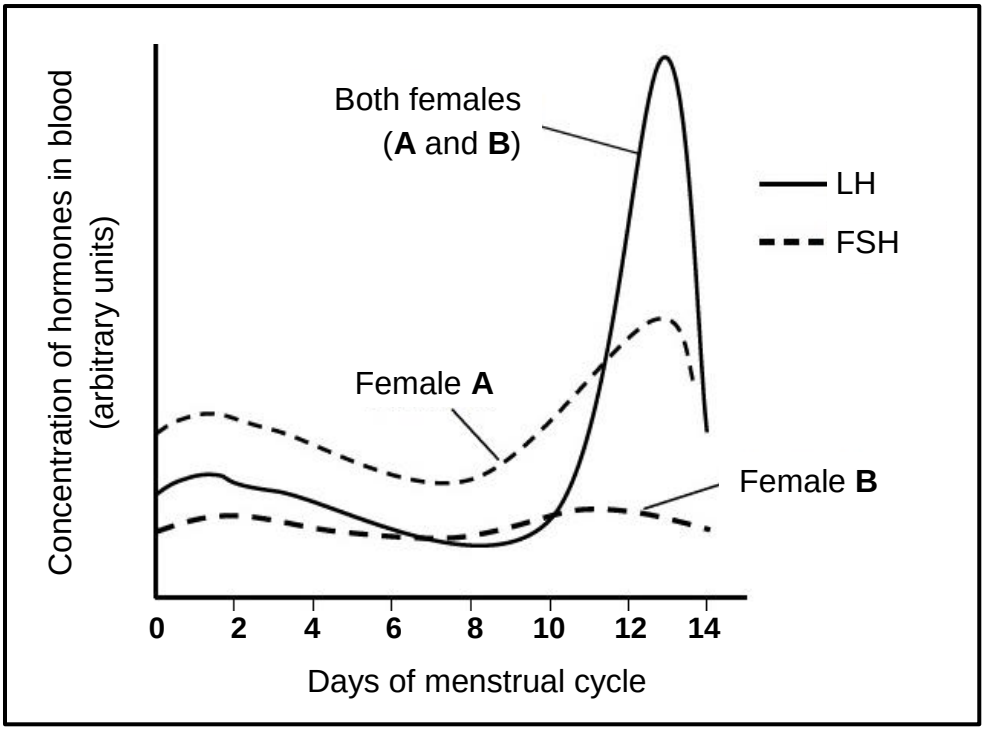
A seminal vesicles.
B scrotum.
C prostate gland.
D **epididymis**. ✓✓

1.1.4 Which one of the following parts in the diagram of a sperm cell contains a haploid number of chromosomes?



A 1 B 2 C **3** ✓✓ D 4

1.1.5 The graph shows the changes in concentration of female hormones FSH and LH in two females during the first two weeks of the menstrual cycle.



Which one of the following statements is **correct** regarding female **A**?

A FSH increases on day 14 because the Graafian follicle is secreting progesterone.

B FSH increased after day 9 as the pituitary gland is secreting progesterone.

C FSH decreased after day 4 to ensure implantation occurs.

D **FSH increases in the first two days to stimulate the development of the follicle**. ✓✓

(5 x 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The gland which produces a fluid to provide the sperm cells with energy.

Seminal vesicles ✓

1.2.2 The vesicle containing enzymes found in the head of a sperm cell.

Acrosome ✓

1.2.3 The process which produces ova.

Oogenesis ✓

1.2.4 The type of fertilisation in which the nucleus of a sperm fuses with the nucleus of an ovum inside the body of the female.

Internal ✓ fertilisation

1.2.5 A hormone that stimulates the development of the corpus luteum.

Luteinising hormone ✓ / LH

1.2.6 The fluid that protects the human embryo against injuries and large-scale temperature changes.

Amniotic ✓ fluid

1.2.7 The blood vessel in the umbilical cord that transports nutrients to the foetus.

Umbilical vein ✓

1.2.8 The inner lining of the uterus where implantation of the embryo occurs.

Endometrium ✓

1.2.9 A type of reproduction in humans where the foetus develops inside the uterus.

Vivipary ✓ / Viviparous

1.2.10 The stage in humans were sexual maturity is reached.

Puberty ✓

(10 x 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 Forms the placenta	A: chorionic villi B: endometrium

1.3.2 The production of ova by meiosis	A: menopause B: ovulation
1.3.3 A hollow ball of cells into which fertilised ovum develops	A: amnion B: chorion
1.3.4 The reproductive structures where meiosis occurs.	A: testes B: ovaries
1.3.5 Place where fertilisation occurs in humans	A: cervix B: fallopian tube

(5 x 2) = (10)

1.3.1 **Both A and B ✓✓**

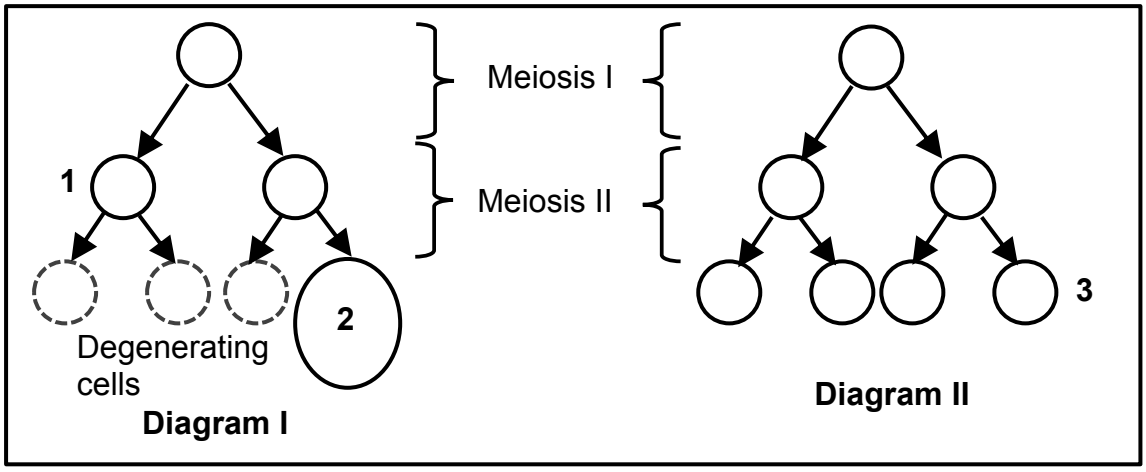
1.3.2 **None ✓✓**

1.3.3 **None**

1.3.4 **Both A and B ✓✓**

1.3.5 **B only ✓✓**

1.4 Diagrams I and II below (not to scale) represent gametogenesis in human males and females (not in any particular sequence).



1.4.1. Identify the specific type of gametogenesis in Diagram I. (1)

Oogenesis ✓

1.4.2. Explain your answer to question 1.4.1 by referring to a visible difference between Diagram I and Diagram II. (2)

- At the end of the process in Diagram I, one gamete forms ✓ / three cells degenerate

- At the end of the process in Diagram II, four gametes form ✓ / none of the cells degenerate

1.4.3. Where in the human body does the type of gametogenesis shown in Diagram II take place? (1)

Testes ✓ / Seminiferous tubules

1.4.4. Give the chromosome number of:

a) the cells at 1 (1)

23 ✓

b) cell 2 (1)

23 ✓

1.4.5. Name two processes that take place during Meiosis I that lead to genetic variation in the four cells at 3 in Diagram II. (2)

Crossing over ✓

Random arrangement of chromosomes ✓

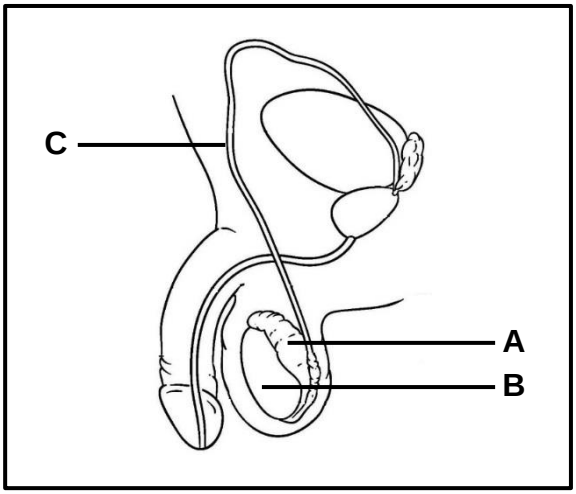
1.4.6. Explain the implication for the human population size if the three cells referred to in Diagram I did not degenerate, but remained as gametes. (2)

- This will result in multiple births ✓ / there will be an increased chance of fertilisation

- which will lead to an increased population ✓

(10)

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



1.5.1 Give labels for each of the following:

a) **A** Epididymis ✓ (1)

b) **B** Testis ✓ (1)

c) **C** Vas deferens ✓ / sperm duct (1)

1.5.2 State one function of part **A**. (1)

Store sperm cells temporarily ✓

1.5.3 What is the name of the structure in which part **B** is enclosed? (1)

Scrotum ✓

1.5.4 Explain the consequences for reproduction if part **C** is surgically cut. (3)

- Sperm cells will not pass to urethra ✓
- to fertilise the egg ✓
- and hence he will not be able to have children. ✓

1.5.5 Explain why it would still be possible for an HIV-positive man to infect another person during sexual intercourse after part **C** is surgically cut. (2)

The HI-virus may still be passed on ✓ during sexual intercourse through the secretions of the accessory glands ✓ (semen without sperm cells will be released during ejaculation)

(10)

Section A: [50]

Section B

Question 2

2.1 An investigation was carried out to determine the effects of smoking during pregnancy on the baby's birth weight. Babies born weighing 2 499 g or less have a low birth weight.

The table below compares the percentage of babies with a low birth weight born to mothers who smoked with mothers who did not smoke in a certain city in 2009.

Birth weight (grams)	**Percentage of total births in 2009**	
	Mothers who smoked	**Non-smoking mothers**
< 1000	0,7	0,2
1000 – 1499	0,9	0,3
1500 – 1999	2,2	1,1
2000 – 2499	7,1	3,2

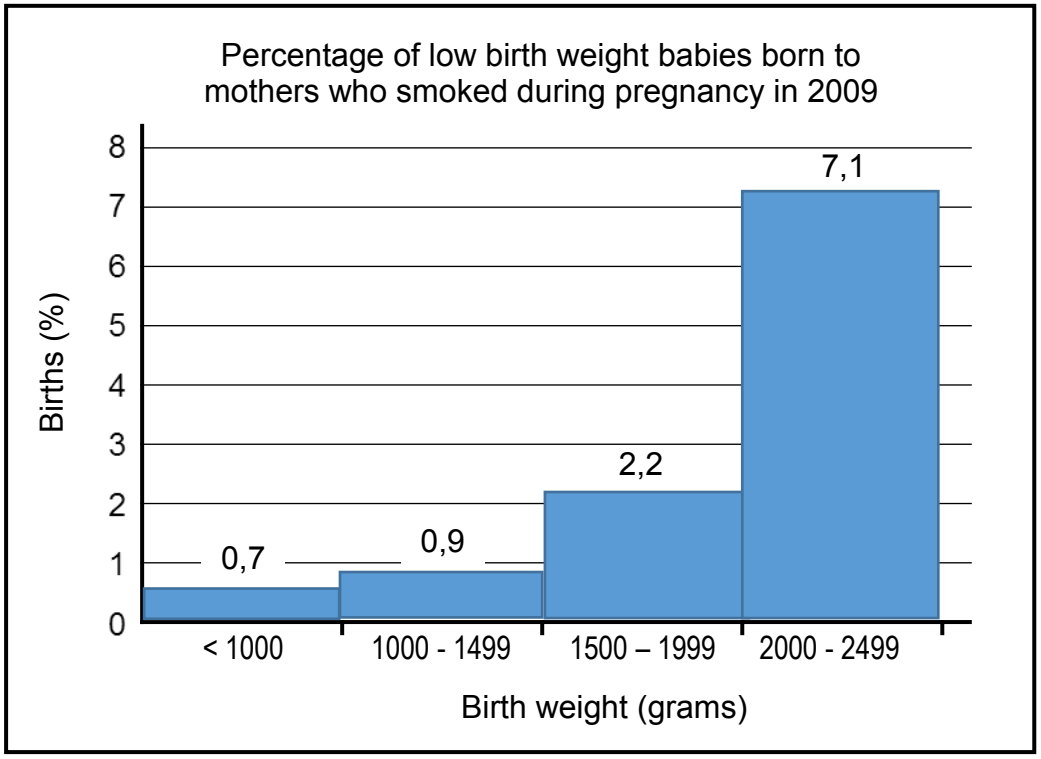
(adapted from www.ainw.gov.au)

2.1.1 Draw a histogram to represent the percentage of births in each weight group born to mothers who smoked. (6)

Guidelines for marking graph

Criteria	Mark allocation
Histogram drawn	✓
Title of graph (with both variables)	✓

Correct label for X- and Y-axes	✓
Correct scale and width of bars	✓
Plotting	✓: 1 to 3 bars drawn correctly ✓✓: All 4 bars drawn correctly



2.1.2 Why were babies that weighed more than 2 500 g at birth not included in the investigation? (1)

Babies that weigh 2500 g or more are considered to be of a normal / healthy birth weight ✓

2.1.3 State a general conclusion for the investigation based on the data in the table. (2)

The total percentage of low birth weight babies born to mothers who smoked was higher than those born to mothers who did not smoke ✓✓

OR

The total percentage of low birth weight babies born to mothers who did not smoke was lower than those born to mothers who smoked ✓✓

2.1.4 Describe how chemicals from cigarette smoke are able to reach the baby's blood from the mother's blood. (2)

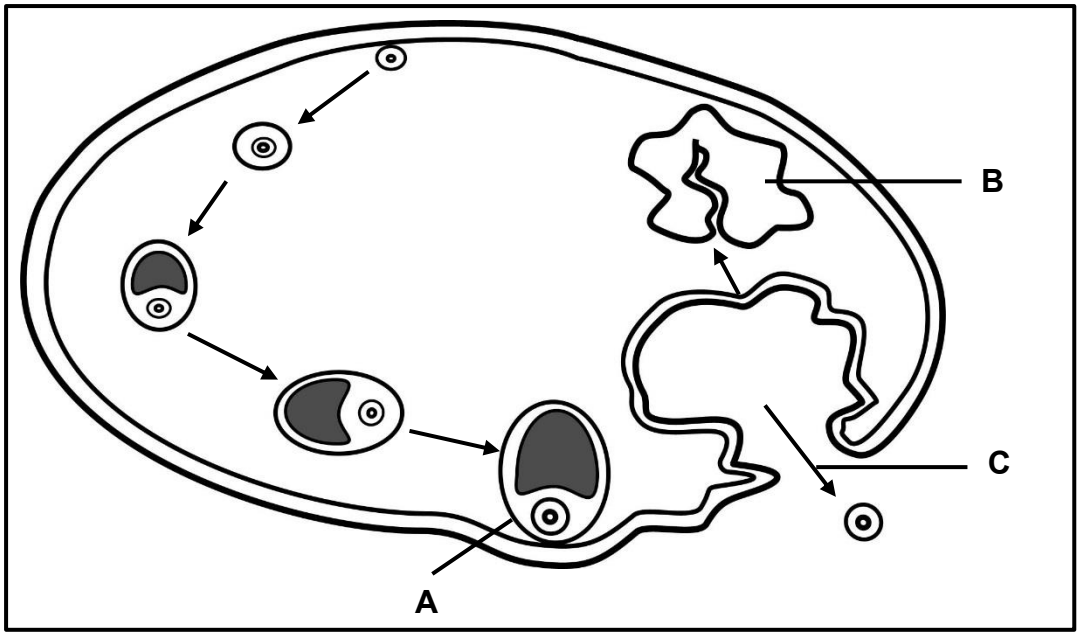
Chemicals are dissolved in the mother's blood ✓

are able to move across the placenta ✓ / and through the umbilical cord into the babies blood

by diffusion ✓ (any two × 1)

(11)

2.2. The diagram below represents the sequence of events that takes place during the ovarian cycle of a female.



2.2.1 Give the name of the:

a) Hormone that controls the development of structure **A**. (1)

FSH ✓ / Follicle stimulating hormone

b) Process taking place at **C**. (1)

Ovulation ✓

2.2.2 Structure B degenerates if fertilisation does not take place. Explain the implications of this for the …

a) ovarian cycle (2)

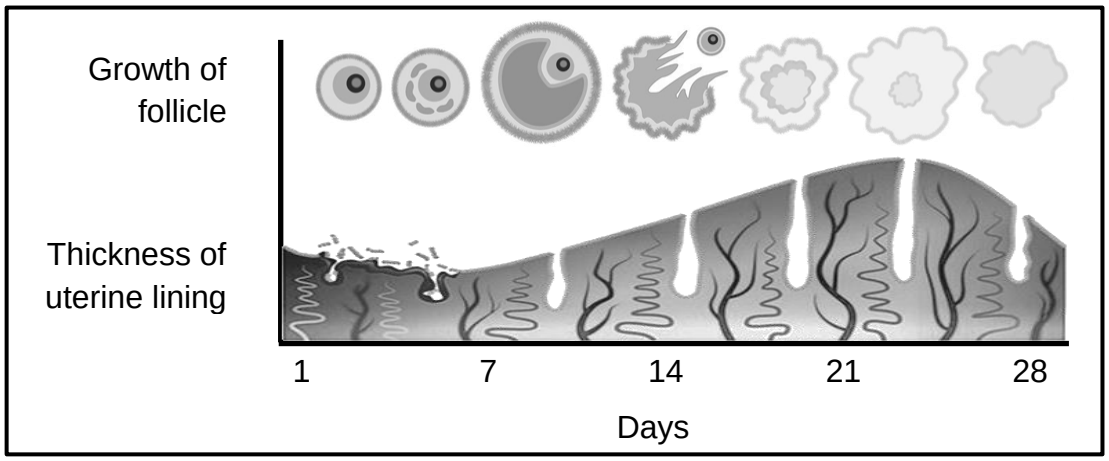
- The levels of progesterone drop ✓
- therefore, FSH secretion is no longer inhibited ✓ / FSH secretion is resumed
- and a new follicle starts to develop. ✓ (Mark any two)

b) uterine cycle (2)

- The levels of progesterone drop ✓
- therefore, the endometrium is no longer maintained ✓
- and menstruation takes place. ✓ (Mark any two)

(6)

2.3. The diagram shows some changes during the menstrual cycle.



2.3.1 Describe the developmental changes in the fertilised ovum until implantation occurs in the uterus. (4)

- The zygote ✓
- undergoes mitosis ✓
- until a ball of cells in formed ✓
- called a morula. ✓
- The morula continues to divide and forms a mass of cells with a hollow cavity ✓
- called a blastocyst ✓
- the outer membrane of the blastocyst forms chorionic villi / attachment villi ✓
- which attaches to the endometrium ✓ (Any four × 1)

2.3.2 Some females use an ovulation monitor so that they can be aware of the days when they are fertile. These monitors measure the level of hormones in the blood.

a) Why would females want to know when they are fertile? (1)

For family planning ✓ / to know when they can get pregnant

b) Explain which hormone is likely to be monitored by the ovulation monitor. (3)

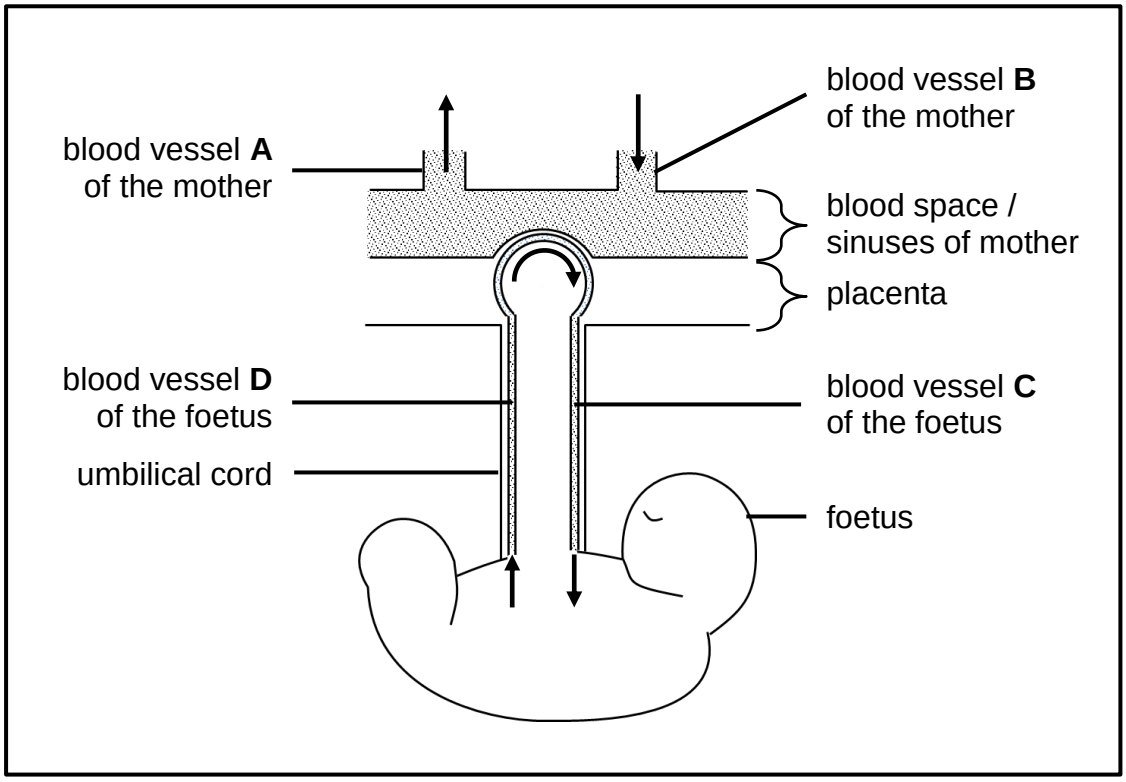
- LH ✓ / FSH / oestrogen
- There is a rise in levels ✓ of LH / FSH / oestrogen around the time of ovulation ✓

(8)

[25]

Question 3

3.1 The diagram below represents the relationship between the blood system of the foetus and that of the mother. The arrows indicate the direction of blood flow in the blood vessels.



3.1.1 Apart from playing a role in the diffusion of substances from the mother's blood to the foetus' blood, and vice versa, state two other functions of the placenta. (2)

- It acts as a micro-filter ✓ / prevents harmful substances from reaching the foetus.
- It secretes progesterone ✓ / oestrogen during pregnancy
- Immunity is transferred from mother to foetus ✓ (Any 2)

3.1.2 Blood vessel **D** is an artery. Tabulate two differences between the composition of the blood found in blood vessel **C** and blood found in blood vessel **D**. (5)

Blood vessel C	Blood vessel D
High concentration of nutrients ✓ / example of nutrient	Low concentration of nutrients ✓ / example of nutrient
Low concentration of waste products ✓ / example of waste product	High concentration of waste products ✓ / example of waste product
High concentration of oxygen ✓	Low concentration of oxygen ✓

Low concentration of carbon dioxide✓	High concentration of carbon dioxide ✓

(Mark first two only)

Table: (1) and (Any two × 2)

3.1.3 Explain one consequence for the foetus if blood vessel **D** becomes blocked preventing blood flow. (2)

- Waste products / nitrogenous waste / CO_2 will accumulate ✓ in the foetus' body
- causing the death of the foetus ✓

3.1.4 If the blood of the mother and the blood of the foetus come into contact with each other, it could lead to the death of the foetus. Describe why this would occur. (2)

- Harmful substances ✓ / bacteria
- May pass from mother's blood to the blood of the foetus ✓

OR

- The blood types ✓ / other proteins of the mother and baby may not be compatible (any two)

(11)

3.2 Read the following extract and answer the questions that follow.

> Several recent studies have suggested a gradual decline in sperm production in men. Endocrine disruptions as well as life style have been suggested as risk factors. One life style factor that may affect human fertility is driving a vehicle for a prolonged period. It is suggested that the driving position may increase the scrotal temperature.

3.2.1 State any one risk factor identified by the researchers. (1)

- The endocrine disrupter ✓ / malfunctioning of endocrine glands
- Life style ✓ / life style variations / driving a vehicle for a prolonged period of time (any one × 1)

3.2.2 Explain why regular long-distance driving with no breaks could possibly lower the sperm count in healthy males. (3)

- Long distance drive extends the period sitting in a fixed position causing male reproductive organ to remain tightly squeezed between the thighs for a considerable period of time ✓
- As the temperature rises ✓ in the area, the scrotum is unable to pull the testis away from the body due to lack of spacing,
- Hence, the testes remain in contact with the body and maintain a higher temperature causing a disruption in spermatogenesis. ✓

3.2.3 Suggest a consequence of lower sperm count in males. (2)

The low sperm count reduces the chances of fertilization ✓ and may lead to male infertility. ✓

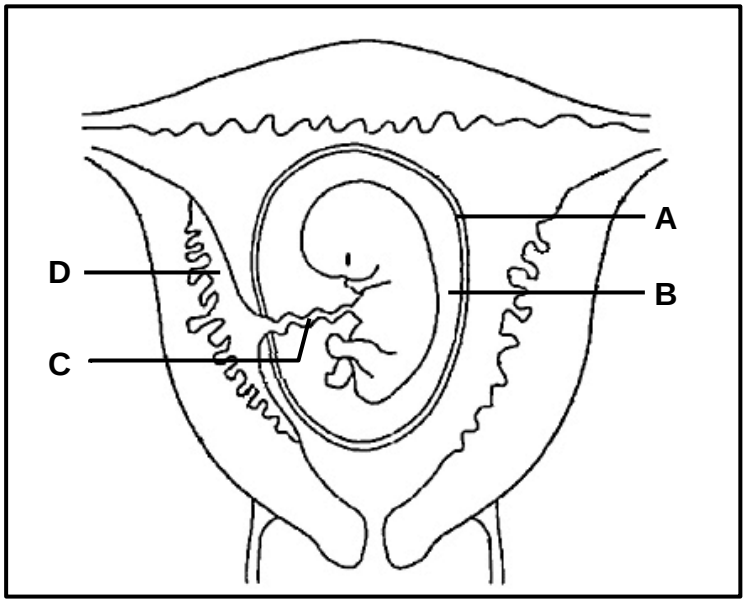
3.2.4 State any one daily life style trend or routine (other than the one mentioned in the extract) that should be avoided to maintain the optimum scrotal temperature. (1)

- Use of tight underwear ✓
- Sitting in a hot water tub for a long time as daily routine. ✓

(Any one × 1)

(7)

3.3 The diagram below represents a developing foetus in a human body.



3.3.1 Identify:

a) **A** Chorion ✓ / Amnion (1)

b) **C** Umbilical cord ✓ (1)

3.3.2 State two functions of the fluid **B**. (2)

- Protects the foetus from shock ✓ / Acts as a shock absorber
- Protects the foetus from drying out ✓
- Protects the foetus from temperature changes ✓
- Allows free movement of the foetus ✓

(Mark first two only; any 2 × 1)

3.3.3 Name one system in the baby's body that takes over the function of part **D** once the baby is born. (1)

- Gaseous exchange system ✓

- Excretory system ✓
- Digestive system ✓

Mark first one only; any one × 1)

3.3.4 Explain one negative impact on the foetal development if part **D** is reduced significantly. (2)

- The foetus will receive less nutrients ✓
- and therefore, have a lower birth mass ✓ / physical under-development / mental under-development

OR

- The foetus will receive less oxygen ✓
- and therefore, have a lower birth mass ✓ / physical under-development / mental under-development

OR

- Waste will accumulate ✓
- And it will affect the functioning of the foetus ✓

(Mark first one only; any one × 2)

(7)

[25]

Section B: [50]

Total marks: [100]

Cognitive levels distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1				✓	2
1.1.2		✓			2
1.1.3	✓				2
1.1.4	✓				2
1.1.5				✓	2
	4	2		4	10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	10				10
1.3.1	✓				2
1.3.2	✓				2
1.3.3	✓				2
1.3.4	✓				2
1.3.5	✓				2
	10				10
1.4.1	✓				1
1.4.2		✓			2
1.4.3		✓			1
1.4.4 a - b			✓		2 (1+1)
1.4.5				✓	2
1.4.6				✓	2
	1	3	3	4	10
1.5.1 a - c	✓				3 (1+1+1)
1.5.2	✓				1
1.5.3	✓				1
1.5.4		✓			3
1.5.5		✓			2

	5	5			10
2.1.1		✓	✓	✓	6 (2+2+2)
2.1.2			✓		1
2.1.3			✓		2
2.1.4			✓		2
		2	7	2	3
2.2.1 a - b		✓			2 (1+1)
2.2.2 a - b				✓	4 (2+2)
		2		4	6
2.3.1	✓				4
2.3.2 a - b		✓			4 (1+3)
	4	4			8
3.1.1	✓				2
3.1.2		✓	✓		5 (4+1)
3.1.3				✓	2
3.1.4		✓			2
	2	6	1	2	11
3.2.1		✓			1
3.2.2		✓			3
3.2.3				✓	2
3.2.4	✓				1
	1	4		2	7
3.3.1	✓				2
3.3.2	✓				2
3.3.3	✓				1
3.3.4				✓	2
	5			2	7
	42	28	11	20	100

CHAPTER 5: GENETICS AND INHERITANCE

Overview

Time allocation: 4 weeks (16 hours)

This chapter consists of the following sections:

1. Introduction
2. Key concepts
3. Concepts in inheritance
4. Mendel as father of genetics
5. Genetic diagrams
6. Genetic lineage (pedigree diagrams)
7. Mutations
8. Biotechnology
9. Summary
10. End of topic exercises

Introduction

This chapter will build on what was covered in the sections on DNA, protein synthesis, meiosis and sexual reproduction to help the learner understand how characteristics are passed down from one generation to the next. Genetics is the study of heredity – how characteristics are passed on from parents to child. Every individual inherits a set of genes from a father and a mother which is unique to that individual, but similar enough to identify the individual's species.

Key terminology

hereditary	passing of hereditary characteristics from parent to offspring
filial generation (F_1)	offspring of parent organisms
locus	the exact position (location) of a gene on a chromosome
genetic engineering	techniques used to change the genetic material of a cell or living organism – a form of biotechnology

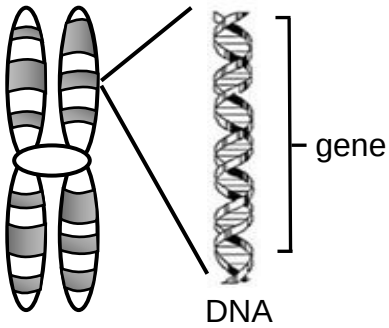
Key concepts

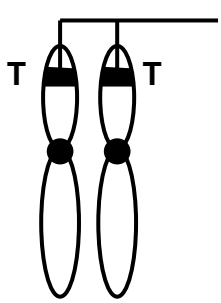
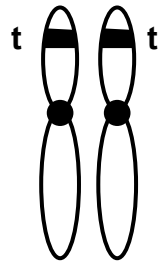
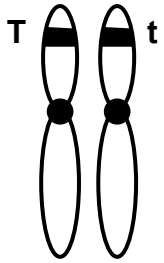
- Terminology in inheritance
- Gregor Mendel is the ‘Father of Genetics’
- Monohybrid crosses: a genetic cross involving one characteristic controlled by a pair of alleles
- Sex determination: sperm has either an X or a Y gonosome so the sex of the offspring depends on which sperm gets to the egg first.
- Sex-linked inheritance: examples of genetic diseases carried on the sex chromosomes.
- Blood grouping and paternity testing: an explanation of the four blood groups in man and how blood groups can be used as a way to see if the man could be the father of a particular baby.
- Genetic lineage/pedigrees: how to use pedigree diagrams to trace ancestry.
- Dihybrid crosses: a genetic cross involving two different characteristics.
- Mutations: how changes to the DNA/chromosomes in a sex cell affects the offspring produced after fertilisation.
- Genetic engineering: how knowledge of DNA has led to biotechnology to help humans in various ways.
- Genetic links in evolution: specifically how mitochondrial DNA has been used to trace human evolution.

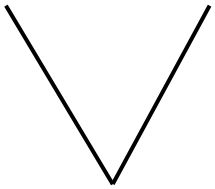
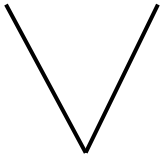
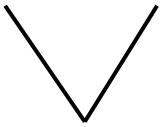
Concepts in Inheritance

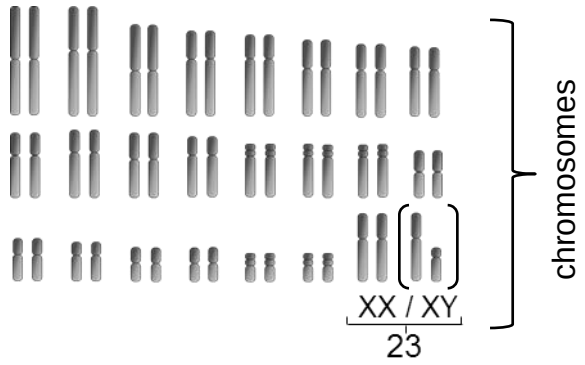
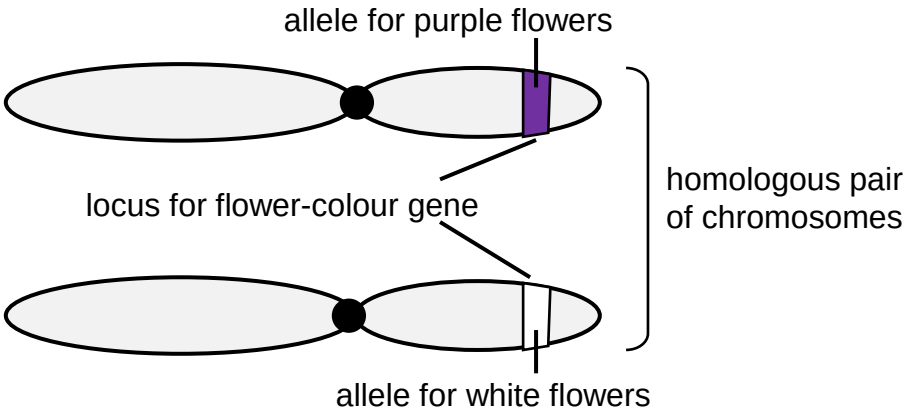
Table 1 below provides further definitions and explanations of key terms that you must know very well.

Table 1: Terms, their explanation and supporting diagrams and notes.

gene	a segment of DNA in a chromosome that contains the code for a particular characteristic	

alleles	different forms of a gene which occur at the same locus on homologous chromosomes	dominant allele (T) – tall plant recessive allele (t) – short plant
genotype	genetic composition of an organism	 • homozygous dominant (both alleles are dominant) • genotype TT • phenotype – tall  • homozygous recessive (both alleles are recessive) • genotype tt • phenotype – short  • heterozygous (one dominant and one recessive allele) • genotype Tt • phenotype - tall
phenotype	the physical appearance of an organism based on the genotype, e.g. tall, short	
dominant allele	an allele that is expressed (shown) in the phenotype when found in the heterozygous (Tt) and homozygous (TT) condition	
recessive allele	an allele that is masked (not shown) in the phenotype when found in the heterozygous (Tt) condition; only expressed in the homozygous (tt) condition	
heterozygous	two different alleles for a particular characteristic, e.g. Tt	
homozygous	two identical alleles for a particular characteristic, e.g. TT or tt	
monohybrid cross	only one characteristic or trait is shown in the genetic cross	Flower colour only, e.g. yellow or white flower – **OR** – shape of seeds only, e.g. round seeds or wrinkled seeds
dihybrid cross	two different characteristics shown in genetic cross	Example: flower colour, e.g. yellow or white flower – AND – shape of seeds, e.g. round seeds or wrinkled seeds

complete dominance	a genetic cross where the dominant allele masks the expression of a recessive allele in the heterozygous condition	- the allele for tall (T) is dominant over the allele for short (t) - offspring will be **tall** because the dominant allele (T) masks the expression of the recessive allele (t)	Tall (TT) x short (tt)  Tall (Tt)
incomplete dominance	cross between two phenotypically different parents produces offspring different from both parents but with an intermediate phenotype	a red-flowered plant is crossed with a white-flowered plant – with incomplete dominance, offspring will have **pink flowers - intermediate colour.**	red × white flower  pink flowers
co-dominance	cross in which both alleles are expressed equally in the phenotype.	red-flowered plant is crossed with a white-flowered plant – with co-dominance, the offspring has flowers with red and white patches	red × white flower  flowers with red and white patches
multiple alleles	more than two alternative forms of a gene at the same locus	blood groups are controlled by three alleles, namely I^A, I^B and i. all three alleles are present in a population, but an individual can only have two alleles	
sex-linked characteristics	traits that are carried in the sex chromosomes	Some examples: haemophilia and colour-blindness - alleles for haemophilia (or colour-blindness) are indicated as superscripts on the sex chromosomes, e.g. X^HX^H (normal female), X^HX^h (normal female), X^hX^h (female with haemophilia), X^HY (normal male), X^hY (male with haemophilia). Both haemophilia and colour blindness are caused by recessive alleles.	

karyotype	the number, shape and arrangement of the chromosomes in the nucleus of a somatic cell	
cloning	process by which genetically identical organisms are formed using biotechnology	Dolly the sheep was cloned using a diploid cell from one parent; therefore, it had the identical genetic material of that parent
genetic modification	manipulation of the genetic material of an organism to get desired changes	An example*:* insertion of the human insulin gene into the plasmid of bacteria so that the bacteria produce human insulin
human genome	mapping of the exact position of all the genes in all the chromosomes of a human	Example: haemophilia is the last gene on the X chromosome; gene number 3 on chromosome 4 is responsible for a particular characteristic
homologous pair of chromosomes	a set of one maternal and one paternal chromosome that pair up with each other inside a cell during meiosis – homologous chromosomes are the same size and shape, and carry the same or similar alleles	

Activity 1: Traits, genes and alleles

1. The paired letters in the diagram below represent alleles of a gene. A number of genes for different characteristics are shown. Write down the relevant letter (A – D) for:

a) The homozygous dominant state

B ✓

b) Two alleles from different genes

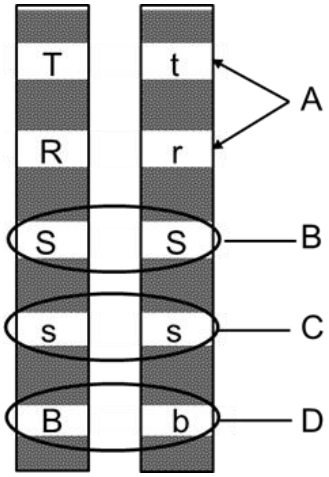
A ✓

c) The homozygous recessive state

C ✓

d) The heterozygous state

D and A ✓



(4)

2. What is the relationship between a gene and a protein? (2)

Genes code for proteins ✓✓

3. What is an allele? (2)

Any of the alternative forms of a gene ✓ that may occur at a specific locus ✓

4. What terms describe a pair of alleles that are:

a) the same? homozygous ✓

b) different? heterozygous ✓ (2)

5. Write a definition of homologous chromosomes using the terms “genes” and “alleles”. (3)

Homologous chromosomes are two chromosomes ✓, one from the mother and one from the father ✓, that have the same length, overall appearance, and genes, although the alleles may differ ✓

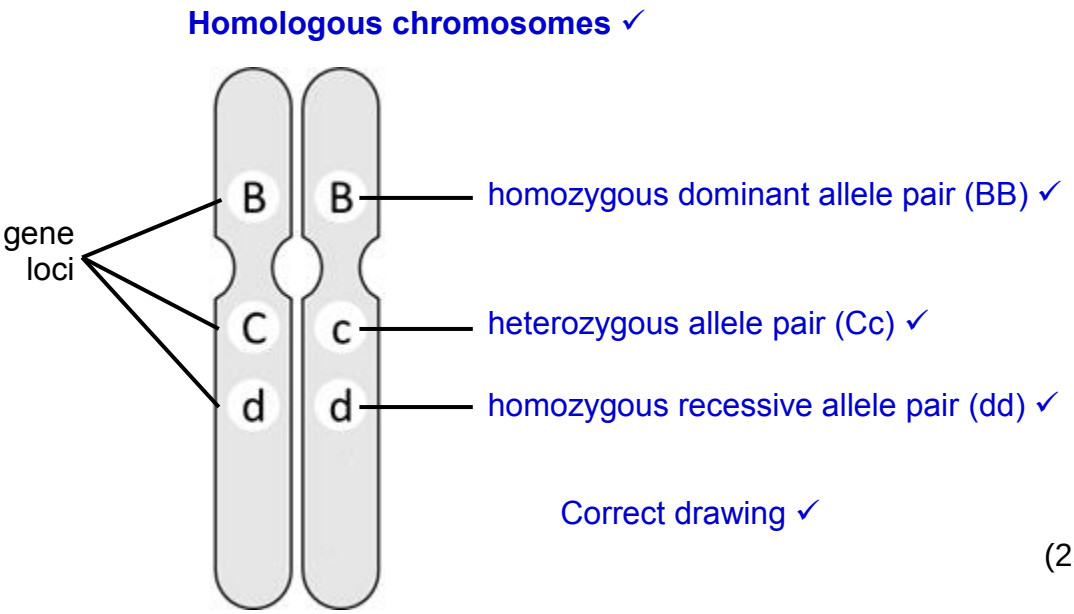
6. How are alleles represented on paper? (1)

As letters ✓, uppercase for dominant and lowercase for recessive

7. Fill in the table below with the missing genotype, phenotype (dominant or recessive), or alleles (TT, Tt, tt) (6)

Genotype	Phenotype	Alleles
homozygous dominant	Tall ✓	T / T ✓
homozygous recessive ✓	short	t / t
heterozygous ✓	Tall ✓	T / t ✓

8. Draw a pair of homologous chromosomes. Label the chromosomes with two sets of genes, one with homozygous dominant alleles, one with homozygous recessive alleles and one with heterozygous alleles. (5)



(25)

Mendel as father of genetics

Gregor Mendel, an Austrian monk (a type of priest), is regarded as the father of genetics for his work on garden pea plants that helped explain **how genes are passed from parents to offspring.**

Mendel's work on the genetics of peas began with the observing peas to determine what traits were inherited. He noticed at least 7 traits that appeared to be inherited.

Mendel's Laws of Inheritance

Mendel formulated the following laws from his experiments.

Mendel's First Law of Inheritance: Law (principle) of Segregation

- Each trait is controlled by two factors (now known as alleles) situated on homologous chromosomes.
- When gametes form during meiosis, the two factors (alleles) are separated or segregated. A gamete contains one of the two factors (alleles) from each parent.

Mendel's Second Law of Inheritance: Law of Dominance

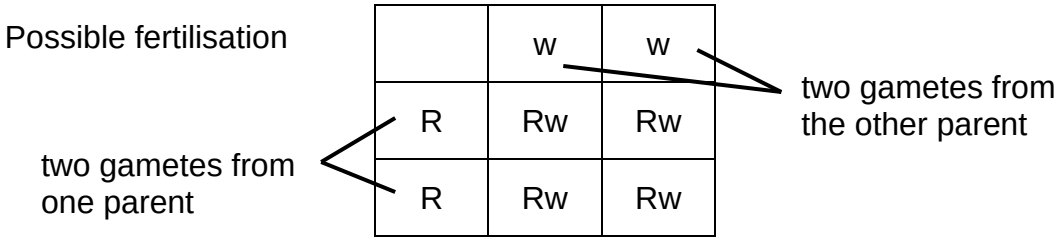
- Certain alleles of a gene exist in either a dominant or a recessive form.
- If the pair of alleles are different (one dominant, one recessive), the phenotype will only show the dominant trait.

Mendel's Third Law of Inheritance: Law (principle) of Independent Assortment

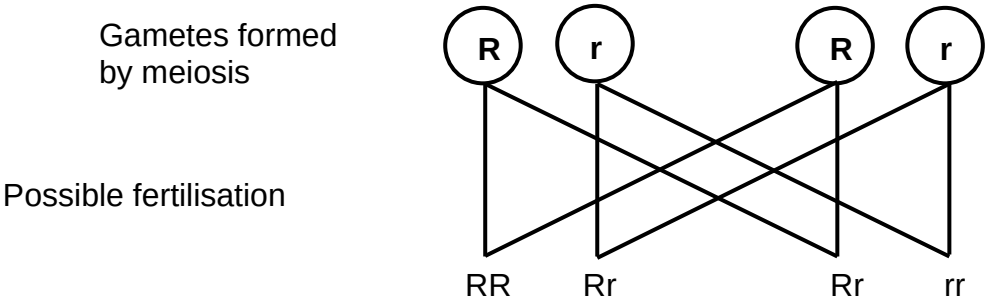
- Due to random arrangement of chromosomes at the equator during meiosis (gamete formation), any one of the two alleles of ONE characteristic can sort with any one of ANOTHER characteristic.
- The alleles of different genes move independently of each other into the gametes. They can therefore appear in the gametes in different combinations.

Genetic diagrams

The next step is to discuss how the gametes COULD combine during fertilisation. The Punnett square is the easiest way to work this out.



Using lines from the male and female gamete shows the process more clearly but once all four possibilities are drawn in, the learners are confused.



Writing each gamete onto individual pieces of paper, putting them into separate 'male' and 'female' bags, and then taking out a male gamete and a female gamete to represent fertilisation works well. This also shows the learners that CHANCE is a large contributing factor.

It is ESSENTIAL that the layout of the **genetic diagram** is followed exactly as marks are allocated for the specific steps.

Learners tend to forget to put in the labels for P_1 and F_1 generations, so they need constant reminders. Try to impress on them that P (Parental) is the PARENT generation and that F (Filial) stands for FAMILY. This could help them to remember the abbreviations.

If you make the learners learn the layout off by heart, it will help them to answer the genetic questions. By linking meiosis to gamete formation and fertilisation (sexual reproduction) to the possible crosses, it should enable the learners to make sense of the whole process.

Dominance

When you teach dominance, it is advisable to link it to the letters that are used in the genetic cross so that the dominant allele is visible as a CAPITAL letter and the recessive allele as a small letter. This means that capital letters are used in complete dominance (ONE capital), incomplete dominance (BOTH capitals) and co-dominance (BOTH capitals).

For co-dominance in blood types, the ONLY acceptable letters are I^A, I^B and i. Older textbooks do not use these symbols so be careful when using such textbooks.

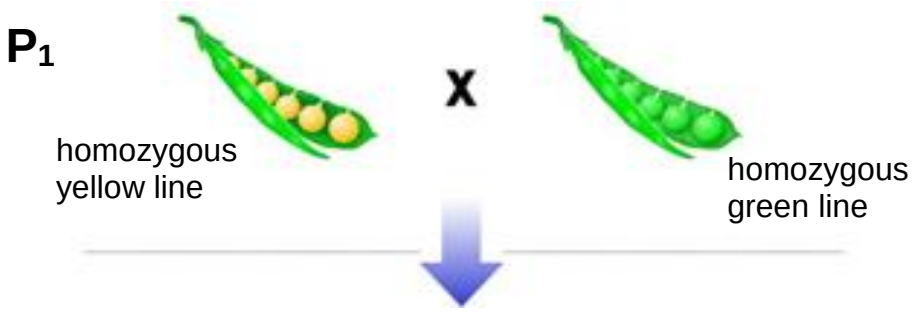
It is important to explain that in:

- **Complete dominance** the dominant allele will always be seen in the phenotype even if only one dominant allele is present e.g. in Tt is tall.
- **Incomplete dominance** there is always a blending of the two alleles in the phenotype to produce a NEW phenotype e.g. RW is pink.
- **Co-dominance** BOTH alleles can be seen in the phenotype of the offspring e.g. red and white spotted cattle or roan horses which have both white and red hairs in the coat resulting in a chestnut colour.

Activity 2: Monohybrid crosses with complete dominance

1. Mendel crossed homozygous plants with green seeds with homozygous plants which had yellow seeds and found that all the offspring were yellow (Figure 1). Construct a genetic diagram (using the above template) to show the **F_1** and **F_2** generations.

   Choose a letter for each allele. Note: use one letter: capitalised for the dominant allele and small (lower-case) for the recessive allele. (6 + 6)



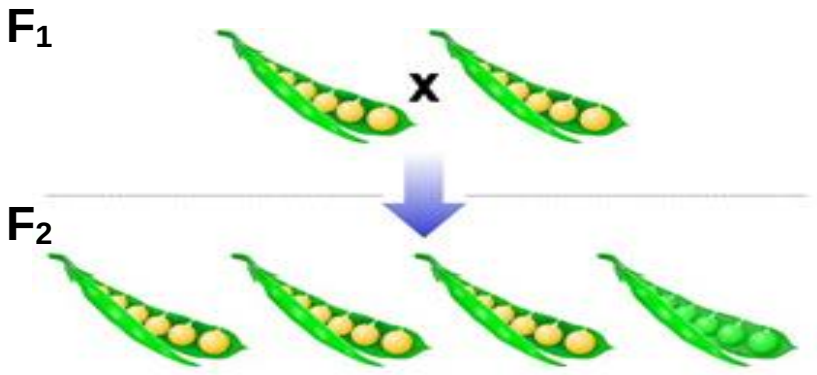


Figure 1: Monohybrid cross showing inheritance of seed colour

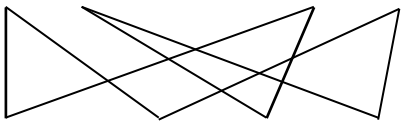
P_1 Phenotype Yellow seeds x Green seeds ✓

Genotype YY x yy ✓

Meiosis

G/gametes Y Y x y y ✓

Fertilisation



F_1 Genotype Yy Yy Yy Yy ✓

Phenotype All (100%) Yellow seeds ✓

P_1 and F_1 ✓ Meiosis and Fertilisation ✓ (any 6)

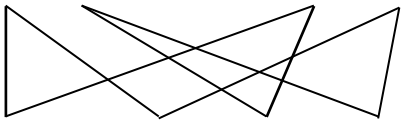
P_2/F_1 Phenotype Yellow seeds x Yellow seeds ✓

Genotype Yy x Yy ✓

Meiosis

G/gametes Y y x Y y ✓

Fertilisation



F_1 Genotype YY Yy Yy yy ✓

Phenotype Yellow seeds Yellow seeds Yellow seeds Green seeds ✓

Genotypic Ratio: 1YY : 2Yy : 1yy (1:2:1)

Phenotypic Ratio: 3 Yellow seeds : 1 Green seeds (3:1)

P_1 and F_1 ✓ Meiosis and Fertilisation ✓ (any 6)

2. The ability to roll one's tongue (Figures 2 and 3 below) is a dominant characteristic. Explain (without a genetic diagram) why it is possible for a non-roller child to be born to parents who can both roll their tongues. Use the letters **R** and **r** in your answer. (3)

Figure 2: Tongue-roller

Figure 3: Non-roller

Tongue rolling is dominant, and both parents were heterozygous (**Rr**) (✓). If both parents have the recessive gene for non-rolling tongue and the child received both the recessive alleles (✓) one from father's recessive (r) and one from mother (r) then it creates a strong gene for non-rolling tongue (**rr**). (✓)

(15)

Activity 3: Monohybrid cross with incomplete dominance

1. Two grey mice were mated. Some of the offspring were grey, others black and some white. How is this possible? Do a genetic cross to explain this result. (6)

P_1	Phenotype	Grey	x	Grey ✓
	Genotype	BW	x	BW ✓
Meiosis				
	Gametes	B W	x	B W

Fertilisation

Gametes	B	W
B	BB	BW
W	BW	WW

1 mark for gametes ✓

F_1	Genotype	BB	BW	BW	WW ✓
	Phenotype	Black	Grey	Grey	White ✓

Genotypic Ratio: 1BB: 2BW: 1WW (1:2:1)

P_1 and F_1 ✓ Meiosis and Fertilisation ✓ (any 6)

2. Incomplete dominance is seen in the inheritance of hypercholesterolemia (high blood cholesterol levels). **H** represents the allele for very high levels and **L** for low levels.

2.1 Sipho and Andiswa are both heterozygous for this characteristic and both have high cholesterol levels but not as high as their daughter Sihle who has levels that are six times above normal. She is homozygous for high cholesterol levels. Do a full genetic diagram to explain your answer. (7)

P_1 Phenotype: Sipho high cholesterol levels x Andiswa high cholesterol levels ✓

Genotype: HL x HL ✓

Meiosis

G/gametes: H L x H L

Fertilisation

Gametes	H	L
H	HH	HL
L	HL	LL

✓ - for gametes

F_1 Genotype: HH HL HL LL ✓

Phenotype: Very High, High, High, Low ✓

(Cholesterol levels)

50% ✓ * of their children will have high but not extreme cholesterol levels

P_1 and F_1 ✓ Meiosis and Fertilisation ✓ (*1 compulsory + any 6)

2.2 What is the percentage chance that their next child will have …

a) low cholesterol levels? 25% ✓ (1)

b) extremely high cholesterol levels like Sihle? 25% ✓ (1)

(15)

Sex determination and sex-linked diseases

Here you need to start by revising what a karyotype is (full set of chromosomes) and that it is made up of 44 autosomes (which control the body structure and functioning) and two gonosomes (which determine the sex).

Then explain that the X chromosome is much larger than the Y chromosome so even though these two chromosomes are regarded as homologous, not all of the alleles on the X have corresponding alleles on the Y because it is too small.

The sex-linked diseases that the learners are required to know are all caused by RECESSIVE alleles. To answer the questions on these diseases, the learner must first do a monohybrid cross using XX and XY and then add in the alleles for the disease e.g. X^hY.

The most common errors the learners make in these questions are:

- not knowing which diseases are sex-linked
- putting an allele onto the Y chromosome

Activity 4: Sex-linked diseases

1. Haemophilia is a sex-linked disease caused by the presence of a recessive allele (**X^h**).
   A normal father and heterozygous mother have children. Construct a genetic cross to determine the possible genotype and phenotype of the children of the parents. (6)

P_1 Phenotype: Normal father x Normal mother ✓

Genotype X^HY x X^HX^h ✓

Meiosis

Gametes	X^H	Y
X^H	X^HX^H	X^HY
X^h	X^HX^h	X^hY

1 mark for correct gametes

Fertilisation

F_1 Genotype X^HX^H ; X^HX^h ; X^HY ; X^hY ✓

Phenotype

50% Normal female; 25% Normal male ; 25% Affected male ✓

P_1 and F_1 ✓

Meiosis and Fertilisation ✓ (any 6)

2. Explain why the chances of men having a sex-linked disorder is much higher than it is for women. (4)

The allele for the trait is carried on the X-chromosome ✓. The Y-chromosome does not carry the allele for the trait ✓. Males only have one X-chromosome ✓. A male only needs one recessive allele ✓ to be affected, whereas for a female to be affected both alleles must be recessive ✓. (any 4)

3. Read the following extract on cystic fibrosis and answer the questions that follow.

Cystic Fibrosis (CF)

CF is a progressive, genetic disorder caused by a recessive allele on chromosome number 7. One in twenty people of European descent carry the CF allele. One in 400 couples of European descent will be carriers of CF.

The disorder causes persistent lung infections and limits the ability to breathe over time. In people with cystic fibrosis, the defective gene causes a thick, build-up of mucus in the lungs and it clogs the airways and traps bacteria leading to infections and then eventually respiratory failure.

3.1 Explain why cystic fibrosis is not a sex-linked disease. (2)

The gene ✓ for this disorder is located on the autosomes and not on the sex chromosomes / gonosomes ✓.

3.2 Use a genetic cross to show what percentage of children will be affected if one of the parents is heterozygous and the other is homozygous normal. The recessive allele is represented as **b.** (6)

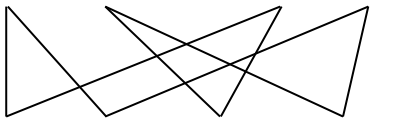
P_1 Phenotype: Normal parent x Normal parent ✓

Genotype Bb x BB ✓

Meiosis

Gametes B b x B B

Fertilisation



F_1 Genotype BB BB Bb Bb ✓

Phenotype Normal Normal ✓

P_1 and F_1 ✓ Meiosis and Fertilisation ✓

0% chance to have a child with cystic fibrosis ✓ * Compulsory mark

Compulsory 1 + any 5

3.3 Maggie and William want to start a family, but Maggie's brother had cystic fibrosis. She doesn't want her own child to suffer as her brother did. Maggie and William decided to visit a genetic counsellor. Explain how this may help Maggie and William in their decision. (2)

To determine their chances of having a child with the disorder ✓ to help them to make an informed decision ✓ on whether to have children or not.

(20)

Multiple alleles – blood type / group

The genetic crosses dealt with thus far involved two alleles for a gene, e.g.: T or t, R or W. Sometimes a characteristic is however controlled by more than two alleles. Blood type (or blood grouping) is an example of such a characteristic.

There are four blood types in humans: A, B, AB or O. These **phenotypes** are controlled by three alleles but <u>each person still inherits two alleles</u>. It is very important to know how to name (or write down) these three alleles as they are very specific to blood groups namely $\mathbf{I^A}$, $\mathbf{I^B}$ or **i**.

Activity 5: Monohybrid crosses using blood types

1. If the child has blood group **O** and the mother blood group **A**, could the man with blood group **AB** be the father of that child? Use a genetic diagram to explain your answer. (6)

P_1 Phenotype: Father blood group **AB**

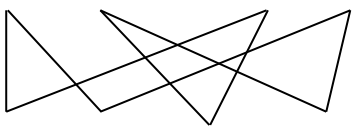
x Mother blood group **A** ✓

Genotype I^AI^B x $\mathbf{I^Ai}$ ✓

Meiosis

Gametes $\mathbf{I^A}$ $\mathbf{I^B}$ x $\mathbf{I^A}$ $\mathbf{i}$

Fertilisation



F_1 Genotype $\mathbf{I^AI^A}$; $\mathbf{I^Ai}$; $\mathbf{I^AI^B}$; $\mathbf{I^Bi}$ ✓

Phenotype Blood group **A, A, AB and B** ✓

P_1 and F_1 ✓

Meiosis and Fertilisation ✓

Hence the man with blood group AB cannot be the father of that child ✓. * Compulsory mark

(Compulsory 1 + any 5**)**

2. Human blood groups are controlled by multiple alleles.

a) List all the alleles that control human blood groups. (3)

I^A ✓, I^B ✓, i ✓

b) How many of the alleles named in a) can any individual inherit? (1)

2 ✓

c) Give a reason for your answer to question b). (1)

Any individual inherits one allele from each parent ✓

d) Which 2 alleles are co-dominant in the inheritance of blood groups? (2)

I^A ✓, I^B ✓

e) A man has blood group **A** and his wife blood group **B**. Their first child has blood group **AB** and the second child blood group **O**. What can one conclude about the blood groups of their future children? (2)

Each child has an equal ✓, i.e. a 25% chance of having any blood group ✓ – A, B, AB, or O.

(15)

Dihybrid crosses

Dihybrid crosses involve **two pairs** of alleles representing **two different** characteristics, e.g.: the height of a plant and the colour of its seeds.

Mendel explained the results obtained from dihybrid crosses according to his Law of Independent Assortment. According to the Law of Independent Assortment, alleles of a gene for one characteristic segregate independently.

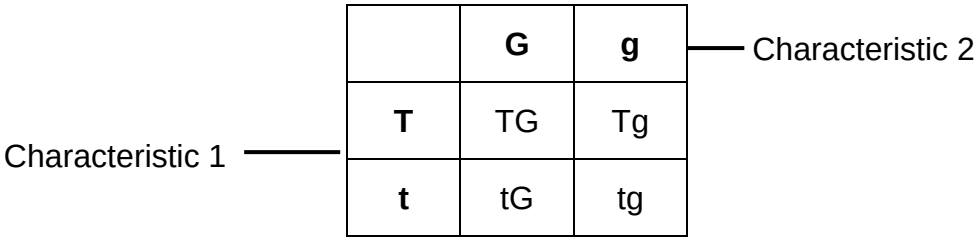
Learners are very scared of these crosses but again, it is easy if one follows the steps:

- Find the two characteristics in the question (e.g. ears and lips in the animal).
- Find which letters are being used (e.g. Pp and Ll) – these questions are always dealing with complete dominance.
- Read the question carefully to find out the genotypes of the parents.
- Work out the gametes using a Punnett square - REMEMBER TO ERASE IT AFTERWARDS!

The easiest way to calculate the gametes is to use a Punnett square:

e.g.: for Tt Gg

NB: Do NOT do this as part of your answer. Do it in pencil and then ERASE it.



	G	g
T	TG	Tg
t	tG	tg

- Remember that there will be FOUR gametes and the Punnett square will have SIXTEEN blocks.
- It is useful to make the Punnett square big enough to fit in the genotype AND the phenotype (see Activity 8.2).
- If this is done, it is not necessary to write out all the genotypes under F_2 generation.

Activity 6: Dihybrid crosses

1. Two characteristics of an animal (length of the ears and shape of the lip) were studied. Each of these characteristics has two variations: Ears may be long or short, and the lip may be a wide or pointed.

   A male animal homozygous for wide lips (**LL**) and heterozygous for short ears (**Ee**) is crossed with a female animal that is heterozygous for wide lips (**Ll**) and homozygous for long ears (**ee**).

   1.1 What term describes a genetic cross involving two characteristics? (1)

   Dihybrid ✓ crossing

   1.2 Give the

   a) dominant phenotype for the length of ears (1)

   short ✓ ears

   b) recessive phenotype for the shape of the lip (1)

   pointed ✓ lip

   c) possible genotype for an animal with short ears and a pointed lip (1)

   EEll or Eell ✓

   1.3 A male animal with genotype EELl is crossed with a female animal with genotype Eell. List all the possible gametes that could be produced by the male animal. (2)

   EL ✓ and El ✓

   1.4 Explain how Mendel's Law of Independent Assortment applies to parents with LlEe genotypes during gamete formation. (4)

Due to random arrangement of chromosomes at the equator ✓ during meiosis ✓ any one of the two alleles of a characteristic can sort with any two of another characteristic

The alleles of different genes move independently ✓ of each other into the gametes ✓

They can therefore appear in the gametes in different combinations: LE, Le, lE, le ✓ (any 4)

2. In humans the allele for short fingers (brachydactyly – a shortening of the fingers and toes), represented by **B**, is dominant over the allele for normal fingers (**b**). The allele for curly hair (**H**) is dominant over the allele for straight hair (**h**).

   Andrew, with genotype **Bbhh**, married Susan, with genotype **bbHh**.

   2.1 How do Andrew and Susan's phenotypes differ from each other? (2)

   Andrew has short fingers while Susan has normal fingers ✓. Andrew has straight hair while Susan has curly hair ✓

   2.2 List all possible genotypes of the gametes produced by Andrew. (2)

   Bh ✓, bh ✓

(14)

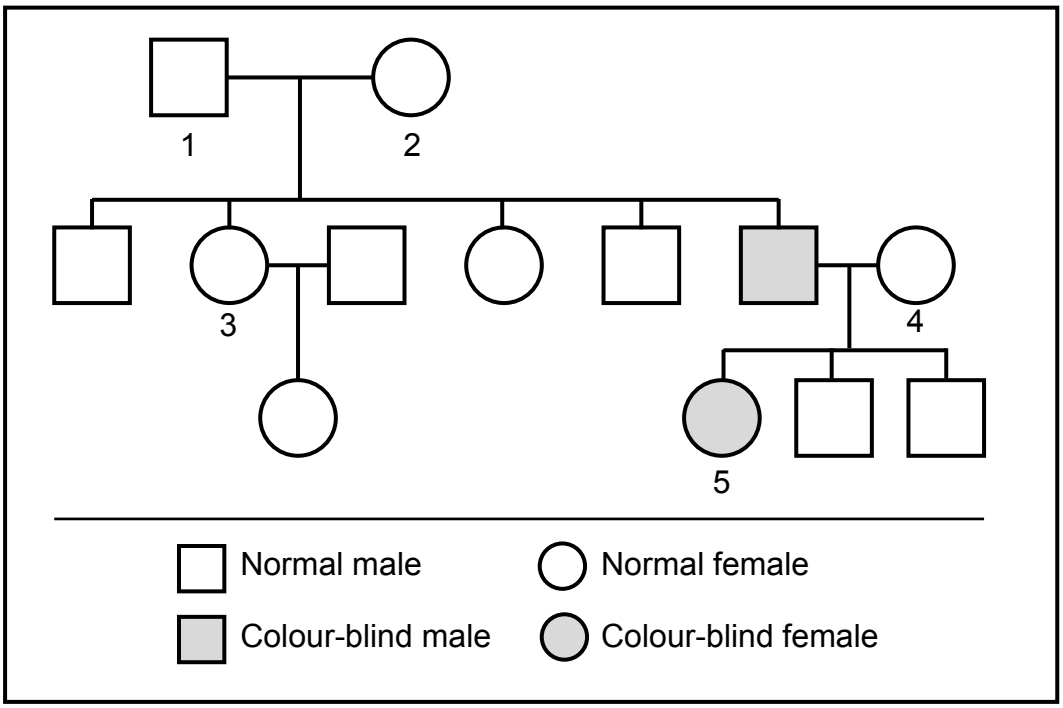
Genetic lineage (Pedigree diagrams)

Pedigree diagrams are quite daunting to some learners but if they follow the basic rules, they will be able to answer them easily.

- In these diagrams, squares always represent males and circles represent females.
- Try to look past the squares and circles until the genotypes have been put in or else they will confuse the issue.
- In the examination papers, the shaded circles will be the recessive (affected) phenotype and the unshaded the dominant (healthy) phenotype.
- Always start by putting in the genotypes for the shaded individuals as they will carry the homozygous recessive allele.
- Then work BACKWARDS from the recessive offspring (shaded) to the parents as each offspring gets ONE allele from the mother and the other from the father. If both parents are unshaded (dominant) and the offspring is shaded (recessive), you will know that the parents are heterozygous.

Activity 7: Pedigrees

1. The pedigree diagram below shows the inheritance of colour-blindness (also called Daltonism) in a family. Colour-blindness is sex-linked and is caused by a recessive allele (**d**). The ability to see colour normally is caused by a dominant allele (**D**).



Inheritance of colour-blindness

1.1 How many of the male offspring of parents 1 and 2 were normal? (1)

2 ✓

1.2 What percentage of males in this pedigree diagram are affected? (2)

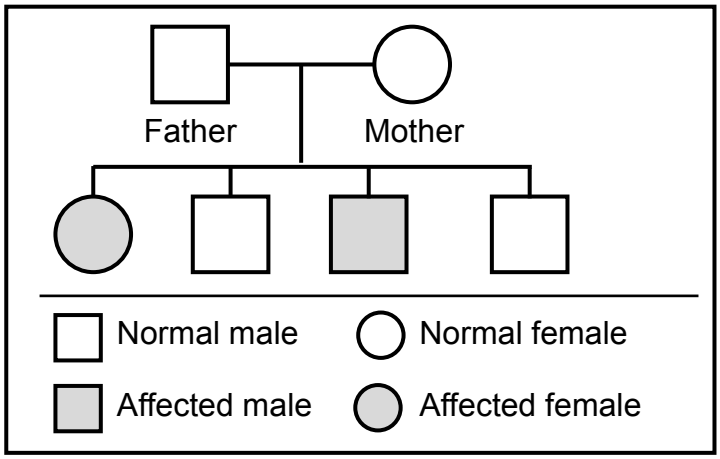
$\frac{1}{7}$ x 100 ✓ = 14,3% ✓

1.3 State the genotype of

a) Individual 2 X^DX^d ✓ (1)
b) Individual 5 X^dX^d ✓ (1)

1.4 If individual 5 marries a normal male, what percentage of their daughters will have an allele for colour-blindness, but will not be colour-blind? 100% ✓ (1)

2. The pedigree diagram below shows the pattern of inheritance of a certain genetic disorder controlled by a recessive allele. The dominant allele is represented by **N** and the recessive allele by **n**.



2.1 Explain why both parents must be heterozygous for this characteristic.

Because they were normal they must each have one dominant allele ✓ and in order for their children to be affected each parent must have one recessive allele ✓ (2)

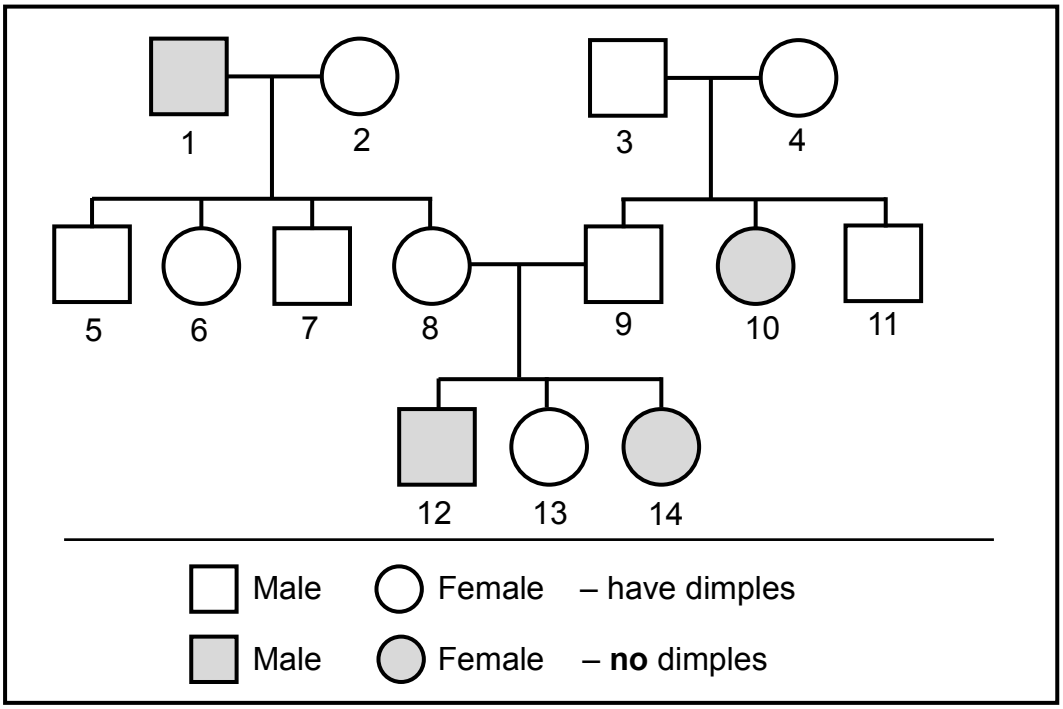
2.2 Give the possible genotype(s) of the normal children. (2)

NN ✓ or **Nn** ✓

2.3 Provide evidence from the pedigree diagram to show that this characteristic is not sex-linked. (3)

The father ✓ would have been affected ✓ if it was sex-linked in order for the daughter to be affected ✓

3. Use the pedigree diagram below to answer the questions about dimples (small depressions on the cheeks when smiling). The dimple gene (**D**) controls whether a person has dimples or does not have dimples. The allele for having dimples is dominant to the allele for not having dimples (**d**).



3.1 How many family members have dimples? 10 ✓ (1)

3.2 What is the genotype of the individuals?

a) **3** Dd ✓ (1)

b) **4** Dd ✓ (1)

3.3 State whether the following individuals are homozygous or heterozygous for having dimples:

a) **2** homozygous ✓ (1)

b) **9** heterozygous ✓ (1)

3.4 State the family relationship between individual **12** and individual **2**. (1)

Individual 2 is the grandmother ✓ of individual 12 or

Individual 12 is the grandson ✓ of individual 2.

Mutations

A mutation is caused by a permanent change to the DNA of a cell. Mutations can be harmless, harmful or useful.

You will need to start this section by revising the gene mutations from Chapter 1.1 as well as the chromosome mutations from Chapter 1.2. Then elaborate on the genetic diseases that are required namely the autosomal recessive **diseases**: haemophilia (gene mutation), sickle cell anaemia (gene mutation), albinism (gene mutation) AND the chromosomal mutation: Down syndrome.

Biotechnology

It is important to stress that Biotechnology is a broad spectrum of technologies of which FOUR are required to know:

- DNA profiling (from Chapter 1)
- Genetic Engineering (e.g., recombinant DNA technology)
- Stem Cell technologies
- Cloning

This is a VERY wide field and it is developing very rapidly so new techniques and breakthroughs are constantly being developed. To keep up to date, you will need to Google regularly!

Learners struggle to distinguish between stem cells and cloning. They also mix up IVF (in vitro fertilisation) with cloning so you have to teach this section carefully.

- Link stem cells to mitosis because these cells are able to GROW into new tissues by mitosis.
- Cloning is divided into two types:
    1. Therapeutic cloning involves stem cells.
    2. Reproductive cloning involves making a new organism from a BODY cell rather than two gametes.

IVF is NOT CLONING because it involves a male and a female gamete and is therefore sexual reproduction. Fertilisation in IVF takes place in a petri dish (vitro meaning glass) and not in the body of a female

Activity 8: Biotechnology

1. Read the section of an article below taken from www.greens.org.

> In the 1950s, the media were full of information about the great new scientific miracle that was going to kill all harmful insects in the world, wipe out insect-borne diseases and feed the world's starving masses. That was DDT.
>
> There are claims that genetic engineering will feed the starving and help eliminate disease. The question is the price tag. As has been with most technologies, such as DDT and nuclear energy, the promise of benefit in the short-term is overwhelmed by long-term disasters.
>
> As more human genes are being inserted into non-human organisms to create new forms of life that are genetically partly human, new ethical questions arise.
>
> What percent of human genes does an organism have to contain before it is considered human?
>
> The Chinese are now putting human genes into tomatoes and peppers to make them grow faster. You can now be a vegetarian and a cannibal at the same time!
>
> What about the mice that have been genetically engineered to produce human sperm? How would you feel if your father was a genetically engineered mouse?
>
> *http://www.greens.org/s-r/20/20-01.html*

1. What did present day scientists learn from using DDT in the 1950s? (2)

   They learnt that what one thinks ✓ will happen is not likely to happen in reality.✓

2. Explain what is meant by “the question is the price tag”. (2)

   Genetic engineering is expensive ✓ so only rich countries can use it. ✓

3. Explain two short term benefits and one long term disaster of GMO food. (6)

Short term:

- greater yield ✓ therefore better food security. ✓
- enhanced nutrient content ✓ e.g. vitamin A in rice.
- easier to grow ✓ as the crop is less likely to get a disease and can grow in harsh conditions. ✓ (any 2 + 2)

Long term:

- possible health ✓ issues due to excessive use of herbicides ✓ or allergic to 'new' gene.
- loss of biodiversity. ✓
- using genetic engineering for experiments ✓ which push the limits of ethics and morality ✓ e.g. human genes in mice. (any 1 + 1)

4. What is meant by "you can now be a vegetarian and a cannibal"? (2)

If a human gene is incorporated into a vegetable (tomatoes / peppers) and you eat it ✓, you are actually also eating a very small part of a human cell ✓.

5. What method could be used to insert human genes into mice? (1)

Recombinant DNA technology ✓

6. How would you feel if you father was a genetically engineered mouse? (2)

BAD ✓: "Playing God with nature" in this way could lead to psychological and social problems. ✓ or GOOD: Could feel special ✓ because you were created by a unique scientific experiment ✓

(15)

Mitochondrial DNA and tracing genetic links

This section is dealt with in the Evolution chapter. It is based on mutations to the DNA carried by the mitochondria.

Summary

- Genetics is the s**tudy of inheritance.**
- **Characteristics** are passed on from parents to offspring in the form of genes (sections of DNA).

Each characteristic is controlled by one or more pairs of **genes** found at particular positions (loci) on the chromatids: one allele is found on the maternal chromosome and the corresponding allele on the paternal chromosome. These two chromosomes make up a bivalent (two homologous chromosomes).

Homologous chromosomes are the same size and shape and carry alleles for the same characteristics (genes). If both alleles are the same, it is referred to as homozygous. If the alleles are different, it is heterozygous.

If one allele of a gene pair "overshadows" the other allele, it results in **complete dominance** whereby only the dominant allele is expressed in the phenotype. The recessive allele is only expressed if both alleles are recessive (homozygous). Examples: tall/short plants, wrinkled/smooth seeds.

If the two alleles "blend" when they occur together to form a NEW phenotype, it is called **incomplete dominance**. Example: pink flowers coming from red and white-flowering plants.

If the phenotype of BOTH alleles are seen in the offspring, it is called **co-dominance**. Examples: blood types, spotted cattle.

- **Gregor Mendel** is the Father of Genetics. His Law of Segregation explains how the two alleles carried on the homologous chromosomes are separated into daughter cells (gametes) during meiosis.
- **A genetic diagram** is a representation of how alleles of a gene are separated during meiosis and the possible ways in which they COULD combine during fertilisation to form the offspring. The parents are called the P1 generation. They produce possible offspring called the F1 generation. If the F1 offspring breed with each other (inbreeding/self-pollination), they are called the P2 generation (parents of the next generation) and produce offspring called the F2 generation.
- **Sex is determined** by a pair of gonosomes. If they are the same (XX), the individual is female. Males carry one X and a small Y chromosome.

  A few characteristics (e.g. hairy ears) and sex-linked diseases are carried on the gonosomes. Most of the diseases are carried on the X chromosome with no corresponding allele on the Y chromosome. This makes males more likely to have a sex-linked disease e.g. haemophilia and red-green colour blindness.
- **Genetic diagrams for blood types** are very specific: the alleles MUST be written correctly, i.e. blood group A is controlled by the allele I^A, blood group B by I^B and blood group O is i.

  Blood groups A and B are co-dominant and group O is recessive to both A and B.

Phenotype: Blood group	**Genotype**: possible alleles
A	I^AI^A or I^Ai
B	I^BI^B or I^Bi
AB	I^AI^B
O	ii

- **Pedigree diagrams** are used to show the inheritance of a particular characteristic or disease over a number of generations.
- **Dihybrid crosses** involve TWO pairs of alleles. It is important to remember that the diagram will have FOUR gametes and the Punnett square will have 16 possible offspring.
- **Mutations** arise when there is a change in the DNA strand. These could be harmless, harmful or useful. Useful mutations could possibly lead to evolution. Mutations can affect genes or whole chromosomes.

  Gene mutations can cause diseases such as haemophilia, sickle cell and albinism.

  Chromosome mutations can occur during Anaphase 1 when bivalent chromosomes do not separate (non-disjunction). Down's syndrome is an example of non-disjunction of chromosome pair 21.
- **Biotechnology** is the use of organisms or biological processes to improve the quality of human life. DNA profiling, genetic engineering, stem cells and cloning are examples of biotechnology.
- **Genetic engineering** involves moving a gene from one chromosome in one organism to a chromosome in a second organism. This results in a genetically modified organism (GMO).

  One method which can be used to move the gene is called **Recombinant DNA Technology**. This process uses restriction enzymes to cut the DNA strand and ligase enzymes to attach the gene into the new DNA strand.
- **Genetically modified plants and transgenic animals** have a number of advantages most of which concern food security. The disadvantages include health safety and expense.
- **Stem cells** are undifferentiated cells that have the potential to form any type of tissue. Embryonic stem cells are taken from embryos and have the potential to form any tissue.

  Adult stem cells are mainly found in bone marrow and cord blood but can only form certain tissues.

- **Cloning** occurs naturally when organisms reproduce asexually or when identical twins are formed.

  Medically, there are two forms of cloning:

  - **Therapeutic** cloning, which uses stem cells to grow a specific tissue e.g. skin cells.
  - **Reproductive** cloning, which involves the formation of a baby which is an exact replica of the parent. The baby is made from a somatic cell and not the fusion of two sex cells.

- **Mitochondrial DNA** (mtDNA) is a short section of DNA found in all mitochondria. Analysis of mutations in mtDNA is useful in tracing the genetic lineage of the human race. It has been used as proof that humans originated in Africa and then migrated northwards to other continents.

End of topic exercises

Section A

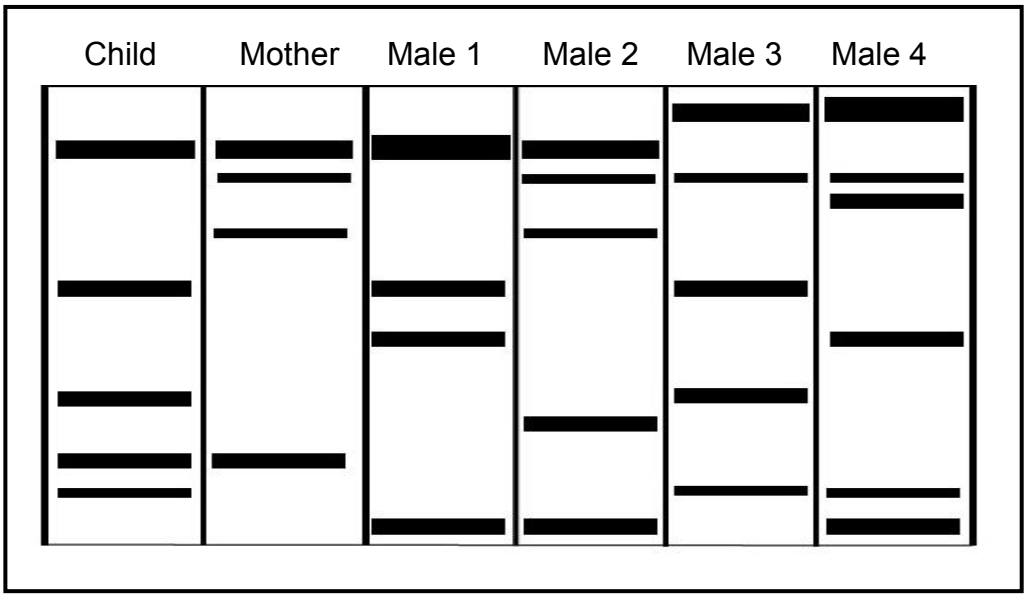
Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 If a recessive allele on the X-chromosome is passed on to the offspring it is an example of…

A **sex-linked inheritance** ✓✓
B incomplete dominance
C multiple alleles
D co-dominance

1.1.2 The diagram below shows the DNA profiles of a child, her mother and four males. There is uncertainty about who the biological father is. To establish paternity, DNA profiling was conducted.



Which male is the biological father of this child?

A Male 1
B Male 2
C **Male 3** ✓✓
D Male 4

1.1.3 The advantage of cloning is that it…

A will reduce the variation within a population.
B **produces genetically identical individuals with desirable characteristics**. ✓✓
C will enable offspring to survive under any unfavourable conditions.
D Is the only scientific technique that is accepted by all religious denominations and faiths.

1.1.4 In humans, brown eye colour is dominant over blue eye colour. A mother with blue eyes has two children; a boy with brown eyes and a girl with blue eyes. The eye colour of the father is…

A brown, because the allele for brown eye colour is sex-linked.
B **brown, because at least one of the parents must have brown eyes**. ✓✓
C blue, because at least two other members of the family have blue eyes.
D blue, because at least one of the parents must be heterozygous for eye colour.

1.1.5 An extra finger in humans is rare, but is due to a dominant gene. When one parent is normal and the other parent has an extra finger but is homozygous for the trait, what is the chances that their children will be normal?

A **0%** ✓✓
B 25%
C 50%
D 75%

(5 x 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 Undifferentiated animal cells that can form any type of tissue.

Stem ✓ cells

1.2.2 Type of inheritance where none of the two alleles is dominant over the other and an intermediate phenotype is produced.

Incomplete dominance ✓

1.2.3 The breeding of organisms by humans to achieve a desirable phenotype.

Artificial selection ✓ / Selective breeding

1.2.4 The physical appearance of an organism.

Phenotype ✓

1.2.5 A genetic disorder characterised by the absence of blood clotting factor.

Haemophilia ✓

1.2.6 Organisms that have different alleles at a given locus.

Heterozygous ✓

1.2.7 A human disorder caused by the non-disjunction of chromosome pair 21.

Down Syndrome ✓

1.2.8 The type of genetic cross involving two different characteristics.

Dihybrid cross ✓

1.2.9 The organelle involved in making a spindle.

Centrosome ✓

(9 x 1) = (9)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 A specific pattern of bands representing a unique sequence of nucleotides that resemble bar codes	A: DNA profiling B: DNA replication
1.3.2 The number, shape and arrangement of all the chromosomes in the nucleus of a somatic cell	A: Karyotype B: Genome
1.3.3 Identical alleles for a trait	A: Heterozygous B: Homozygous
1.3.4 An allele that is not shown / expressed in the phenotype when found in the heterozygous genotype	A: Dominant B: Recessive
1.3.5 An example of biotechnology	A: Cloning B: Genetic modification

Note: the wording must be exact

1.3.1 **A only ✓✓**

1.3.2 **A only ✓✓**

1.3.3 **B only ✓✓**

1.3.4 **B only ✓✓**

1.3.5 **Both A and B ✓✓**

(5 x 2) = 10

1.4 Read the extract below and answer the questions that follow.

> Genetic engineering involves a process whereby a gene is isolated from one organism and transferred into another organism. This gene can become part of the new host's genome. Usually the gene transfer takes place between organisms from different kingdoms.
>
> For example, a gene from a certain bacterium codes for an enzyme that deactivated a herbicide (a weed-killer). This gene is isolated from the bacterium and inserted into the chromosome of a crop plant. The resulting plant will now be herbicide-resistant.
>
> Before the products of genetic engineering can be sold, many tests must be done.
>
> Some seed companies have exclusive rights to sell the seeds that they have genetically engineered. Farmers cannot use seeds harvested from the crops that they have grown. Farmers must buy seeds from the seed companies every time they want to plant the crop.
>
> Adapted from *Microbiology and Biotechnology*, 1994

1.4.1 What is meant by the term *genome* referred to in the extract.

An organism's complete set of genes. ✓ (1)

1.4.2 State one way in which genetic engineering described in the extract differs from selective breeding.

Genetic engineering: involves transfer of genes ✓ from one organism to another. / (manipulation of DNA)
Selective breeding: Parents with desirable phenotypes are selected to mate / breed to produce offspring with desirable phenotypes. ✓
OR
Genetic engineering can involve gene transfer between organisms from different kingdoms. ✓

Selective breeding can occur using organisms from the same or different species within a kingdom. ✓ (2)

1.4.3 Give one reason why the products of genetic engineering must undergo many tests before they can be sold.

- To assess the risks to human health ✓ / the environment
- To determine if the presence of the transferred gene will affect the expression of other genes ✓
- To test the effectiveness ✓ of the product

(Mark first one only) (1)

1.4.4 Explain the value of growing herbicide-resistant crops.

- The spraying of herbicide will kill the weeds ✓ without killing the crops ✓
- thus reducing the competition ✓ and increasing the yield. ✓

(Any three) (3)

1.4.5 State THREE advantages of genetic engineering in crop production other than those mentioned in the extract above.

- Produce crops that are resistant to adverse conditions ✓ / drought / disease / pests
- Increase crop yield ✓
- Change the time for the ripening of fruits ✓
- Increase shelf life of plant products ✓
- Improve nutritional value of food ✓
- Improve the taste ✓ of food
- Developing fruit / plants with desirable characteristics ✓

(Mark first three only) (3)

1.4.6 Give a reason why seed companies insist that they must have the exclusive rights to the selling of seeds.

The companies have invested ✓ a lot of time ✓ / money to make the GM seeds

OR

The companies want to control the seed market ✓ thus increasing their profit ✓

(Any one x 2) (2)

(12)

1.5 Gregor Mendel conducted breeding experiments with pea plants to study the inheritance patterns of four different traits (plant height, seed shape, seed colour and seed coat colour).

For each trait, for example plant height, he crossed homozygous tall plants with homozygous dwarf plants. The offspring in the F_1 – generation were then interbred to form the F_2 – generation. He did the same for each of the other traits.

The results obtained for the F_2 – generation are shown in the table below.

Trait	Results of F_2-crossing		Ratio
Plant height (Tall or dwarf)	Tall:	787	2,84 : 1
	Dwarf:	277	
Seed shape (Round or wrinkled)	Round:	5 474	**X**
	Wrinkled:	1 850	
Seed colour (Yellow or green)	Yellow:	6 022	**Y**
	Green:	2 001	
Seed coat colour (Grey or white)	Grey:	705	3,15 : 1
	White:	224	

[Adapted from Basic Concepts in Biology, 3rd edition., C.Starr, 1997]

1.5.1 What is the expected phenotypic ratio for the trait involving two heterozygous parents?

3 : 1 ✓ (1)

1.5.2 From the results, calculate X and Y. Also state which trait provided a ratio closest to the expected phenotypic ratio mentioned in QUESTION 1.5.1. Show all working.

X: Seed shape = $\frac{5474}{1850}$ = 2,96 : 1 ✓ / 2,95 : 1

Y: Seed colour = $\frac{6022}{2001}$ = 3,01 : 1 ✓

Closest: Seed Colour ✓ / (Y) (3)

1.5.3 Give a possible reason why the ratio selected in QUESTION 1.5.2 was closest to the theoretical ratio.

Y has the largest ✓ sample size ✓ (2)

1.5.4 Using the results, state whether the allele for round seeds or for wrinkled seeds is dominant.

Round ✓ seeds (1)

1.5.5 State ONE factor that Mendel controlled during these breeding experiments.

- All plants must be homozygous in P_1 ✓

- All plants must be heterozygous in P_2 ✓
- Same type of plant ✓/ species
- Same environmental conditions ✓
- Same method of pollination ✓

(Mark first ONE only) (1)

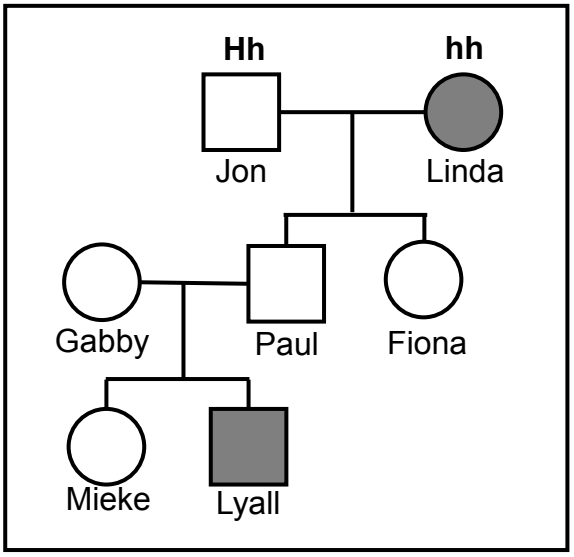
(8)

Section A: [49]

Section B

Question 2

2.1 The diagram shows the pattern of inheritance of deafness in a family. The letter **H** represents the allele for hearing and **h** represents the allele for deafness.



2.1.1 How many of each of the following are represented in the diagram?

a) Males 3 ✓ (1)

b) Generations 3 ✓ (1)

2.1.2 Give the

a) phenotype of Jon Normal hearing ✓ (1)

b) genotype of Paul Hh ✓ (1)

2.1.3 Both Lyall's parents can hear, yet he is deaf. Explain how deafness is inherited.

Lyall inherited one recessive allele ✓ from each parent ✓ (2)

2.1.4 Lyall marries a woman is homozygous dominant for hearing. Use a genetic cross to show the percentage chance of them having a deaf child.

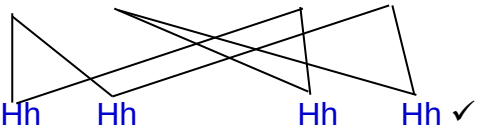
P_1 Phenotype Hearing x Deaf ✓

Genotype HH x hh ✓

Meiosis

Gametes H H x h h ✓

Fertilisation



F_1 Genotype Hh Hh Hh Hh ✓

Phenotype All hearing ✓

0% deaf ✓*

P_1 and F_1 ✓

Meiosis and fertilisation ✓

1* Compulsory mark + Any 6

OR

P_1 Phenotype Hearing x Deaf ✓

Genotype HH x hh ✓

Meiosis

Fertilisation

Gametes	H	H
h	Hh	Hh
h	Hh	Hh

1 mark for correct gametes

1 mark for correct genotypes

F_1 Phenotype All hearing ✓

0% deaf ✓*

P_1 and F_1 ✓

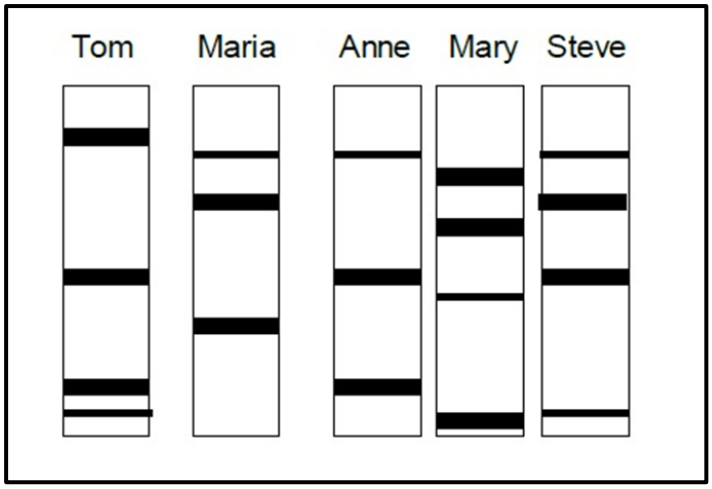
Meiosis and fertilisation ✓

1* Compulsory mark + Any 6

(7)

(13)

2.2 Tom and Maria have three children. One of the three children was adopted. A DNA profile for each member of the family was prepared to determine if Tom is the father of all three children (Anne, Mary and Steve). The DNA profiles are given below.



2.2.1 Which one of the children was adopted?

Mary ✓✓ (2)

2.2.2 Explain your answer to question 2.2.1.

There are no matching bands / bars / patterns ✓ common to Mary and both of the parents ✓ (2)

(4)

2.3 Humans have different blood groups which are coded for by a number of alleles. Mary has genotype I^Ai and her son Joseph has blood type AB.

2.3.1 How many alleles code for blood groups?

3 ✓ (1)

2.3.2 Give all the possible genotypes for Joseph's father.

I^AI^B ✓ I^BI^B ✓ I^Bi ✓ (3)

(4)

2.4 Haemophilia is a genetic disorder caused by a recessive allele on the X-chromosome. A haemophiliac female marries a normal male. Explain why all their sons will be haemophiliacs.

- An individual inherits one allele from each parent ✓
- The Y-chromosome was inherited from the father ✓
- And the recessive allele / X^h was inherited from the mother ✓
- Since the mother has two recessive alleles ✓/ X^hX^h
- A son only needs to get one recessive allele to be haemophiliac ✓
- since the Y-chromosome does not carry any allele to mask ✓ the h allele

(any four × 1) (4)

[25]

Question 3

3.1 Coat colour in mice is controlled by two alleles, black (**B**) and grey (**b**). Tail length is controlled by two alleles, long (**T**) and short (**t**).

The Punnett square below shows a part of the cross between two mice. Genotype **(i)** has been left out.

Parent 1

Parent 2	Gametes	BT	Bt	bT	bt
	Bt	BBTt	BBtt	BbTt	Bbtt
	Bt	BBTt	BBtt	BbTt	Bbtt
	Bt	BBTt	BBtt	(i)	Bbtt
	Bt	BBTt	BBtt	BbTt	Bbtt

3.1.1 Give the

a) genotype of parent 1 — BbTt ✓ (2)

b) phenotype of parent 2 — Black coat ✓ short tail ✓ (2)

c) genotype of offspring (i) — BbTt✓ (1)

3.1.2 What percentage of the offspring above is grey with short tails?

0% ✓ (1)

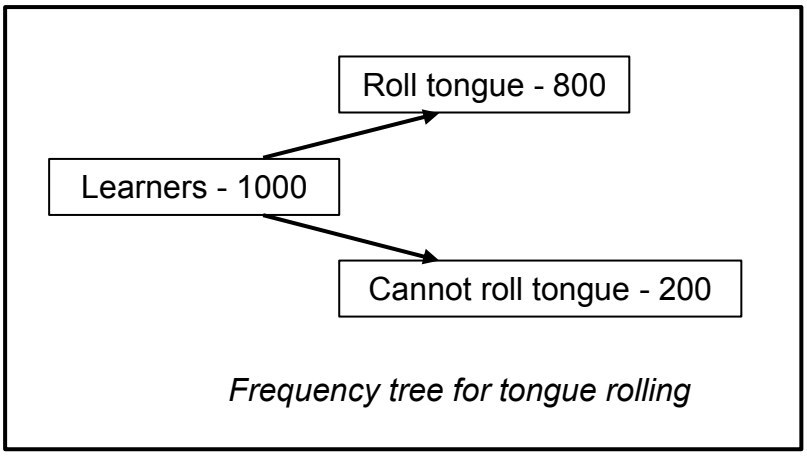
3.1.3 State the genotypes of two gametes from the table above that will result in offspring that are heterozygous for both tails if fertilisation occurs.

Bt ✓ bT ✓ (2)

(8)

3.2 A class of Grade 11 learners conducted an investigation to determine the frequency of dominant and recessive characteristics in their school. The characteristic investigated was the ability to roll one's tongue.

The results obtained were recorded in the frequency tree as shown below.



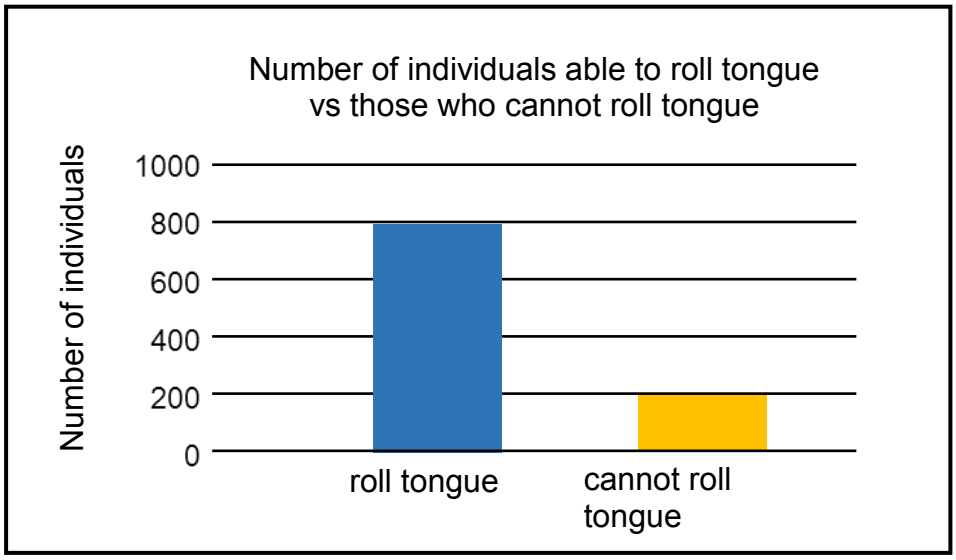
Frequency tree for tongue rolling

3.2.1 List three steps that the learners need to follow while planning this investigation.

- Ask permission from the participants and the school principal to conduct the investigation ✓
- Determine the sample size ✓
- Decide on how data will be recorded ✓
- Decide on data capturers to collect data ✓

(Mark first three only) (3)

3.2.2 Use the data given in the frequency tree to plot a bar graph.



Guidelines for marking graph

Criteria	Mark
Type of graph (T)	✓
Caption (C)	✓

x-axis (equal width of bars AND correct label)	✓
y-axis (appropriate scale and correct label)	✓
Plotting (P)	✓ (both bars plotted correctly)

(5)

3.2.3 Would you classify the ability to roll one's tongue as a continuous or discontinuous variation?

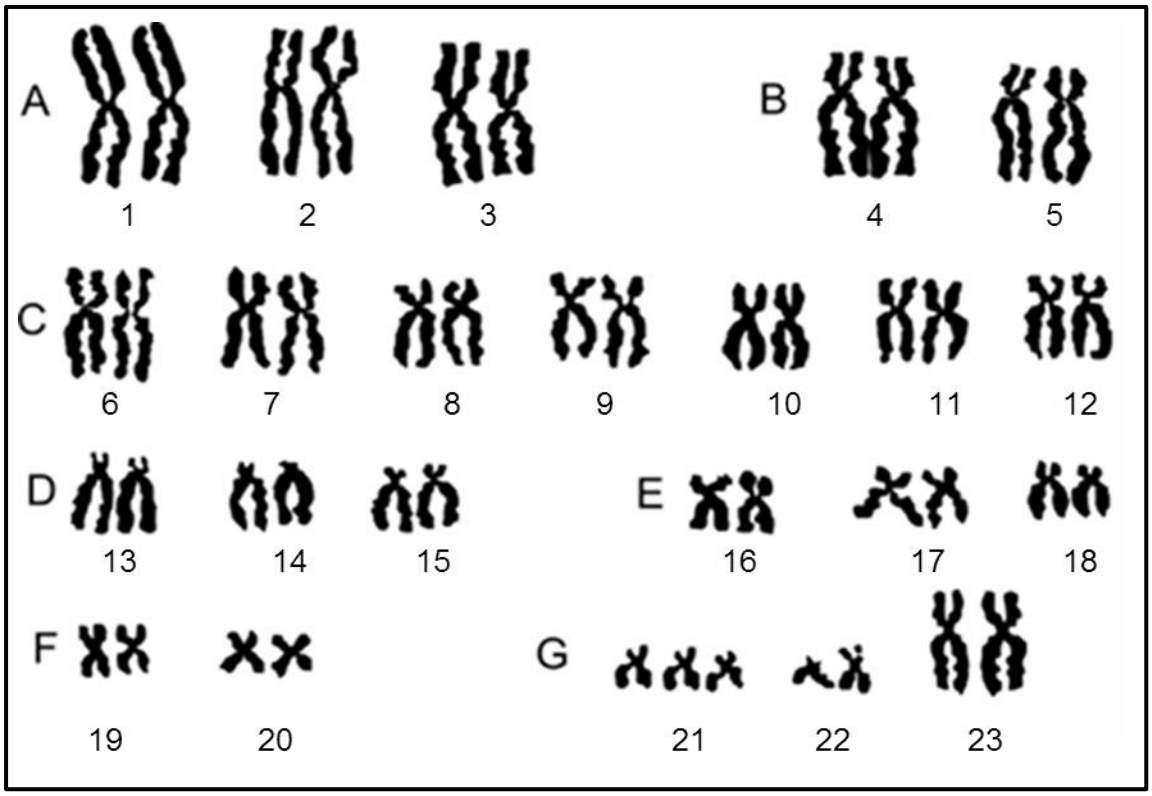
Discontinuous ✓ (1)

3.2.4 Explain your answer to question 3.2.4

There is no range of different phenotypes for tongue rolling ✓ / there are no intermediates between phenotypes, either one can roll their tongue or they cannot ✓ (2)

(11)

3.3 The diagram below is a representation of the chromosomes in a human cell.



3.3.1 How many autosomes are in this cell?

45 ✓ (1)

3.3.2 This individual is a female. Explain why this conclusion is made.

There are two X chromosomes ✓ / XX / The gonosomes are the same (1)

3.3.3 What evidence is there to show that this individual has a genetic disorder?

3 chromosomes present in chromosome pair 21 ✓ (1)

3.3.4 Identify the genetic order mentioned in question 3.3.3.

Down Syndrome ✓ (1)

3.3.5 Name the process that resulted in this genetic disorder.

Non-disjunction ✓ (1)

(5)

Section B: [24]

Total Marks: [98]

Cognitive level distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1		✓			2
1.1.2		✓			2
1.1.3	✓				2
1.1.4		✓			2
1.1.5				✓	2
	2	6		2	10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
	9				9
1.3.1		✓			2
1.3.2		✓			2
1.3.3		✓			2
1.3.4		✓			2
1.3.5		✓			2
		10			10
1.4.1	✓				1
1.4.2		✓			2
1.4.3			✓		1
1.4.4		✓			3
1.4.5		✓			3
1.4.6		✓			2
	1	10	1		12
1.5.1			✓		1
1.5.2			✓		3
1.5.3		✓			2

1.5.4		✓			1
1.5.5		✓			1
		4	4		8
2.1.1	✓✓				(1 + 1)
2.1.2		✓✓			(1 + 1)
2.1.3			✓		2
2.1.4			✓		7
	2	2	9		13
2.2.1		✓			2
2.2.2		✓			2
		4			4
2.3.1	✓				1
2.3.2			✓		3
	1		3		4
2.4			✓		4
			4		4
3.1.1 a - c	✓	✓✓			(2+2+1)
3.1.2		✓			1
3.1.3		✓			2
	2	6			8
3.2.1			✓		3
3.2.2			✓		5
3.2.3		✓			1
3.2.4		✓			2
	1	3	8		11
3.3.1	✓				1
3.3.2		✓			1
3.3.3	✓				1
3.3.4	✓				1
3.3.5	✓				1
	4	1			5
	20	47	29	2	98

CHAPTER 6: HUMAN RESPONSES TO THE ENVIROMENT

Overview

Time Allocation: 4 Weeks (16 Hours)

This chapter consists of:

1. Introduction
2. Key concepts and terminology
3. Human responses to the environment
4. The human nervous system
5. Disorders, injuries and effects of drugs
6. Sense organs – the human eye and the human ear
7. Summary
8. End of topic exercises

Introduction

Humans respond to the environment in various ways to maintain homeostasis, function efficiently and protect themselves from danger. The human nervous system as well as receptor organs allows the body to respond.

Key concepts and terminology

- The central nervous system consists of the brain and spinal cord. These delicate structures are protected by the meninges which are membrane layers as well as bone structures.
- The brain contains various sections such as the cerebrum, cerebellum and medulla oblongata. Each section of the brain performs a different function.
- The spinal cord is an extension of the brain which passes through the vertebral column. It plays a very important role in reflex actions which protects the body from harm.

- The peripheral nervous system consists of the nerve tissue outside of the central nervous system. It consists of different types of neurons which are sensory, connector and motor neurons.
- The peripheral nervous system can be somatic (voluntarily controlled) or autonomic (automatically controlled).
- A sensory neuron detects changes in the environment and a motor neuron brings about a response to that change. Neurons are connected by synapses.
- A reflex action is the quick, automatic response of the body to a change in the environment. A reflex arc is the pathway taken to achieve the reflex action.
- A reflex arc is vitally important to protect the body from harm.
- Receptors are the organs which detect stimuli in the environment.
- The human eye has various structures which each perform a different function to enable the eye to see. The eye can adapt to the amount of light present (pupillary mechanism) and the distance at which an object is viewed (accommodation).
- The ear has various structures which each perform a different function to enable hearing and balance. The receptor cells within the ear are the organ of Corti for hearing and the macula and crista for balance.

Key terminology

receptor	structure that receives a stimulus and converts it into an impulse
effector	gland or organ that brings about a response to stimuli received by the body
stimulus	detectable change in the internal or external environment
impulse	electrical signal created by receptor organs in response to stimuli
transmit	to send something from one place to another
autonomic nervous system	controls our involuntary bodily functions; it is divided into the parasympathetic and sympathetic nervous system
peripheral nervous system	the system of nerves connected to the outside of the central nervous system, part of which is under involuntary control

Human responses to the environment

Learners are required to know that humans have two systems that respond to the environment. The human nervous system and endocrine system function together to

enable responses. The nervous system is discussed in this chapter, the endocrine system is discussed as a separate topic in chapter 7.

This section is an opportunity to use models and diagrams as well as perform dissections. Learners should be actively involved during their learning of this topic as they often find it a difficult and detailed section of work to study.

This section can be quite challenging for learners, so teachers should try to teach in a simple fashion and systematically to ensure learners have a good grounding of a particular section before moving on. There is a vast amount of detail available, however learners are only required to know the basics and teachers should bear this in mind during their presentation of the work, both through visual aids used and information relayed to learners.

The human nervous system

Key terminology

cranium	part of the skull that contains and protects the brain
meninges	protective membranes surrounding the brain & spinal cord
cerebrospinal fluid	fluid around the brain and spinal cord to aid in protection
grey matter	part of the brain and spinal cord consisting of cell bodies and dendrites
white matter	part of the brain and spinal cord consisting of myelinated axons
neuron	specialised nerve cells which transmits nerve impulses
dendrites	fibres that transmit impulses to a cell body in a neuron
nerve	bundle of neurons
synapse	the gap between the axon of one neuron and the dendrite of another
neurotransmitter	chemicals which carry impulses across the synapse
Alzheimer's disease	disease caused by nerve defects usually in older people and characterised by memory loss and confusion
multiple sclerosis	disease cause by damage to the myelin sheath of neurons and characterised by physical and mental disabilities
homeostasis	the tendency of living organisms to maintain their internal environment constant within narrow limits irrespective of changes in the external environments

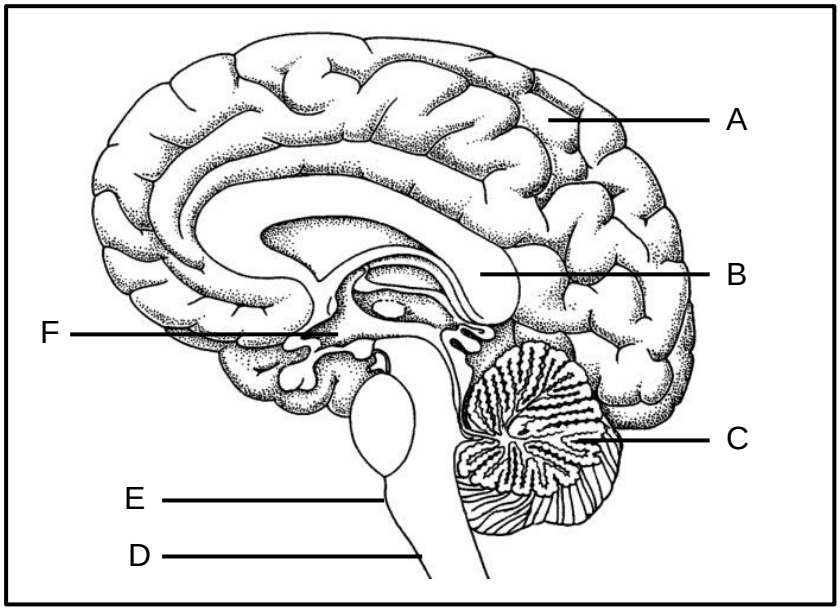
It is important to focus on the location and function of the nervous systems. For nerve structure and the reflex arc learners must focus on structure and function as well as the structural suitability of the part to its function.

Learners must be able to identify the cerebrum, cerebellum, medulla oblongata and the spinal cord in diagrams. The types of neurons must be clearly defined and learners should be able to identify each type using diagrams. Learners are only required to know neurons as motor, sensory and interneurons.

The reflex arc is often asked in external examinations. Learners must apply their knowledge to the scenario laid out in examination.

Activity 1: The central nervous system

The diagram below represents a human brain. Study it, then answer the questions that follow.



1. Give the names of the parts labelled A to C. (3)

   A – cerebrum ✓, B – corpus callosum ✓, C – cerebellum ✓

2. Give the letter and the name of the part responsible for:

   a) co-ordinating all voluntary movements (2)

   C ✓ – cerebellum ✓

   b) memorising a cell phone number (2)

   A ✓ – cerebrum ✓

3. Give two functions of parts:

   a) E (2)

   controls breathing, peristalsis, heart beat and swallowing ✓

   transmits impulses from the spinal cord to the brain ✓

controls less important reflexes such as blinking, coughing, sneezing, vasodilation, vasoconstriction and salivating ✓ (any two)

b) F (2)

control centre for things such as hunger, thirst, sleep, body temperature and emotions (✓- any two)

4. Provide two ways in which part D is protected. (2)

The spinal cord is protected by vertebrae with cartilage discs between them to act as shock absorbers ✓, by membranes called meninges ✓, and cerebrospinal fluid ✓ (any two)

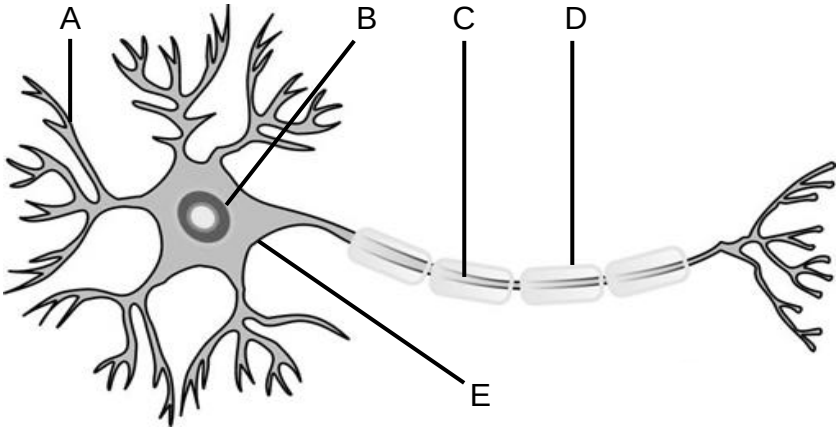
5. Which functions of the body might be affected if the lower back part of the head receives a significant impact in a car accident? (2)

The medulla oblongata would be affected. This could lead to problems with .. breathing ✓, heartbeat ✓, digestion ✓, communication between the brain and the spinal cord ✓. (any two)

(15)

Activity 2: Neuron structure

The diagram below represents the structure of a neuron.



1. Name the type of neuron shown in the diagram above. (1)

motor neuron ✓

2. Identify the parts A to E. (5)

A – dendrite ✓, B – nucleus ✓, C – axon ✓, D – myelin sheath ✓, E – cell membrane ✓

3. Provide the functions of the following parts:

a) C (1)

transmits impulses away from the cell body ✓

b) D (1)

speeds up the transmission of impulses ✓

4. Describe the pathway of an impulse through the neuron shown above. (1)

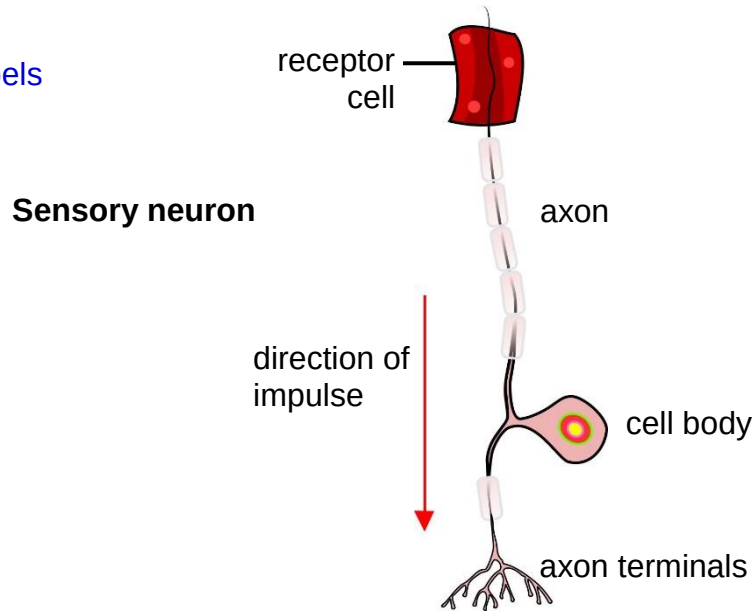
Dendrites receive the impulse and move them towards the cell body ✓. They pass through the cell body and are transmitted down the axon.

5. Draw a fully labelled diagram to show the structure of a neuron which receives impulses and transmits them to the central nervous system. (4)

Mark allocation: correct type of neuron – title: a sensory neuron ✓

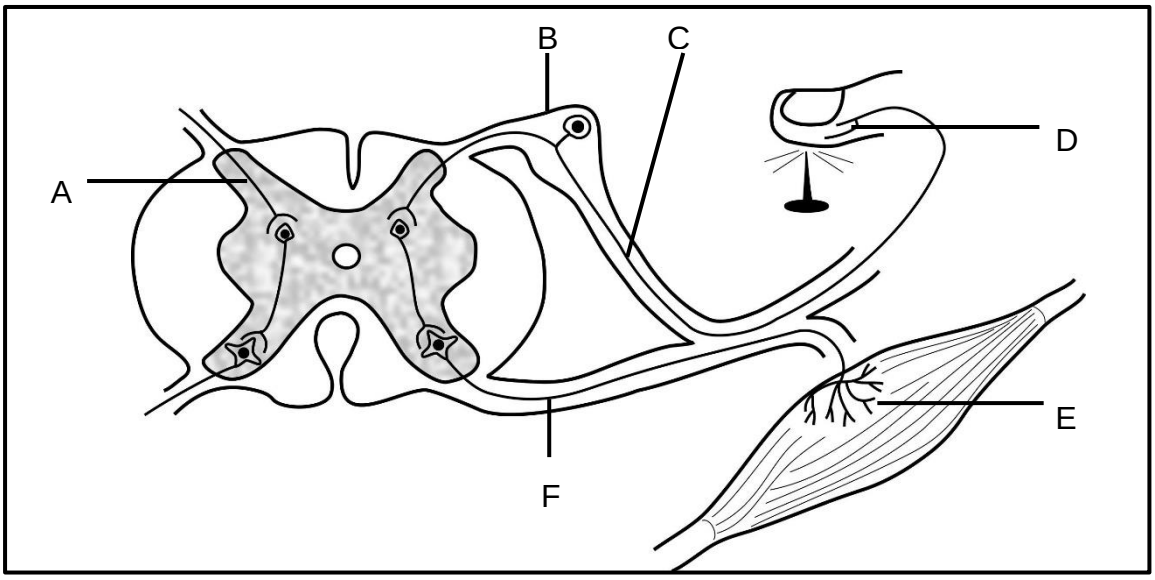
correct direction of impulse ✓

any two correct labels ✓✓



Activity 3: Reflex arc

The diagram below shows the reflex arc.



1. Give only the letter of the part that represents the:
   a) effector (1)
   E ✓
   b) interneuron (1)
   A ✓
   c) sensory neuron (1)
   C ✓
2. State one function of each of the following parts:
   a) D (1)
   The receptor detects the stimulus, in this case a pin prick, and generates impulses ✓.
   b) F (1)
   transmits impulses from the central nervous system to the effector to bring about a response ✓.
3. Explain why the brain is not initially involved in the reflex action. (3)
   The spinal cord shortens the reaction time by sending impulses directly to the effector. ✓ The brain delays the reaction as impulses must travel further, ✓ which could cause injury or even death. ✓
4. Explain the effect on the body if the following parts were cut:
   a) C (4)
   The receptor would detect the stimulus and generate impulses ✓, however the impulses would not reach the central nervous system ✓ because the sensory neuron is cut ✓. The sensation would not be felt and the body would not be able to respond ✓.
   b) F (4)
   The receptor would detect the stimulus and generate impulses ✓ which will reach the central nervous system ✓. The sensation will be felt but the body will not be able to respond ✓ because the motor neuron is cut so impulses cannot reach the effector ✓.

(16)

Activity 4: Practical investigation on reaction times

Thando conducted an experiment to determine which gender has the faster reaction time amongst his classmates. Out of 15 learners in his class he randomly selected a sample of 5 girls and 5 boys. The following steps were followed for each member of the sample during the experiment:

- Thando held a meter ruler between his thumb and index finger just above the 100 cm mark.
- The pupil placed the thumb and index finger on either side of the meter ruler at the 0 cm mark, with only the thumb touching it.

- As Thando dropped the meter ruler the pupil caught it by closing the thumb and forefinger.
- During each trial Thando recorded the distance at which the meter ruler was caught.
- The procedure was repeated five times for each pupil.

The table below shows the average distance at which the meter ruler was caught by 5 boys and 5 girls over five trials.

Average distance at which the meter ruler was caught over 5 trials (cm)

Boys	**average distance (cm)**	**Girls**	**average distance (cm)**
Boy 1	5,8	Girl 1	4,8
Boy 2	5,0	Girl 2	4,7
Boy 3	4,9	Girl 3	4,2
Boy 4	4,8	Girl 4	4,0
Boy 5	4,6	Girl 5	3,9
overall average	5,02	**overall average**	4,32

1. Identify the
   a) independent variable of the experiment, and (1)
   Gender ✓
   b) dependent variable of the experiment. (1)
   Reaction time ✓
2. Give two reasons why the results of this experiment may be regarded as reliable. (2)
   - Each trial was repeated 5 times for each of the participants ✓
   - Relatively large sample size was taken ✓
3. Mention two factors which should be kept constant during the experiment. (2)
   - Same group of learners used ✓
   - Same person dropping the ruler ✓
   - Same meter ruler ✓
   - Same time of day ✓ (any two)
4. Thando's initial hypothesis was rejected on the basis of the results obtained. Suggest what Thando's initial hypothesis could have been. (2)
   Boys have faster reaction time than girls. ✓✓ **OR** Girls have lower reaction times than boys. ✓✓ **OR** Both girls and boys have the same reaction time. ✓✓

Disorders, injuries and effects of drugs

Learners are required to know the causes and symptoms of Alzheimer's disease and multiple sclerosis. There are many other disorders which can be used for class discussion but these are the two required for assessment purposes.

There are many injuries which could affect the nervous system and depending on where the injury occurs the effects will differ. Learners must know that much research is being done on stem cells and the possibility of repairing injuries by using stem cells in the future. This can be linked to the chapter on genetics and inheritance.

The effects of various drugs can be discussed with learners though this section is not examinable. It is very useful though to make learners aware of the various effects of drugs on the human body. They should be made aware that alcohol may be considered a drug since it has similar effects on the body.

Sense organs

Sense organs contain a high concentration of receptor cells which are able to detect stimuli to bring about a response. Learners only need to know the names and details of the receptors for light and sound which are the eye and ear.

The human eye

Learners must know the structure and functioning of the human eye. Learners must know the processes of accommodation and pupillary mechanism as these are often asked and learners should apply their knowledge to the scenario laid out in the question. The defects associated with the eye such as short-sightedness, long-sightedness, astigmatism and cataracts must be understood with the aid of diagrams.

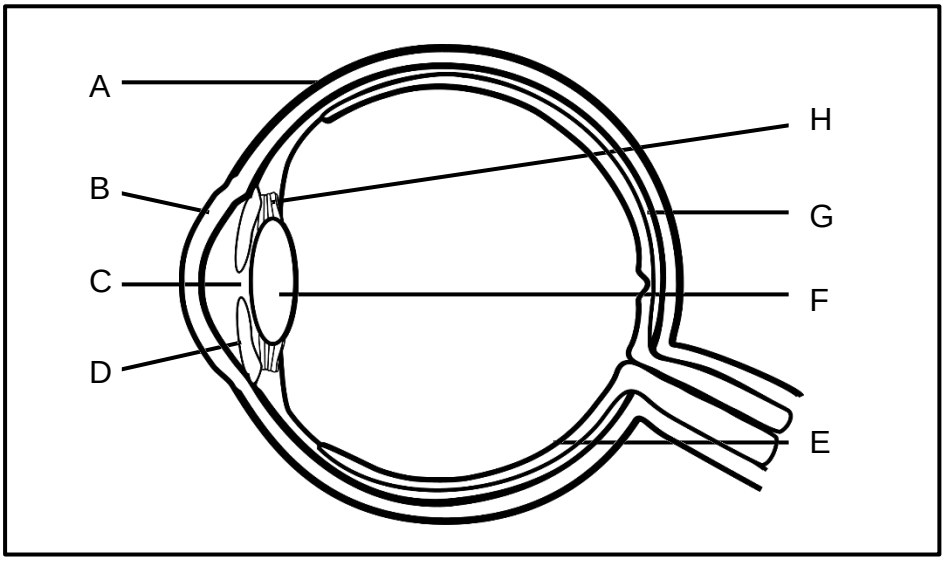
Key terminology

rods	receptor cells found in the retina of the eye which are sensitive to dim light and help to distinguish between black and white
cones	receptor cells found in the retina of the eye which are sensitive to bright light and help to distinguish between different colours
pupil	central opening within the iris which allows light to enter
pupillary mechanism	regulation of the pupil size to control the amount of light entering the eye

accommodation	the ability of the lens of the eye to alter its shape for clear vision when viewing both near and distant objects
field of vision	the area that one eye can see
convex	a shape which curves outwards, thicker in the middle than the edges
concave	a shape which curves inwards, thinner in the middle than the edges

Activity 5: The human eye

The diagram below represents a section through a human eye.



1. Identify parts C, D and H. (3)

   C – pupil ✓, D – iris ✓, H – suspensory ligaments ✓

2. Explain how part B is adapted to perform its function. (2)

   The cornea is transparent to allow light to enter ✓ and it is curved to allow for refraction of light ✓.

3. Provide the functions of E and G respectively. (2)

   E – contains rods and cones which are the receptors sensitive to light. These allow for an image to form ✓.

   G – pigments absorb excess light to prevent reflection ✓; blood vessels supply oxygen and nutrients ✓ (any one)

4. Write down the letter only for the part that

   is able to change shape to refract light F ✓ (1)

   provides structural support to the eyeball A ✓ (1)

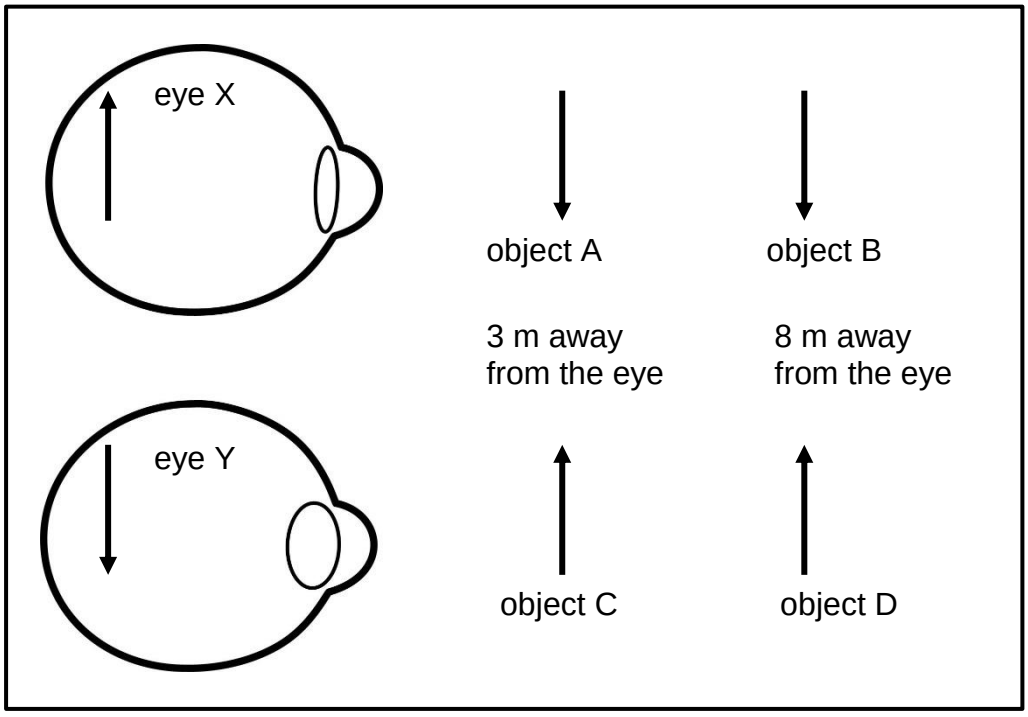
5. Name and describe the process which involves the iris controlling the amount of light entering the eye when a person is exposed to bright light. (5)

- pupillary mechanism ✓
- the circular muscles of the iris contract ✓
- the radial muscles of the iris relax ✓
- the pupil constricts ✓
- the amount of light entering the eye is reduced ✓

(14)

Activity 6: Accommodation

The diagram shows two eyes (X and Y) focused on objects (represented by arrows) at different distances from the eye. Objects A and C were 3 metres away from the eye. Objects B and D were 8 metres away from the eye. The diagrams below are not drawn to scale.



1. Write down the letter of the object that:
   a) eye Y is focussed on C ✓ (1)
   b) eye X is focussed on B ✓ (1)
2. a) Name the eye defect which results in the inability of the eye Y to focus on the object D. (1)

   short-sightedness ✓

   b) Name the type of lens used to rectify the defect in 2(a) above. (1)

   concave lens ✓

3. Identify and describe the process that allows eye Y to form a clear image on the retina. (5)

accommodation

ciliary muscles contract while the suspensory ligaments become slack ✓; tension on the lens decreases ✓; the lens becomes more convex (bulgy) ✓; this causes light rays to bend more ✓; a clear image is formed on the retina ✓

Activity 7: Case study on visual defects

Read the extract below and answer the questions that follow.

> Kayise, age 60, had failed her vision test for her driver's license. All her life she had suffered from extreme near-sightedness. In fact, without her glasses she was legally blind. When she was denied her license renewal, Kayise came to Dr Nobadula for help. During an examination, it became clear that Kayise had cataracts in both eyes. A cataract is a clouding of the lens in the eye, which reduces vision. The lens is inside the eye and focuses light onto the retina at the back of the eye, where an image is recorded. The lens also adjusts the eye's focus. The lens is made of mainly water and protein. The latter is arranged so the lens stays clear, allowing light to pass through it. Yet, with age, the protein may form clumps that cloud the lens. This is a cataract. The best solution to Kayise's situation was surgery that removed the cataracts and implanted tiny artificial lenses within the eye. Dr Nobadula conducted this procedure. Today, for the first time in her life, Kayise enjoys 20/20 vision without glasses.

1. Explain what is meant by near-sightedness. (2)

The person is able to see near objects ✓ but cannot see objects more than 6 metres away clearly ✓

2. Which type of lens can be used to correct this defect? (1)

Concave lenses ✓

3. What causes the clouding to form in the lens? (1)

The protein found in the lens forms clumps that cloud the lens ✓.

4. In your opinion, what would happen to Kayise if she did not have surgery? (1)

She would eventually become totally blind ✓.

5. Explain the cause of Kayise's near-sightedness and why she did not need glasses after surgery. (4)

Kayise's near-sightedness is caused by a lens that cannot adjust adequately to focus the incoming light (is no longer supple) ✓, and is cloudy ✓. During surgery, the lens is removed and replaced with an artificial lens ✓. As a result, Kayise could see clearly without glasses ✓.

6. Describe what happens to light rays in the eye of a person with cataracts. (3)

Light rays enter through the cornea but are not able to be refracted through the lens correctly ✓. The clouding prevents the refraction of light ✓ and the light rays are not focused onto the yellow spot ✓, which leads to vision becoming blurry.

7. Name one other visual defect not mentioned in the extract above. (1)

Long-sightedness / astigmatism (✓ - any one)

(13)

The human ear

Key terminology

organ of Corti	receptor for hearing
crista (plural: cristae)	receptor which detects changes in speed and direction of the head
maculae	receptor which detects changes in the position of the head
semicircular canals	canals which are fluid filled and contain receptors
ampulla (plural: ampullae)	swelling at the base of the semicircular canals which contain the crista
vestibule	structure made up by the sacculus and utriculus, these contain the maculae
grommet	small structure inserted into the tympanic eardrum; has a hole through the middle to allow air flow

Learners must know the structure and functioning of the human ear.

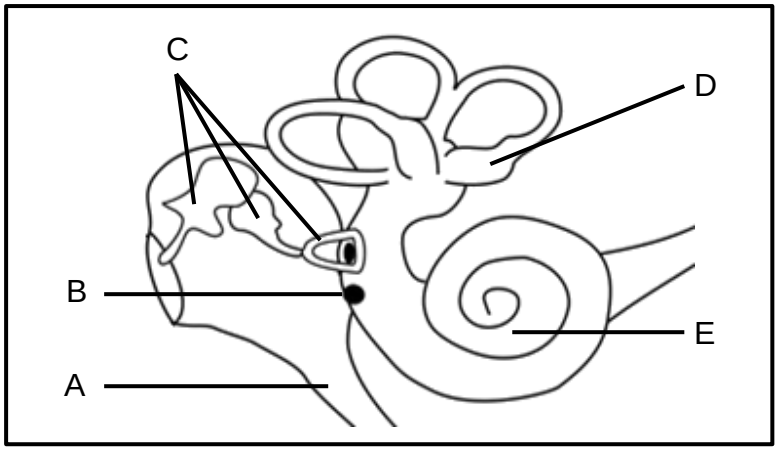
Learners must have a good understanding of which receptors are responsible for hearing and balance and know the structures of each.

Learners should be able to apply their knowledge to various scenarios.

The defects associated with the ear such as middle ear infection and deafness must be understood and the treatment thereof must be discussed. The side effects of these defects such as needing speech therapy and using sign language should be discussed with learners.

Activity 8: The human ear

The diagram below represents a part of the human ear.



1. Identify:
   a) part A — Eustachian tube ✓ (1)
   b) part B — round window ✓ (1)
   c) part E — cochlea ✓ (1)
2. Provide the collective name for the bones found at C. State two functions of these bones. (3)

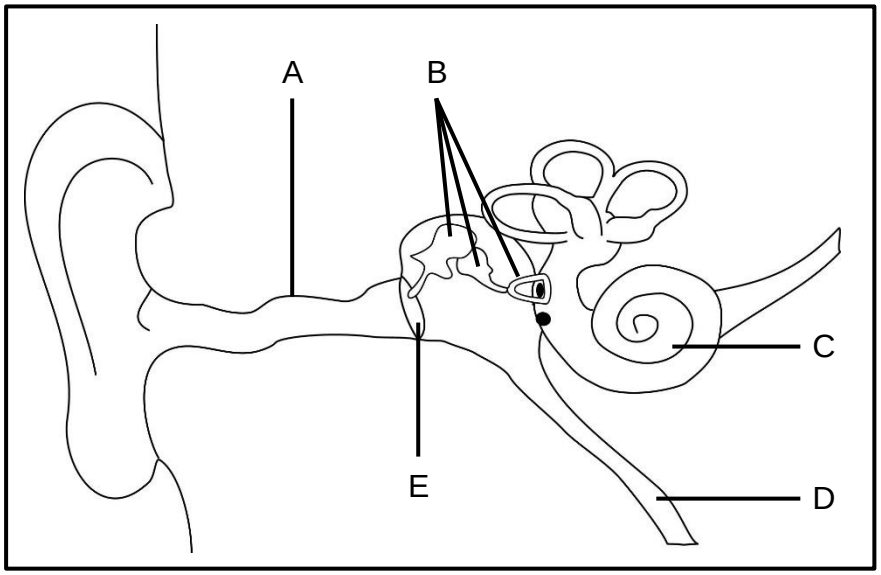
   ossicles ✓; transmits vibrations from the tympanic membrane to the inner ear ✓; amplify the vibrations ✓
3. The structure labelled D contains receptors.
   a) Name the receptors found in this structure. (1)

      crista ✓
   b) Give the stimulus to which these receptors respond. (2)

      they detect changes ✓ in speed and direction of the body ✓

Activity 9: Balance, hearing and defects

Study the diagram below, then answer the questions that follow.



1. Write down the letter only of the part which:

   a) amplifies the vibrations from the tympanic membrane B ✓ (1)

   b) contains the receptors for hearing C ✓ (1)

2. Otosclerosis is a genetic form of hearing loss caused by the stirrup becoming immovable. Explain how this conditions may cause hearing loss. (3)

   The stirrup cannot vibrate ✓ and the vibrations will not be transmitted to the inner ear ✓. The organ of Corti will not be stimulated ✓ resulting in hearing loss.

3. Two devices used to treat deafness are hearing aids and cochlear implants. The way in which they function is given in the table below:

Device	Method of functioning
hearing aid	receives, transmits and amplifies sound vibrations
cochlear implant	receives sound vibrations and converts them into an electrical impulse which is transmitted directly to the auditory nerve

   By referring to the diagram above, give the letters of the parts where the defect may occur:

   a) when a hearing aid is used (2)

   E – tympanic membrane ✓, or B – ossicles ✓

   b) when a cochlear implant is used (1)

   C – the cochlea ✓

4. The vestibular branch of the auditory nerve transmits impulses from the semi-circular canals to the cerebellum. Explain the consequence if this nerve is infected by a virus. (2)

   A virus or inflammation of the inner ear disrupts the transmission of sensory information from the ear to the brain ✓. This may result in dizziness, difficulties with balance, with hearing, and lead to a ringing in the ears (tinnitus) ✓.

Summary

- The brain is protected by the cranium and the meninges.
- The brain is divided into different regions, each of which have their own functions.
- The cerebrum, which is the largest part of the brain, functions to control voluntary actions, detects the five senses and allows for higher thought processes.
- The structure which divides the cerebrum into left and right hemispheres is the corpus callosum which allows for communication between the hemispheres.
- The cerebellum functions to control the co-ordination of voluntary actions and maintains balance, posture and muscle tone.
- The medulla oblongata, which is found as the lower part of the brain stem, is surrounded by cerebrospinal fluid. It is the relay centre of impulses between the brain and spinal cord and functions to control breathing, swallowing, heart beat and peristalsis as well as less important reflexes such as coughing, blinking, salivating and sneezing.
- The spinal cord is protected by 33 individual vertebrae, the meninges with cerebrospinal fluid and cartilage. It extends from the medulla oblongata to the lower back and allows for the attachment of spinal nerves.
- Each spinal nerve has a dorsal root and a ventral root.
- The spinal cord contains reflex centres which function automatically and allow for impulses to be transmitted between receptors, the brain and effectors.
- The peripheral nervous system is found outside of the central nervous system and is divided into the somatic nervous system (voluntary) and the autonomic nervous system (involuntary). It consists of 12 pairs of cranial nerves and 31 pairs of spinal nerves.
- The peripheral nervous system functions to transmit impulses from receptors to the central nervous system via the sensory neurons and from the central nervous system to effectors via motor neurons.
- The autonomic nervous system is subdivided into the sympathetic nervous system and the parasympathetic nervous system. These function antagonistically to maintain homeostasis.
- Nerves are made up of neurons. There are three types of neurons: sensory, interneuron and motor.

- The sensory neurons respond to stimuli and generate impulses which are transmitted to the central nervous system. In the central nervous system, the impulse is interpreted. The motor neurons transmits impulses from the central nervous system to the effector to bring about a response.
- All neurons are made up of a dendrite, a cell body and an axon. The dendrites receive impulses, the cell body contains a nucleus and controls the metabolism of the neuron, and impulses are then directed down the axon.
- Neurons are in contact with each other via synapses.
- A reflex action is a quick, automatic response to stimuli. A reflex arc is the functional unit of the nervous system and is the pathway taken by impulses to bring about a response.

  Stimulus → Receptors → Sensory neuron → Enters dorsal root of the spinal nerve → Interneuron → Motor neuron → Exits ventral root of the spinal nerve → Effector → Response

- This allows for the body to respond quickly, protecting it from harm.
- There are many diseases which affect the nervous system, Alzheimer's Disease and Multiple Sclerosis are two such diseases with severe symptoms and side effects.
- Depending on where an injury may occur in the nervous system, the effect will vary. Scientists hope that in the future, stem cells may be used to repair nerve tissue that has been damaged.
- The eye contains cones and rods which respond to the stimulus of light. The vision from each eye overlaps allowing for three dimensional imaging.
- The eye is adapted to allow for vision at different distances (accommodation) and to have vision under different light conditions (pupillary mechanism).
- There are many defects associated with the eye, including short-sightedness, long-sightedness, astigmatism and cataracts.
- The ears contain the organ of Corti which responds to sound to allow for hearing and the maculae and crista which are receptors for balance.
- There are many defects associated with the ear including middle ear infections and deafness.

End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A- D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Which one of the following pathways represents a reflex arc?

A Muscle → spinal cord → brain
B Effectors → spinal cord → receptor
C Receptor → spinal cord → brain
D **Receptor → spinal cord → muscle ✓✓**

1.1.2 The process in the eye which allows a person to adapt to see at different distances:

A Pupillary mechanism
B Astigmatism
C **Accommodation ✓✓**
D Cataracts

1.1.3 Which one of the following is a function of the medulla oblongata?

A Controls voluntary muscular activities.
B Processing all sensory information.
C Balance and co-ordination.
D **Controls heartbeat and breathing. ✓✓**

1.1.4 A patient experiences slight visual and speech disturbance after a serious head injury. Which section of the brain has possibly been damaged?

A **Cerebrum ✓✓**
B Cerebellum
C Hypothalamus
D Medulla oblongata

1.1.5 A person can feel pain in his legs but cannot move his legs. This is as a result of damage to the…

A sensory neuron.
B sensory and motor neuron.
C **motor neuron**. ✓✓
D sensory and interneuron.

(5 × 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The part of the neuron that conducts impulses away from the cell body.
Axon ✓

1.2.2 The part of the autonomic nervous system that tends to slow down organ activity.
Parasympathetic ✓

1.2.3 A disorder of the nervous system that is characterised by the breakdown of the myelin sheath of neurons.
Multiple sclerosis ✓

1.2.4 A group of nerve cell bodies of neurons that form a swelling outside the spinal cord.
Ganglion ✓

1.2.5 The part of the nervous system that is made up of cranial and spinal nerves.
Peripheral nervous system ✓

1.2.6 A collective name for the membranes that protect the brain.
Meninges ✓

1.2.7 The part of the brain that maintains muscle tone, balance and equilibrium.
Cerebellum ✓

1.2.8 The division of the nervous system that controls involuntary actions and has a homeostatic function.
Autonomic nervous system ✓

1.2.9 The structure that connects the left and right hemispheres of the brain, allowing communication between them.
Corpus callosum ✓

1.2.10 A disorder of the central nervous system that leads to memory loss in humans.
Alzheimer's disease ✓ (10 x 1) = (10)

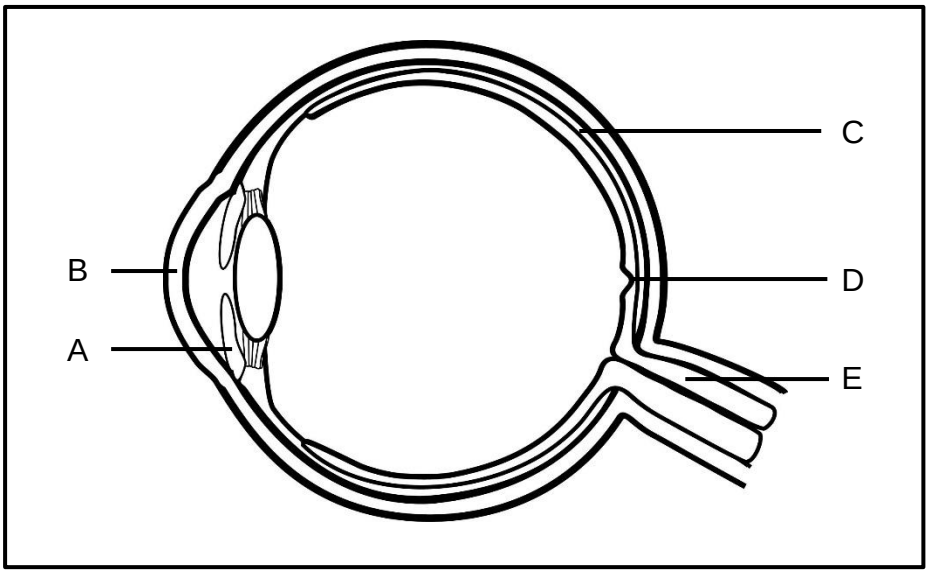
1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 The part of the brain that connects the two hemispheres	A: corpus callosum B: cerebellum
1.3.2 A brain disorder that results in memory loss	A: Alzheimer's disease B: Multiple sclerosis
1.3.3 A structure in the nervous system that detects a stimulus.	A: effector B: receptor
1.3.4 The part of the autonomic nervous system that controls involuntary actions.	A: sympathetic B: parasympathetic
1.3.5 The central nervous system is made up of the…	A: cranial and spinal nerves B: brain and spinal chord

(5 x 2) = (10)

1.3.1 **A only ✓✓**
1.3.2 **A only ✓✓**
1.3.3 **B only ✓✓**
1.3.4 **Both A and B ✓✓**
1.3.5 **B only ✓✓**

1.4 The diagram below represents the structure of the human eye



Give the letter and name of the part which:

1.4.1 Regulates the amount of light entering the eye (2)

A – Iris ✓✓

1.4.2 Supplies food and oxygen to the eye (2)

C – Choroid ✓✓

1.4.3 Transmits impulses to the brain (2)

E – Optic nerve ✓✓

1.4.4 Contains cones and is the area of clearest vision (2)

D – Yellow spot ✓✓

1.4.5 Assists in the refraction of light rays (2)

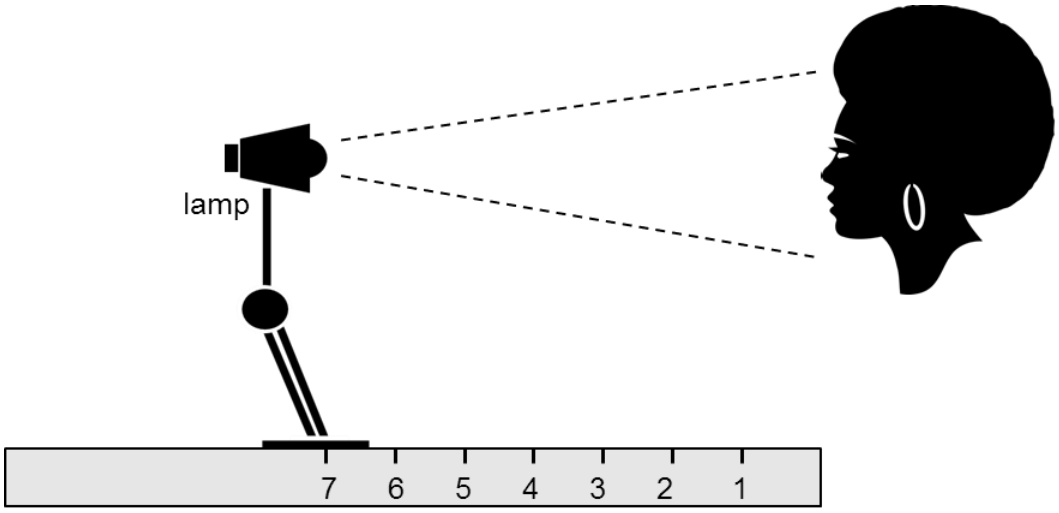
B – Cornea ✓✓ (10)

Section A: [40]

Section B

Question 2

2.1 An experiment was conducted to investigate the diameter of the pupil to change in light intensity. A lamp was placed at various distances from the face of a person as shown. Study the diagram and the table of data below to answer the questions.



2.1.1 Suggest a possible hypothesis at the start of the investigation. (2)

An increase / decrease in light intensity will cause the diameter of the pupil to decrease / increase. ✓✓

OR

The diameter of the pupil will increase / decrease as the light intensity increases / decreases ✓✓

OR

An increase in light intensity will have no effect on the diameter of the pupil. ✓✓

2.1.2 Which two factors should be kept constant during the investigation? (2)

The same person's eyes should be tested ✓

The same lamp should be used ✓

The experiment should be done at the same time of day ✓

The experiment should be done in the same environment ✓

(Any two × 1)

2.1.3 Identify the:

a) Independent variable (1)

The light intensity ✓

b) Dependent variable (1)

Diameter of the pupil ✓

The table below shows the diameter of the pupil when the light was placed at various distances from the person's face.

Position of lamp	Diameter of the pupil (mm)
1	1,2
2	1,8
3	2,4
4	3,0
5	3,6
6	4,2
7	4,8

2.1.4 Based on the available data would you accept, or reject the initial hypothesis? (1)

Accept / Reject based on learners initial response in question 2.1.1 ✓

2.1.5 What conclusion can be deduced from the available data? (2)

As light intensity decreases, the diameter of the pupil increases ✓✓

2.1.6 Suppose the lamp was moved from position 7 to position 2. Describe the mechanism that caused the change in the diameter of the pupil. (4)

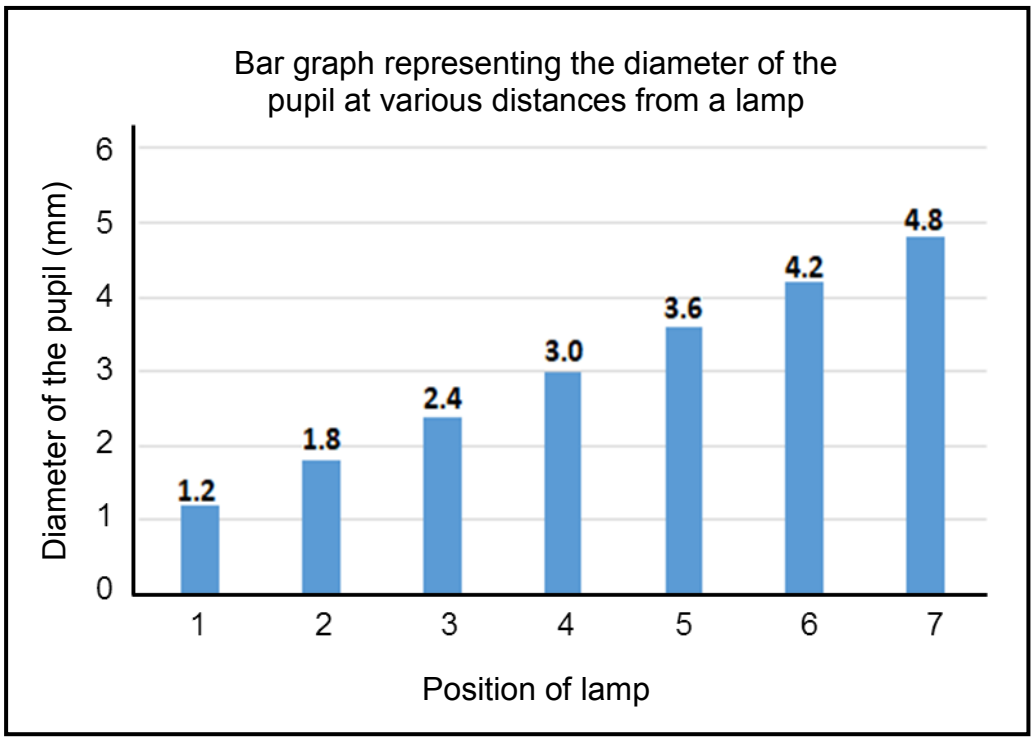
Pupillary mechanism

- The circular muscles of the iris contract ✓
- The radial muscles relax ✓
- The pupil constricts ✓ / becomes smaller
- The amount of light entering the eye is reduced ✓

2.1.7 Name the process mentioned in question 2.1.6. (1)

Pupillary mechanism ✓

2.1.8 Plot a bar graph to represent the data gathered during this investigation. (7)



Guidelines for assessing graph

Correct type and drawing of graph	✓
Title of graph	✓
Correct label of x- and y-axes	✓
Correct scale of x- and y-axes	✓
Plotting of points	✓ for plotting 1 to 3 bars ✓✓ for plotting 4 to 5 bars correctly ✓✓✓ for plotting 6 to 7 bars correctly

NOTE:

- If the wrong type of graph is drawn, 1 mark will be lost for: Correct type of graph.

- If labels of the axes are transposed then 2 marks will be lost for: Correct label AND scale for x-and y-axes.

(21)

2.2 Read the extract below and answer the questions that follow.

A LINK BETWEEN CONCUSSION AND BRAIN DAMAGE

In 2002 a former American football player was found dead in his truck. The doctor who handled the autopsy discovered that the football player had severe brain damage and that his death was caused by repeated blows to the head or repeated concussions. He called this disorder chronic traumatic encephalopathy (CTE).

A more recent study was conducted that involved the brains of 165 people who played football at high school, college or professional level. The study found evidence of CTE in 131 of the brains.

(adapted from www.wikipedia.org and www.theatlantic.com)

2.2.1 The part of the brain affected by CTE is the cerebrum. State two possible symptoms of this disorder. (2)

- Loss of higher thought processes ✓ memory / judgment / problem solving / any example
- Loss of one or more of the senses ✓ / loss of smell / hearing / any example
- Loss of voluntary actions ✓ / paralysis (any two × 1)

2.2.2 State one way in which the brain is protected. (1)

- The skull ✓ / cranium
- The meninges ✓ / name of ALL three i.e. pia mater, arachnoid mater and dura mater
- The cerebrospinal fluid ✓ (any one × 1)

2.2.3 Explain why CTE does not usually affect essential life processes such as breathing or heart rate. (2)

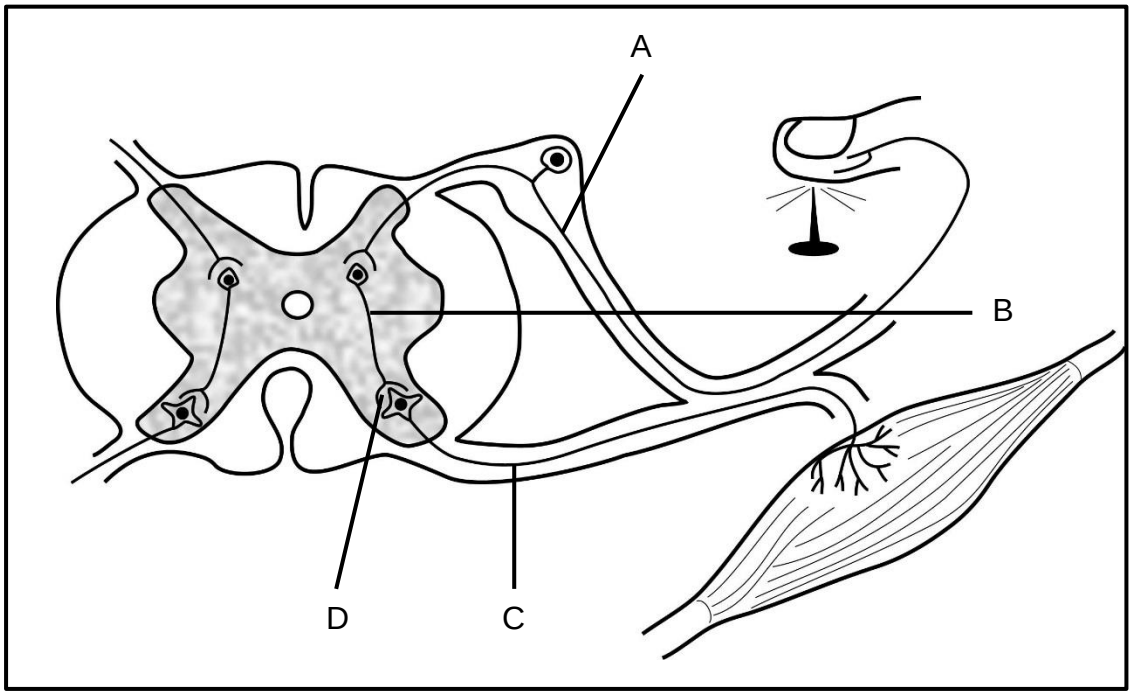
- CTE mainly affects the cerebrum ✓
- Therefore, the medulla oblongata ✓ which controls breathing and heart rate
- Is generally not damaged. ✓ (any two)

(5)

[26]

Question 3

3.1 Study the diagram of a reflex arc below.



3.1.1 What is a reflex action? (1)

A reflex action is a rapid ✓, automatic response ✓ to a stimulus.

3.1.2 Label the following:

a) The functional connection at **D**. (1)

Synapse ✓

b) Neuron **B** (1)

Interneuron ✓ / connector neuron

3.1.3 State the significance of the microscopic gap indicated by **D** (1)

It ensures that the impulse moves in one direction only ✓

It prevents continuous stimulation of neurons ✓

It ensures that the impulse is transmitted from the sensory neuron to the motor neuron. ✓ (any one)

3.1.4 Write down in the correct order, the letters only of the neurons involved from the time a stimulus is received until a response takes place. (2)

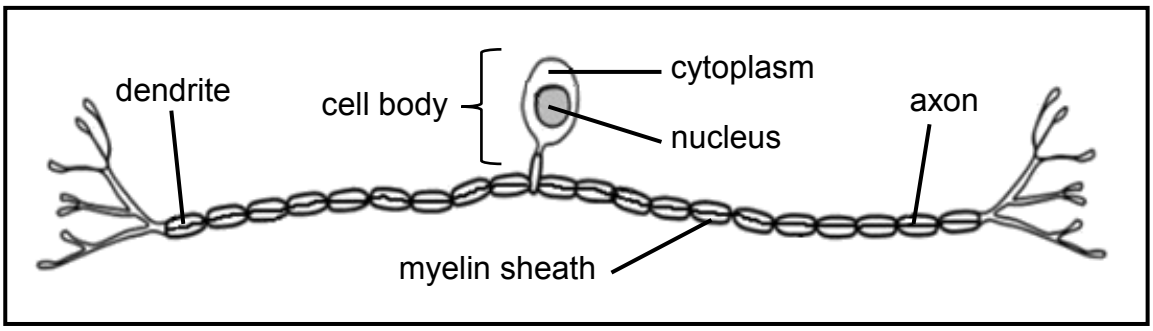
A → B→ C ✓✓

3.1.5 Explain the consequences for a reflex action if neuron **C** is damaged. (2)

The person will be able to receive a stimulus ✓ / feel pain but will not be able to respond to it ✓

3.1.6 Draw a labelled diagram to represent the structure of neuron **A**. (5)

sensory neuron



Guidelines for marking:

Criteria	Mark allocation
Caption	✓
Any THREE labels	3 × ✓

(13)

3.2 Read the article below and answer the questions that follow.

The discovery of Alzheimer's Disease (AD)

Alzheimer's disease (AD) is an irreversible brain disease that slowly destroys brain cells, causing loss in memory and thinking skills serious enough to interfere with daily life. The symptoms first appear after the age of 60, making it the most common cause of dementia among older people.

It is a neurological brain disorder named after a German physician, Alois Alzheimer, who first described it in 1906. He noticed changes in the brain of a woman who had died after an unusual mental illness. Her symptoms included memory loss, language problems and strange behaviour. After she died he inspected her brain and found many clumps and tangled bundles of nerve fibres.

Abnormal clumps, tangled-bundles of nerve fibres and the loss of connections between brain cells are all symptoms of the disease. AD gets worse over time, with death due to organ failure usually occurring two to eight years after the start. At present there is no cure.

adapted from: www.ALZinfo.org. Fischer Centre for Alzheimer's Research Foundation.

The table below presented by the World Health Organisation shows the percentage of people in the general western population affected by AD in different age groups.

Age groups (years)	Percentage patients with AD (%)
65-69	1,4
70-74	2,8
75-79	6,6
80-84	11,1
85+	23,6

3.2.1 What was the percentage increase of patients with AD, between the oldest two age groups? Show all calculations. (1)

(23,6 – 11,1) / 11,1 = 112,6% ✓

3.2.2 What seems to be the earliest symptoms of Alzheimer's disease? (1)

Memory loss ✓

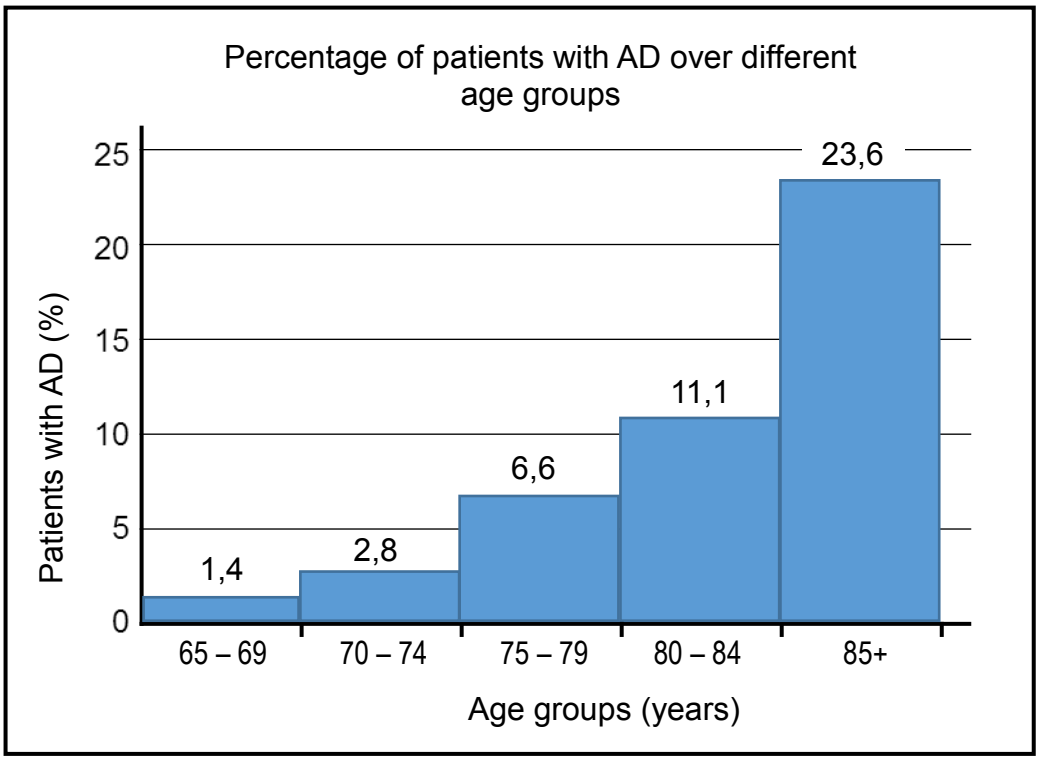
3.2.3 Describe what the person's brain looked like when it was dissected. (2)

It had abnormal clumps ✓ and tangled nerve fibres ✓

3.2.4 What is the main cause of death in a person with AD? (1)

Organ failure ✓ / infections

3.2.5 Use the table to plot a histogram to show the occurrence of AD. (6)



Guidelines for assessing graph

Correct type	✓
Title of graph	✓
Correct label of x- and y-axes	✓
Correct scale of x- and y-axes	✓
Plotting of points	✓ for plotting 1 to 3 bars ✓✓ for plotting all 5 bars correctly

NOTE:

- If the wrong type of graph is drawn, 1 mark will be lost for: Correct type of graph.
- If labels of the axes are transposed then 2 marks will be lost for: Correct label AND scale for x-and y-axes.

(11)

[24]

Section B: [50]

Total marks: [90]

Cognitive levels distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1		✓			2
1.1.2	✓				2
1.1.3	✓				2
1.1.4		✓			2
1.1.5		✓			2
	4	6			10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	10				10
1.3.1	✓				2
1.3.2	✓				2
1.3.3	✓				2
1.3.4	✓				2
1.3.5	✓				2
	10				10
1.4.1			✓		2
1.4.2			✓		2
1.4.3			✓		2
1.4.4			✓		2

1.4.5			✓		2
			10		10
2.1.1				✓	2
2.1.2			✓		2
2.1.3			✓		2
2.1.4			✓		1
2.1.5				✓	2
2.1.6		✓			4
2.1.7	✓				1
2.1.8		✓	✓	✓	7 (3+2+2)
	1	7	7	6	21
2.2.1		✓			2
2.2.2	✓				1
2.2.3		✓			2
	1	4			5
3.1.1	✓				1
3.1.2	✓				2
3.1.3		✓			1
3.1.4			✓		2
3.1.5				✓	2
3.1.6			✓	✓	5 (4+1)
	3	1	6	3	13
3.2.1			✓		1
3.2.2	✓				1
3.2.3	✓				2
3.2.4	✓				1
3.2.5		✓	✓	✓	6 (2+2+2)
	4	2	3	2	11
	33	19	26	11	90

CHAPTER 7: THE HUMAN ENDOCRINE SYSTEM AND HOMEOSTASIS

Overview

Time allocation: 2 ½ weeks (10 hours)

This chapter consists of the following sections:

1. Introduction
2. Key concepts and terminology
3. Endocrine glands
4. Negative feedback
5. Endocrine system disorders
6. Thermoregulation in humans
7. Summary
8. End of topic exercises

Introduction

In this chapter we look at some of the important human mechanism's which enable us to respond and react to the outside environment and with this to maintain a constant internal environment. Our responses are controlled by the nervous and endocrine systems and to an extent, the immune system. The working together of these systems helps to maintain stability within the organism and ultimately this protects us.

The human nervous system, covered in a previous chapter, responds to stimuli rapidly, using electrical impulses and neurotransmitters. The endocrine response tends to be slower and the effect is long lived. Endocrine glands are situated throughout the body and each produce and release specific hormones into the blood stream. An effector organ is targeted, and a response is initiated. When endocrine organs are either over- or under stimulated, endocrine disorders are observed.

Tissue fluid in which our cells are bathed, constitute the internal environment. The conditions within cells would therefore depend on the conditions within the internal environment. When faced with changes from either the external or internal environment the human body controls this impact and homeostasis is achieved.

Homeostatic control involves a negative feedback system. The basic elements of these systems include a specific variable, a receptor, a control centre and an effector. Without homeostasis, organs, systems and ultimately, the whole organism can be negatively impacted. The important variables and homeostatic mechanisms that will be discussed are: the maintenance of water, salts, thyroxin, glucose and CO_2 concentration, as well as the regulation of body temperature.

Key concepts and terminology

- Humans are constantly exposed to changes within their internal, and from their external, environment
- The human body has internal mechanisms to try and regulate these changes
- This regulation is under central control
- The endocrine system is made up of ductless endocrine glands that secrete chemical messengers called hormones directly into the blood stream
- The human body also has ducted exocrine glands that discharge their chemical secretions into an organ or an area where they are needed
- Hormones are carried to target organs where a response is initiated
- Control is in most cases achieved using a negative feedback mechanism
- Negative feedback is the bodies attempt at returning to a ‘normal’ state
- It is a self-regulating mechanism which leads to adjustments within the body
- It enables humans to maintain homeostasis
- Important elements of this mechanism include receptors, a control centre and effectors
- Hormones play an important role in maintaining homeostasis
- The osmotic balance of cells and tissue fluid is determined by water and salt concentrations
- Metabolic reactions are affected by changes in the body temperature as well as by changing concentrations of CO_2, glucose, H_2O and salt within the cells and tissue fluid
- In cold and hot weather, the human body adjusts to maintain its internal temperature at around 36,8°C.
- Situations where balance or homeostasis is not maintained leads to endocrine diseases or disorders

Key terminology

endocrine system	a system responsible for chemical co-ordination and regulation of various activities in the body
homeostasis	a process of maintaining a constant internal environment (blood and tissue fluid) within the body.
hormones	chemical messengers in the body. they travel in the bloodstream and cause an effect elsewhere in the body
negative feedback	operate in the human body to detect changes or imbalances in the internal environment and to restore balance
osmoregulation	regulation of the water balance in the internal environment
osmotic pressure	a measure of the concentration of solutes (e.g. salt, glucose) present in a solution; this may determine whether a cell loses or gains water
antagonistically	to work in opposite ways; if one hormone causes an increase of a substance, the other hormone will cause a decrease of that substance, e.g. insulin and glucagon
thermoregulation	the control of the body temperature to keep it as close to 37°C as possible
endothermic	relates to an organism that generates heat internally through a metabolic process to maintain a constant body temperature
vasoconstriction	narrowing of blood vessels
vasodilation	widening of blood vessels
evaporation	heat loss when sweat changes into water vapour on the surface of the skin
conduction	transfer of heat between objects which are in contact
convection	as warm air rises it is replaced by cooler air
radiation	heat transfer between two objects which are not in contact

Endocrine glands

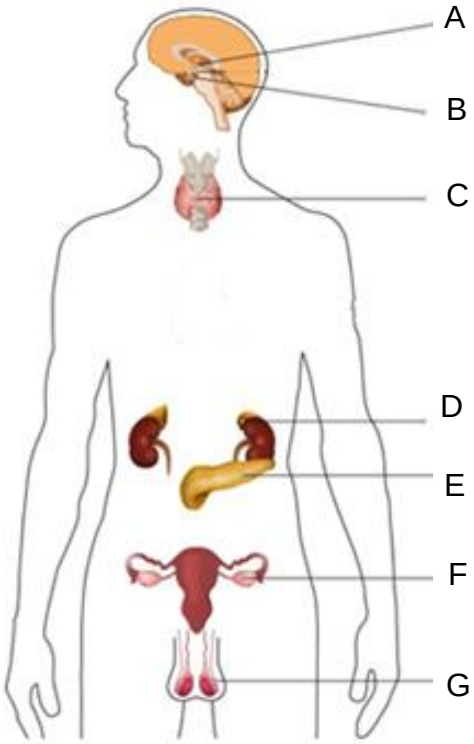
The learners must be able to distinguish between an exocrine and endocrine gland. Ducts / ductless, secretions into organ or surface / secretions into bloodstream are examples of each. Discuss the pancreas as an exocrine (digestive) and endocrine (glucose regulating hormones) gland. Table 1 in the learner text shows the main differences and Figures 1 and 2 represent these glands.

The endocrine system is made up of glands that produce hormones, organic substances (proteins and fats) that travel in the bloodstream to a target area or organ. Learners should be able to locate the most important endocrine glands in the

human body, state what hormones each gland secretes and what the function of these hormones are. Figure 3 in the learner text is a summary.

Activity 1: Endocrine glands and their hormones

The diagram shows some of the human endocrine glands. Name the glands labelled A to G, and list the hormone/s produced by each gland. (20)



A – hypothalamus ✓; ADH ✓

B – pituitary gland ✓; GH ✓, TSH ✓, FSH ✓, LH ✓, prolactin ✓ – any four for a total of 20 marks for Activity 1.

C – thyroid gland ✓; thyroxin ✓

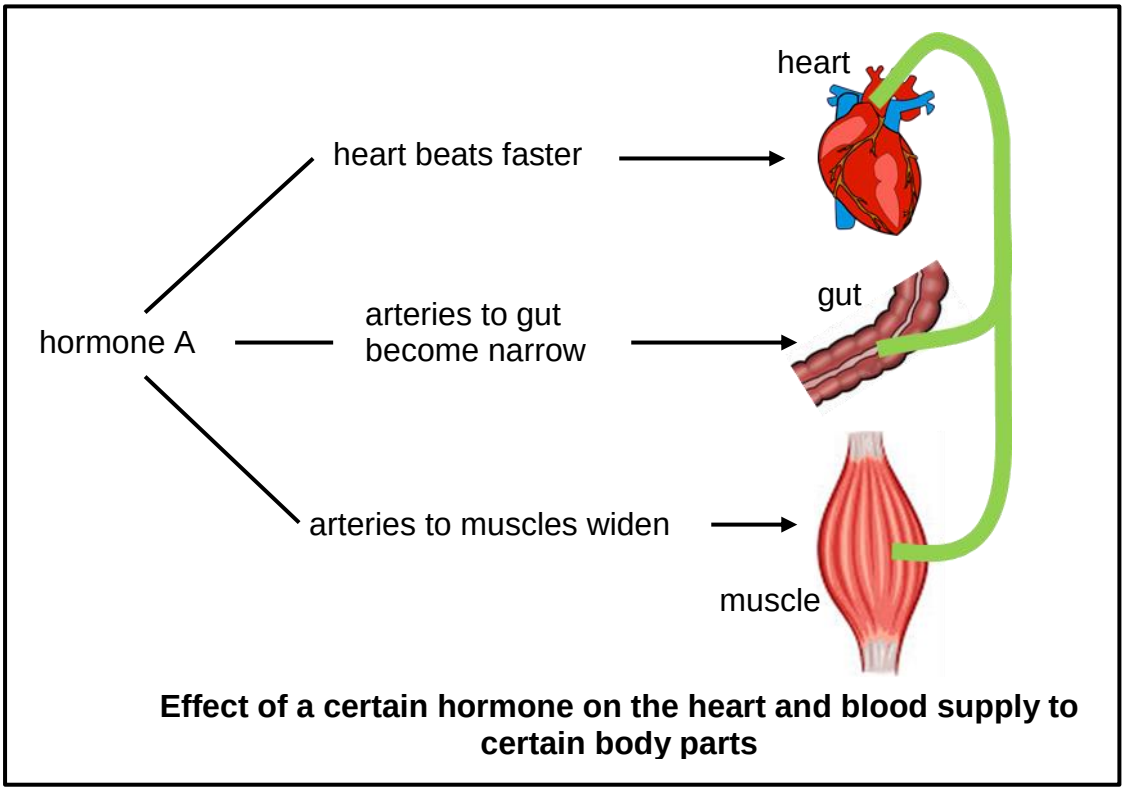
D – adrenal gland ✓; adrenalin ✓ and aldosterone ✓

E – pancreas ✓; glucagon ✓, insulin ✓

F – ovaries ✓; oestrogen ✓ and progesterone ✓

G – testes ✓; testosterone ✓

Activity 2: Effects of a hormone



Effect of a certain hormone on the heart and blood supply to certain body parts

1. Give the name of hormone A. (1)

   Adrenalin ✓

2. State the position of the gland that secretes hormone A in the human body. (1)

   On top of each kidney ✓

3. Explain the importance of the narrowing of the arteries to the gut under emergency conditions. (4)

   Less blood flow to the gut ✓, as it is not involved in responding to the emergency ✓. Blood flow is redirected to organs involved in responding to the emergency ✓ such as: skeletal muscles to improve muscle tone ✓ or heart muscle, for the heart to beat faster so as to increase the transport of oxygen and glucose needed for increased respiration ✓.

4. Name the part of the human eye that is also affected by hormone A. (1)

   Pupil ✓

5. Explain the influence of hormone A on the part named in question 4. (3)

   The pupil dilates ✓ to allow more light to enter the eye ✓ for clear vision ✓ during the emergency situation.

(10)

Negative feedback

Negative feedback is a reaction that causes a decrease in function. It occurs in response to some kind of stimulus. Often it causes the output of a system to be lessened; so, the feedback tends to stabilize the system. This can be referred to as homeostasis.

The following variables and homeostatic mechanisms are discussed.

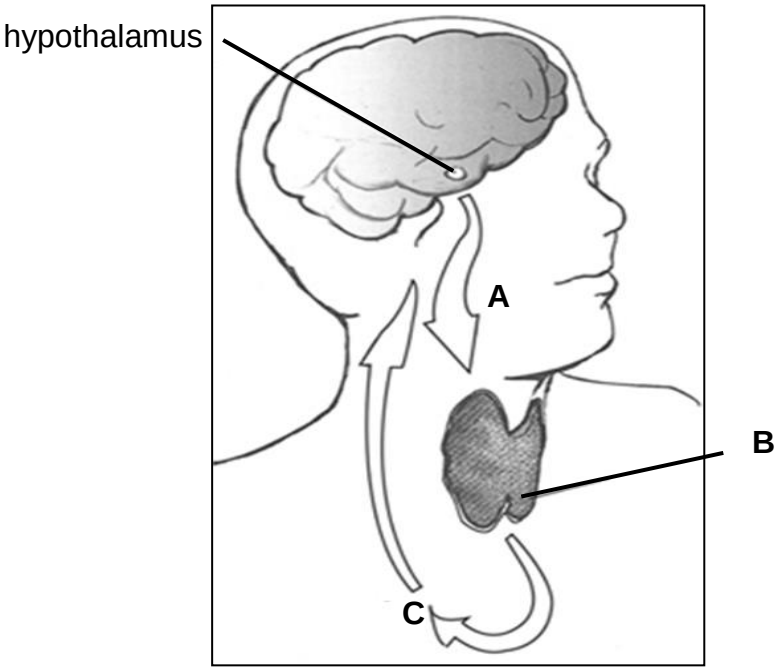
- the maintenance of water levels
- the maintenance of salt levels
- the regulation of thyroxin levels
- the maintenance of glucose levels
- the regulation of the CO_2 concentrations
- the regulation of body temperature

Table 5 in the learner text is a summary of the six important homeostatic controls' humans possess to ensure stability within their internal environment.

Learners should have a good understanding of the various mechanisms for maintaining homeostasis.

Activity 3: A negative feedback mechanism

The diagram below represents the interaction between two important endocrine glands. The hypothalamus is found at the base of the brain while the gland labelled B is present towards the front of the neck.



1. Provide a label for gland **B**. (1)

   Thyroid gland ✓

2. Name hormone **C**. (1)

   Thyroxin ✓

3. State one function of hormone **A**. (1)

   Stimulate the thyroid gland ✓

4. Describe the negative feedback mechanism that operates when the level of hormone C is higher than normal in the blood. (5)

   High levels of thyroxin are detected ✓ by the pituitary gland which leads to a decrease ✓ in the secretion of TSH. Thyroid activity is slowed down ✓ / less thyroxin is produced. Thyroxin levels drop to normal ✓

   (8)

Endocrine system disorders

In certain situations, hormone secretions are disrupted, and this affects homeostasis. Endocrine glands can either secrete too little (hyposecretion) or too much (hyper-secretion) hormone. If this persists a person would be diagnosed with an endocrine disorder.

The focus in this section is on disorders associated with the pituitary glands, the thyroid glands and the pancreas. Learners should be able to identify the various disorders, their causes and symptoms and for diabetes, possible treatment options.

Activity 4: Research task on endocrine disorders

You will need to research an endocrine disorder caused by the hypersecretion or hyposecretion of an endocrine hormone. You will present your information in either a PowerPoint Presentation or a poster format. The following needs to be covered:

1. What hormone is involved with this disorder?
2. Where is the hormone produced?
3. What are the target organs/structures of the hormone?
4. How is the secretion of the hormone regulated/controlled?
5. What is the normal function of the hormone?
6. How does the hormone contribute to homeostasis?
7. What are the causes of hypersecretion or hyposecretion
8. What are the symptoms and effects of hypersecretion or hyposecretion?

9. What are the treatments for under or over activation of the hormone pathway?

Your teacher will provide you with a mark scheme. N.B.: Citation of at least 3 references.

Answers will depend on the hormone you choose to investigate. Your teacher will provide you with a mark scheme. A possible rubric (mark scheme) is given here:

Component	Learners mark	Possible mark
Hormone? Where produced? Target area/organ/s		5
Regulation of hormone		5
Normal function of hormone (homeostatic level)		5
Cause of disease (hyper/hypo)		5
Symptoms/Effects		5
Treatment		5
References (at least 3 and correctly cited)		5
Presentation skills (Quality of PowerPoint or poster)		10
Knowledge in answering questions		5
TOTAL		50

Thermoregulation in humans

Teaching tools

Thermoregulation (54.40 minutes): https://youtu.be/G_NL6raRL5U

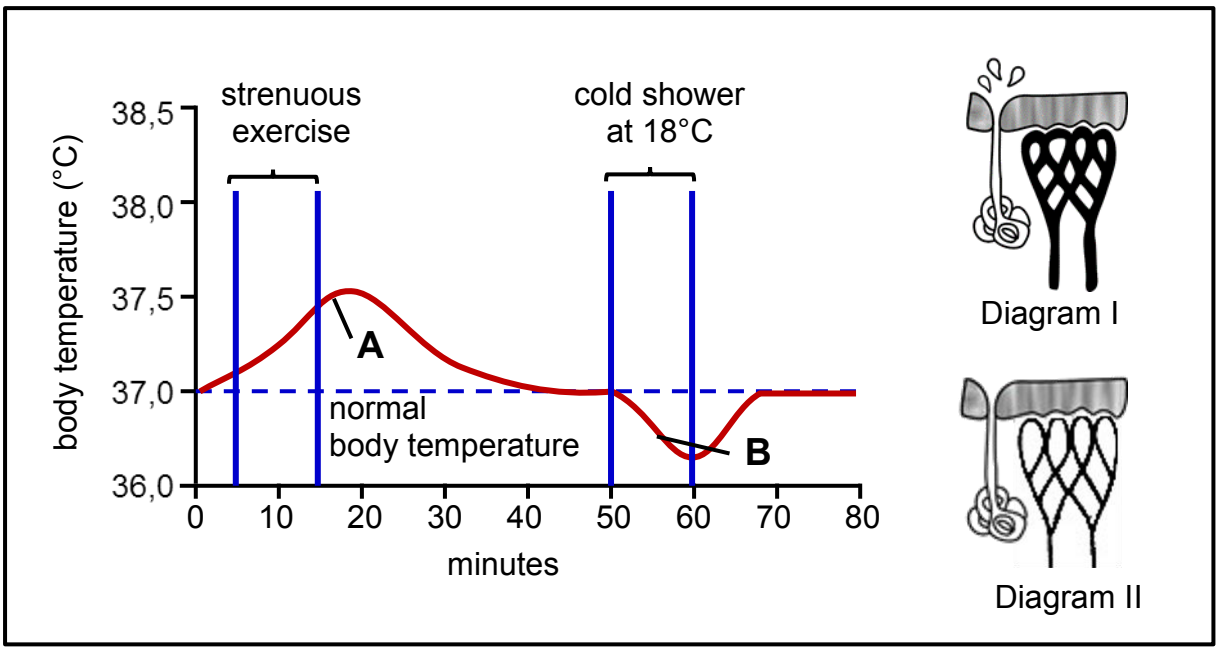
Thermoregulation in circulatory system: https://youtu.be/C_LiAEjuIIc

We humans are endothermic. Our bodies can maintain a constant body temperature of approximately **36,8°C** even when outside temperatures are very high or very low.

It is vital that this happens to ensure that all metabolic functions continue. If body temperature were to drop below 36°C, metabolic processes will slow down and if it were to be raised above a safe level of 37,5°C, enzymes become denatured (cannot function effectively) and many body functions will be disabled.

The body controls its internal core temperature in a process called thermoregulation. The skin is a very important thermoregulator, and its reaction to hot or cold conditions is explained in Table 14 in the learner text.

Activity 5: Body temperature



1. Which part of the brain responds to the temperature changes that occur at A and B on the graph? (1)

   Hypothalamus ✓

2. What was the maximum temperature reached? (1)

   37,5°C ✓

3. For what period of time did the person engage in strenous exercise? (1)

   10 minutes

4. Why should body temperature not be allowed to fluctuate too much? (2)

   Most human activity is controlled by enzymes ✓ and enzymes require optimum temperatures to function ✓

5. Which diagram (I or II) would represent the condition of the skin after 15 minutes? (1)

   Diagram I ✓

6. Explain your answer to question 5. (2)

   Blood vessels dilated to bring more blood to the surface ✓ and so more heat will be lost ✓ OR Increased sweat production ✓ which will cool down the body ✓

(8)

Summary

- Endocrine glands secrete hormones directly into the bloodstream.
- The hormones travel to their target organs.
- Hormones can have a stimulatory or inhibitory affect.
- Hormones have specific functions and influence only their target organs / areas.
- The pituitary gland controls many of the other endocrine glands.
- Hypo- and hypersecretion of hormones leads to endocrine disorders.
- The human body is always striving towards maintaining a stable internal environment.
- Homeostatic mechanisms are implemented to ensure that systems return to normal levels.
- Many of these are negative feedback systems.
- Effective homeostatic mechanisms discussed in this section involve the regulation of the levels of water, salt, CO_2, thyroxin and glucose as well as the regulation of body temperature.
- Slight changes in normal levels are detected by receptors.
- Impulses are sent to a central point.
- An effector is stimulated to respond.
- Hormones are an important part of homeostatic control.
- The factor or variable is then returned to the normal levels.
- If homeostasis is not maintained this can impact negatively on the health of an individual.

End of topic exercises

Section A

Question 1

1.1 Various options are given as possible answers to the following questions. Choose the correct answer and write only the letter (A – D) next to the question number (1.1.1–1.1.5). For example, 1.1.6 D.

1.1.1 The outermost layer of the human skin is the

A hypodermis

B **epidermis** ✓✓

C adipose

D dermis

1.1.2 Which of the following CORRECTLY represents the events involved in the secretion and action of ADH (antidiuretic hormone)?

	Water level in blood relative to normal	Amount of ADH produced relative to normal	Amount of water reabsorbed by kidneys
A	Increase	Increase	Decrease
B	Increase	Decrease	Increase
C	**Decrease**	**Increase**	**Increase** ✓✓
D	Decrease	Decrease	Decrease

1.1.3 A worker spent about ten minutes in a walk-in freezer. Below are some of the changes that occurred in his body in response to the drop in external temperature.

(i) Blood vessels in the skin constrict
(ii) Brain reacts
(iii) Skin temperature changes
(iv) Temperature receptors in the skin detect changes

Which ONE is the correct sequence in which the changes occurred?

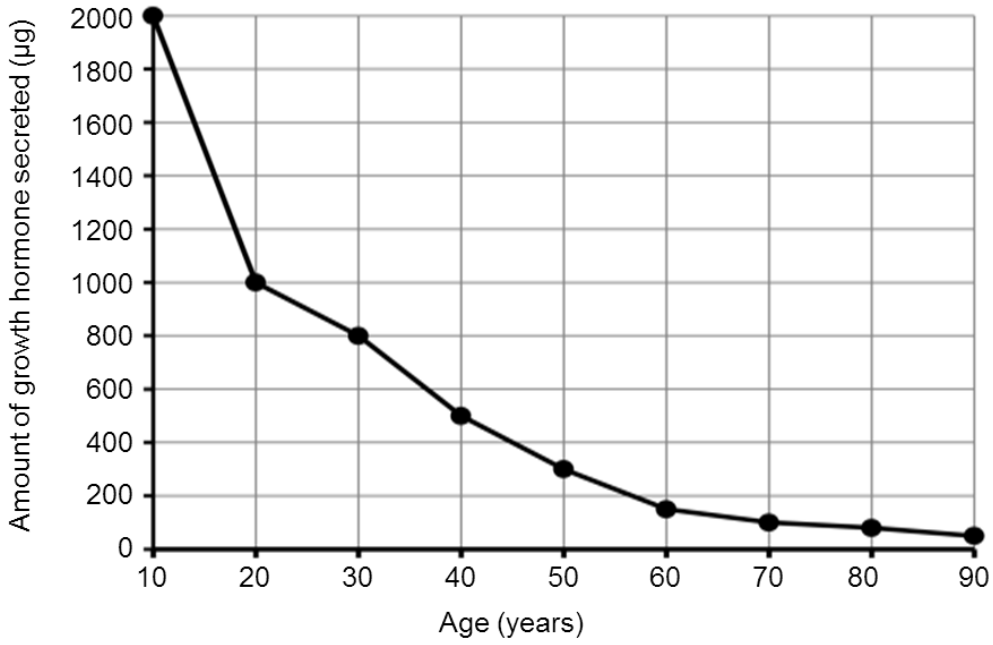
A (ii) → (i) → (iii) → (iv)

B (iii) → (i) → (iv) → (ii)

C **(iv) → (ii) → (i) → (iii)** ✓✓

D (iv) → (i) → (ii) → (iii)

1.1.4 The graph below shows the relationship between the production of growth hormone and age



A general conclusion can be drawn from the results is that …

A growth hormone is not secreted after the age of 50 years
B **the amount of growth hormone secreted decreases with age ✓✓**
C the amount of growth hormone secreted increases with age
D the amount of growth hormone secreted remains stable over time

1.1.5 Which ONE of the following hormones prepares the body to react to emergency situations?

A Insulin
B Aldosterone
C **Adrenalin ✓✓**
D Growth hormone

(5 × 2 = 10)

1.2 Give the correct term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The maintenance of a constant internal environment.

Homeostasis ✓

1.2.2 The maintenance of a constant body temperature.

Thermoregulation ✓

1.2.3 Animals that control body temperature from within.

Endotherms ✓

1.2.4 Widening of blood capillaries in the skin.

Vasodilation ✓

1.2.5 Method by which most heat is lost through sweating.

Evaporation ✓

1.2.6 Control centre for temperature regulation in the brain.

Hypothalamus ✓

1.2.7 A hormone that stimulates milk production in human females.

Prolactin ✓

1.2.8 A disease that results from the bodies inability to produce insulin.

Diabetes ✓ Type 1

1.2.9 An enlarged thyroid gland that is caused by a deficiency of iodine.

Goitre ✓

1.2.10 The secretions that are produced in small quantities by the endocrine glands.

Hormones ✓

(10 × 1 = 10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 Carbon dioxide levels	A: medulla oblongata B: cerebellum
1.3.2 Vasodilation	A: 10°C B: 40°C
1.3.3 Increase the loss of heat in mammals	A: Sweating B: Shivering
1.3.4 Cells and tissue fluid	A: internal environment B: external environment
1.3.5 A gland that has a duct to carry its secretion to where it is needed	A: sweat glands B: pancreas

(5 × 2 = 10)

1.3.1 **A only ✓✓**
1.3.2 **B only ✓✓**
1.3.3 **A only ✓✓**
1.3.4 **A only ✓✓**
1.3.5 **Both A and B ✓✓**

1.4 Complete the table below

	Stimulus/variable	Receptor/s	Control centre	effector
osmoregulation	**1.4.1**	osmoreceptors	hypothalamus	**1.4.9**
salt concentration	salts e.g. Na^+ (high and low)	cells in glomeruli	**1.4.6**	kidneys
carbon dioxide concentration	CO_2 (high and low)	**1.4.4**	**1.4.7**	lungs
thyroxin	**1.4.2**	pituitary gland	thyroid gland	body cells
glucose	blood glucose (high and low)	**1.4.5**	pancreas	**1.4.10**
thermoregulation	**1.4.3**	thermo-receptors	**1.4.8**	skin

(10 × 1 = 10)

1.4.1 H_2O levels (high and low) ✓
1.4.2 high or low metabolic rate ✓
1.4.3 high or low core body temperature ✓
1.4.4 chemoreceptors ✓
1.4.5 islets of Langerhans ✓
1.4.6 adrenal glands ✓
1.4.7 medulla oblongata ✓
1.4.8 hypothalamus ✓
1.4.9 kidneys ✓
1.4 10 liver ✓

1.5 Read the following and answer the questions that follow:

South Africa's very own mountaineer and adventurer

Sibusiso Vilane, became a South African hero after summiting the Earth's highest mountain, Mount Everest, in 2003. He started training in mountaineering by climbing the peaks of the Drakensberg mountains.

Ex-President, Thabo Mbeki, said the following on the summit day "In this, he has shown the heights we can scale in life if we put our shoulder to the wheel. Sibusiso you have done us proud".

He continues to climb great peaks throughout the world and is actively involved in humanitarian work.

Mountaineers like Sibusiso Vilane put their bodies under severe physiological strain when climbing up to heights of 8000 metres. The higher the altitude the greater the stress on the human body. The availability of oxygen decreases and hypoxia (oxygen starvation) can set in. It literally takes your breath away. Average temperatures are well below freezing. Climbers can become disorientated, develop acute mountain sickness (AMS) and get frostbite on their extremities. Many climbers have died on Everest.

Athletes in extreme sports like this will try and acclimatize to these adverse conditions by preparing the body for the physiological challenges. The sherpas who assist climbers live at high altitudes all year around and their bodies have adapted well to the low oxygen levels and to the adverse cold.

This leaves us with words from one of Sibusiso Vilane's motivational speeches: "Every person has their own 'Everest' to climb".

1.5.1 With low oxygen levels what other atmospheric gas levels could become a problem in the system of climbers like Sibusiso? (1)

High CO_2 ✓

1.5.2 How are the levels of the gas that you have given as your answer in 1.5.1 detected? (1)

In the respiratory centre of medulla oblongata ✓/ receptors in the carotid artery

1.5.3 In a flow diagram show how their bodies will try and compensate and adapt to the levels of the gas in their system. (3)

High CO_2 (stimulus) > respiratory centre (receptor) > breathing muscles > increased rate of breathing > normal levels of CO_2 (sequence ✓✓ and in a flow diagram ✓)

1.5.4 The climbers will lose a lot of heat through radiation to the environment. What conscious measures would you suggest they take to reduce this loss? (1)

Cover as much skin as possible with clothes, hats, gloves ✓

1.5.5 Suggest a way in which climbers could prepare their bodies for the challenges of high altitudes, i.e., how in their training could they acclimatize to the conditions on Everest? (1)

Spend more time in places that are higher up and climb smaller peaks e.g. Drakensberg ✓

1.5.6 What is the term used when the oxygen availability in the blood decreases? (1)

Hypoxia ✓

1.5.7 During an expedition led by Sibusiso in 2016, to the highest peak in Africa, Mount Kilimanjaro, one of our other famous sportsmen, Gugu Zulu, a rally driver, tragically fell ill and died. It seemed that he developed the onset of flu while on the climb. The fact that Gugu was not 100% healthy would have worsened the impact of high altitude and cold. One of the symptoms of a flu is fever. Which homeostatic mechanism that has been covered in this section would have been affected and briefly explain how the normal levels had been altered by the flu? (2)

Thermoregulation ✓. Flu causes high temperature ✓ / fever.

Since it was cold outside, instead of retaining heat, Gugu lost heat to the environment ✓. This affected enzyme activity and metabolism ✓ leading to death. (any two)

(10)

[50]

Section B

Question 2

2.1 Study the table below that shows the volume of urine produced by six different people on a hot day and on a cold day and answer the questions that follow.

Person	Volume of urine produced in cm^3	
	Hot day	**Cold Day**
1	430	890
2	350	1060
3	270	930
4	560	1280
5	400	680
6	390	1 160
Average		1 000

2.1.1 Calculate the average volume of urine in cm^3 produced on the hot day. Show all workings. (2)

Average volume on hot day = (430+350+270+560+400+390) / 6 ✓
= 400 ✓

2.1.2 What can you deduce from the difference between the average volume of urine produced on the hot day and the average volume of urine produced on the cold day? (2)

600 cm^3 ✓ more urine is produced on a cold day ✓

2.1.3 Explain why, on a hot day, less water is lost from the body as urine. (2)

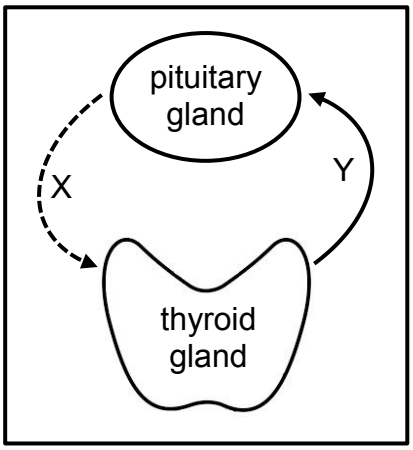
On a hot day a person would sweat. This loss of water would be detected by osmosreceptors in the hypothalamus ✓ and ADH levels will rise to ensure that water reabsorption into the blood capillaries around the kidneys ✓

2.1.4 The composition (make-up) of urine depends on several factors. Name two factors that would affect the composition of urine. (2)

Water content of the blood (over-hydrated or dehydrated) ✓. Salt content of the blood ✓.

(8)

2.2 The diagram below represents a negative feedback mechanism. X and Y represent hormones secreted by the respective glands.



2.2.1 What is the role of any negative feedback mechanism in the human body? (1)

To establish homeostasis in an organism ✓/ to maintain a constant internal environment

2.2.2 Identify hormone X. (1)

Thyroid stimulating hormone (TSH) ✓

2.2.3 Explain the consequences for a person if hormone Y remained abnormally high for extended periods of time. (3)

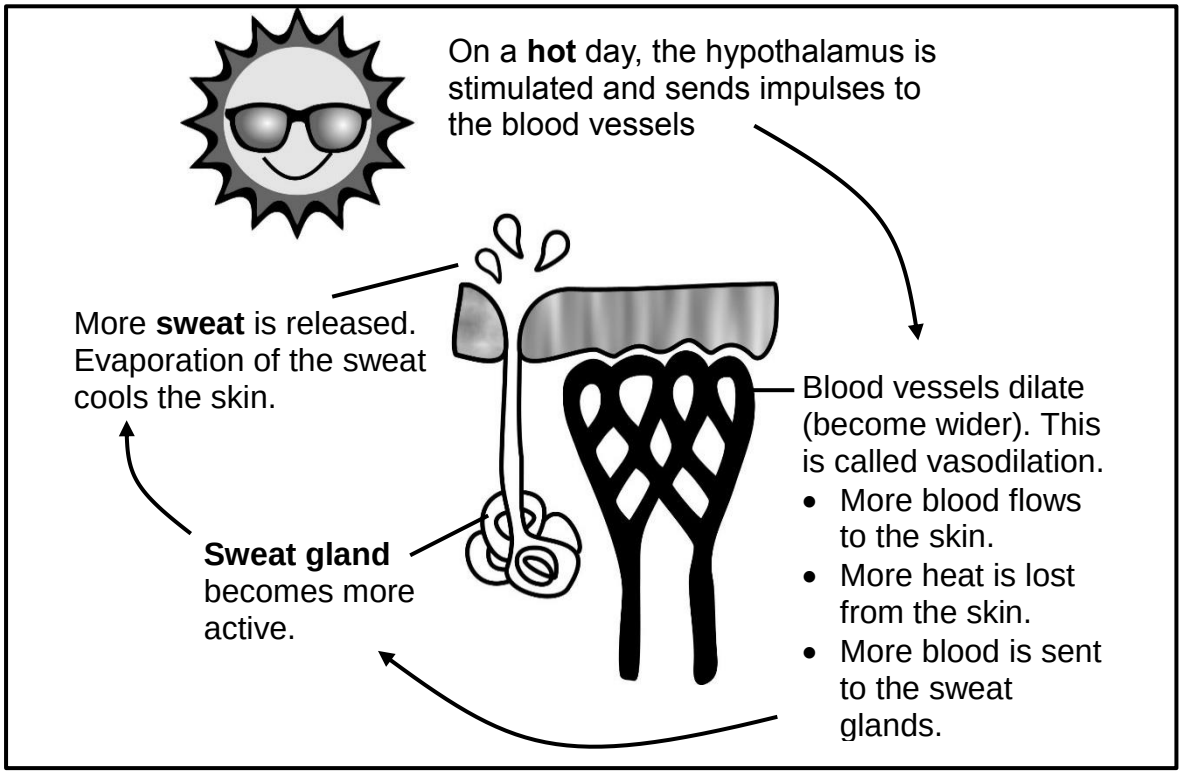
If thyroxin ✓ levels remain high the basal metabolic rate (BMR) will be high ✓ and the person would get tired and the heart will be under strain ✓.

(5)

2.3 Triathletes competing in the Iron Man series are sometimes on the road and in the water for a total of over 8 hours. They will get very hot and thirsty. They will sweat profusely and will drink fluids continually through the race. They often do not need to urinate. Which two mechanisms would these athletes use to regulate their body temperature and fluid loss during the race. (2)

Thermoregulation ✓ and osmoregulation ✓

2.4 The picture below shows how important the skin is in controlling the core body temperature in very warm conditions.



Using the information provided **draw** your own picture, alongside the one given, showing how the skin controls body temperature in cooler conditions.

(5)

Cold day-hypothalamus stimulated ✓, vasoconstriction – blood vessels narrow ✓, reduced blood flow to skin ✓, sweat gland less active ✓, drawing showing constricted blood vessels ✓

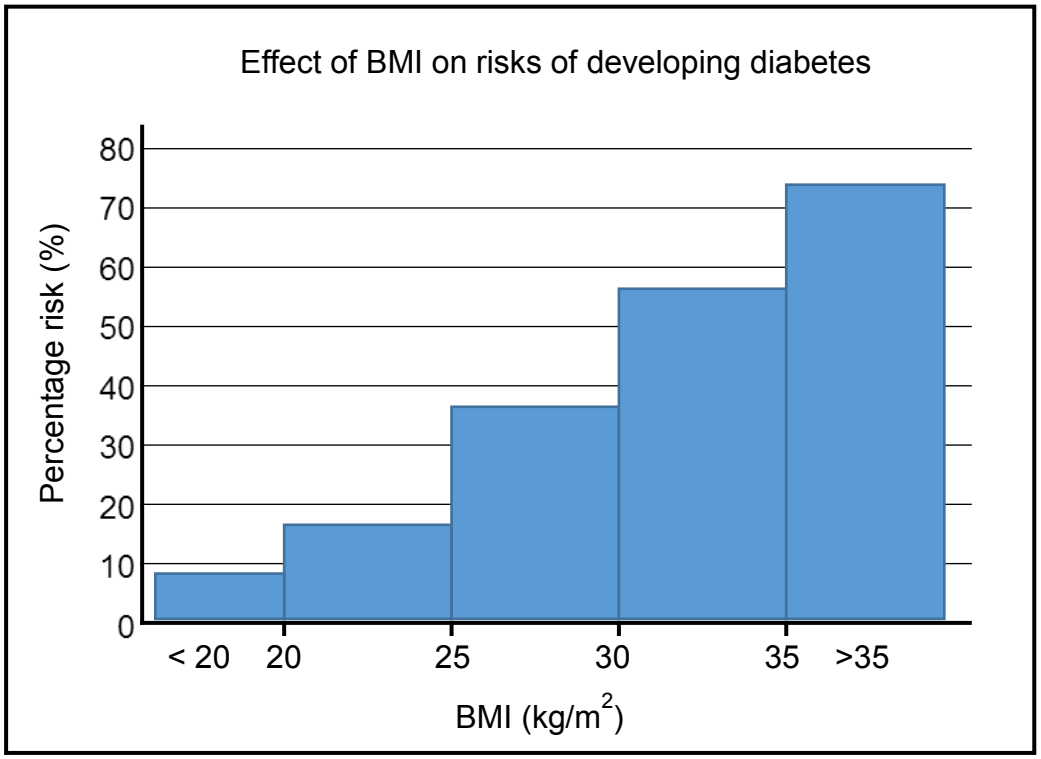
[20]

Question 3

3.1 Type 2 diabetes is often linked to body mass index (BMI). The higher your BMI the greater your chances of developing Type 2 diabetes. The table below shows the results of an investigation into the BMI of women and their risk of developing diabetes (statistics from the American Diabetes Association)

BMI (mass÷height) (kg/m^2)	Relative risk of developing diabetes in females (%)
< 20	7,5
20 – 25	18,0
26 – 30	37,5
31 – 35	57,0
> 35	74,5

3.1.1 Draw a histogram using the data in the table. (5)



Histogram heading ✓– Effect of BMI on risks of developing diabetes

X-axis ✓– BMI (kg/m^2)

Y-axis ✓-% risk.

Bars drawn together. ✓ Scale ✓

3.1.2 Which hormone is deficient in people with diabetes? (1)

Insulin ✓

3.1.3 In which organ is this hormone produced? (1)

Pancreas ✓

3.1.4 Name another hormone that regulates the amount of glucose found in the blood. (1)

Glucagon ✓

3.1.5 Write up your own conclusion from the data given in the table and from your histogram. (2)

The higher the BMI the higher the risk of developing diabetes ✓✓

(10)

3.2 Lerato carried out an investigation to determine the effect of exercise on skin temperature. She asked 100 learners in her school to participate in the investigation. The sample consisted of 100 girls of the same age. The investigation was done as follows:

- The learners were divided into two groups of 50 each (Group A and B).
- The skin temperature was measured for all the participants.
- Group A was asked to run around the sports field for 10 minutes.
- Group B was asked to remain seated on the benches next to the field for 10 minutes.

After 10 minutes the skin temperature of all participants was measured, and the average was calculated for each group (A and B).

3.2.1 In this investigation, identify the:

(a) independent variable (1)

Level of exercise ✓

(b) dependent variable (1)

Skin temperature ✓

3.2.2 State two steps that Lerato took into consideration during the planning of the investigation. (2)

Lerato decided on the …

- Gender to use (girls) ✓
- Age of the participants ✓
- Type of exercise ✓
- Duration of the exercise ✓
- Sample size to use ✓ (any two)

3.2.3 What is the expected results for the participants in group A? (1)

Their skin temperature would rise ✓

3.2.4 Name the one factor that Lerato kept constant during the investigation. (1)

The duration of activity / non-activity ✓ / 10 minutes

3.2.5 Which of the two groups (A or B) will release more sweat? (1)

A ✓

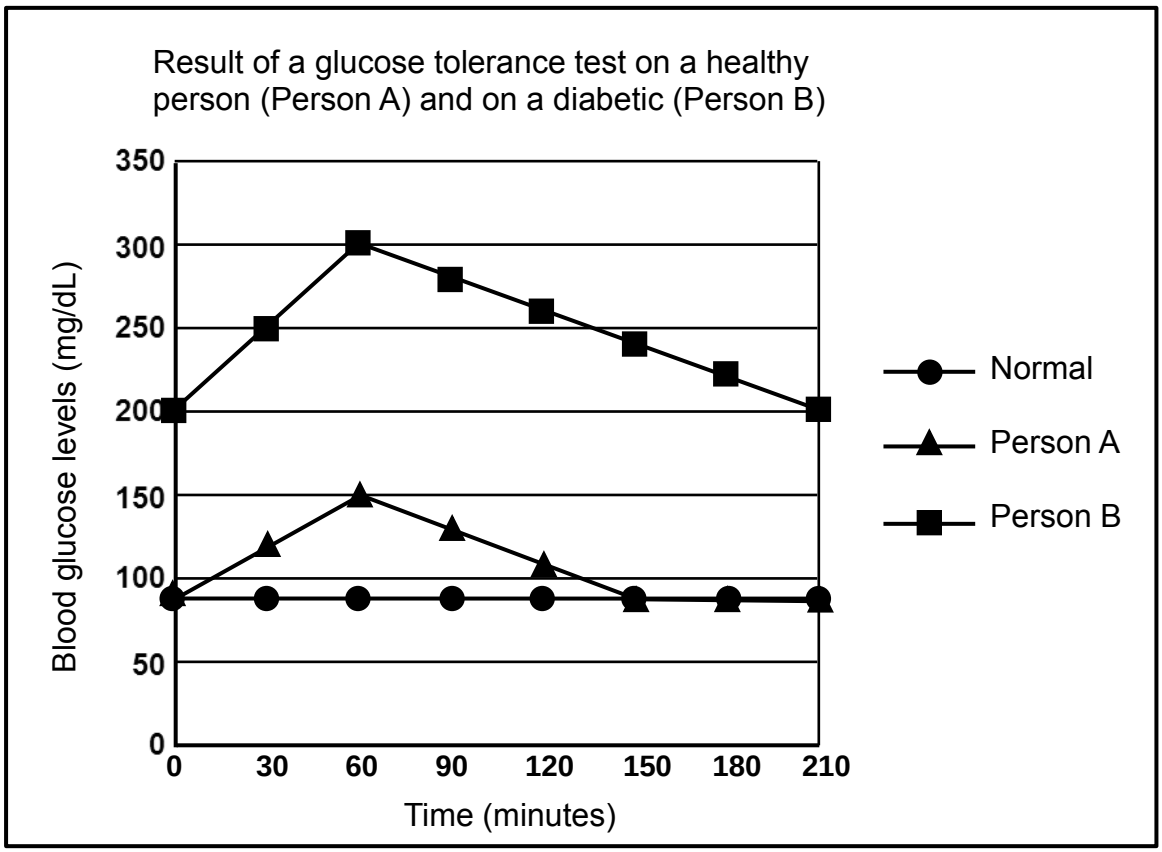
3.2.6 Explain why sweat production will increase in the group identified in question 3.2.5. (3)

Vasodilation occurs ✓. Warm blood comes to the surface of the skin ✓. The learners skin temperature would rise. Heat is lost to the environment ✓. More sweat is produced for cooling by evaporation ✓

(any three × 1)

(10)

3.3 The graph below shows a comparative glucose test on a healthy and a diabetic person. (In the glucose tolerance test the people being tested would have not eaten for at least 8 hours before the test. When they arrive at the hospital/clinic/doctor's rooms their blood is taken, and glucose levels are tested. They then drink a glucose solution and their blood is taken and tested every 30 minutes over at least a 3 hour period.)



3.3.1 What values does the graph accept as normal blood glucose levels? (1)

80 – 90 mg/dL ✓

3.3.2 What is the difference in blood glucose levels at time 0 between person A and person B? (2)

200 – 80 ✓ = 120 mg/dL ✓

3.3.3 What do you think happened in person A to cause the glucose levels to drop after 60 minutes? (2)

The pancreas started secreting insulin ✓ and glucose was converted to glycogen ✓

3.3.4 Name three lifestyle precautions should person B be taking? (3)

A diet with reduced sugar ✓.

Exercise frequently ✓.

Small meals taken frequently ✓.

3.3.5 Besides lifestyle changes what treatment is available for diabetics to regulate their glucose levels? (2)

Inject insulin ✓. Have insulin pumps inserted ✓.

(10)

[30]

Section B: [50]

Total marks: [100]

Cognitive levels distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1	✓				2
1.1.2		✓			2
1.1.3		✓			2
1.1.4		✓			2
1.1.5	✓				2
	4	6			10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	10				10
1.3.1	✓				2
1.3.2	✓				2
1.3.3	✓				2
1.3.4	✓				2
1.3.5		✓			2
	8	2			10
1.4.1	✓				1
1.4.2	✓				1
1.4.3	✓				1
1.4.4	✓				1
1.4.5	✓				1
1.4.6	✓				1
1.4.7	✓				1
1.4.8	✓				1
1.4.9	✓				1
1.4.10	✓				1
	10				10
1.5.1	✓				1
1.5.2	✓				1
1.5.3			✓		3

1.5.4		✓			1
1.5.5		✓			1
1.5.6	✓				1
1.5.7				✓	2
	3	2	3	2	10
2.1.1			✓		2
2.1.2		✓			2
2.1.3			✓		2
2.1.4		✓			2
		4	4		8
2.2.1		✓			1
2.2.2	✓				1
2.2.3			✓		3
	1	1	3		5
2.3		✓			2
		2			2
2.4			✓		5
			5		5
3.1.1			✓		5
3.1.2	✓				1
3.1.3	✓				1
3.1.4	✓				1
3.1.5			✓		2
	3		7		10
3.2.1 a - b	✓				2
3.2.2				✓	2
3.2.3			✓		1
3.2.4			✓		1
3.2.5		✓			1
3.2.6				✓	3
		1	2	7	10
3.3.1		✓			1
3.3.2			✓		2
3.3.3		✓			2
3.3.4				✓	3
3.3.5		✓			2
		5	2	3	10
TOTAL	41	23	26	10	100

CHAPTER 8: PLANT RESPONSES TO THE ENVIRONMENT

Overview

Time allocation: 1 week (4 hours)

This chapter includes the following sections:

1. Introduction
2. Key concepts and terminology
3. Plant hormones
4. Tropisms
5. Weed control
6. Plant defence mechanisms
7. Summary
8. End of topic exercises

Introduction

In this unit we discuss how plants respond to changes in the environment and how plant growth is controlled by internal and external factors.

Learners will be introduced to various plant hormones which regulate plant growth. Plant hormones are responsible for plant growth and dictate whether a plant grows upward or downward in response environmental stimuli e.g. light and gravity.

We review the different types of plant hormones that promote and inhibit plant growth, and look at how these hormones can be used in the control of weeds.

We will then discuss how plants defend themselves from being eating by insects and other herbivores.

Key concepts and terminology

- Growth of plants are controlled by internal factors such as hormones and by external factors such as sunlight, water, gases and touch.

- Plant hormones affect how a plant grows by stimulating plant cells to divide, to enlarge or to stop growing.
- Hormones such as auxin and gibberellins stimulate plant growth.
- The hormone abscisic acid inhibits (prevents) plants from growing and is often used to control the growth of weeds.
- Tropism means 'to turn' and occurs when external stimuli affect the direction in which a plant grows and develops.
- Phototropism is when plants grow either towards or away from the light and is controlled by the presence of auxins.
- Geotropism is when plants grow roots downward in the soil due to gravity and is controlled by the presence of abscisic acid.

Key terminology

hormone	a chemical messenger produced in one part of the plant and has an effect on another part of the stem
tropism	growth or turning movement of a plant or part of a plant in response to external stimulus
phototropism	growth of part of a plant in response to the stimulus of light
geotropism	growth of a plant in response to gravity
unilateral light	light coming from one side or direction
herbicide	a substance that is toxic to plants and destroy unwanted vegetation (weeds)
apical bud	the growing point of the stem located at the tip of the stem
apical dominance	when auxins produced at the tip of the stem inhibit the growth of the branches closer to the tip of the stem

Plant hormones

The learner is introduced to the idea that plants are able to respond to their environment with the help of plant hormones. Learners need to know the three basic plant hormones: auxins, gibberellins and abscisic acid and will need to be able to list at least two basic functions of each hormone. Teachers should revise the basic parts of a plant in order for learners to fully grasp the topic and terminology. A description of each hormone is given, with a special emphasis on auxin, as this hormone plays a significant role in tropism.

Tropisms

Learners are introduced to tropisms – the response of a plant to a particular stimulus. While plants respond to a number of stimuli, the teacher should focus on phototropism and geotropism. Teachers need to explain the differences between positive and negative tropisms. A brief discussion on phototropism and geotropism is given together with some experimental examples of how each process works. Learners will need to understand the biological significance behind why plants bend toward the light and gravity and how this is achieved.

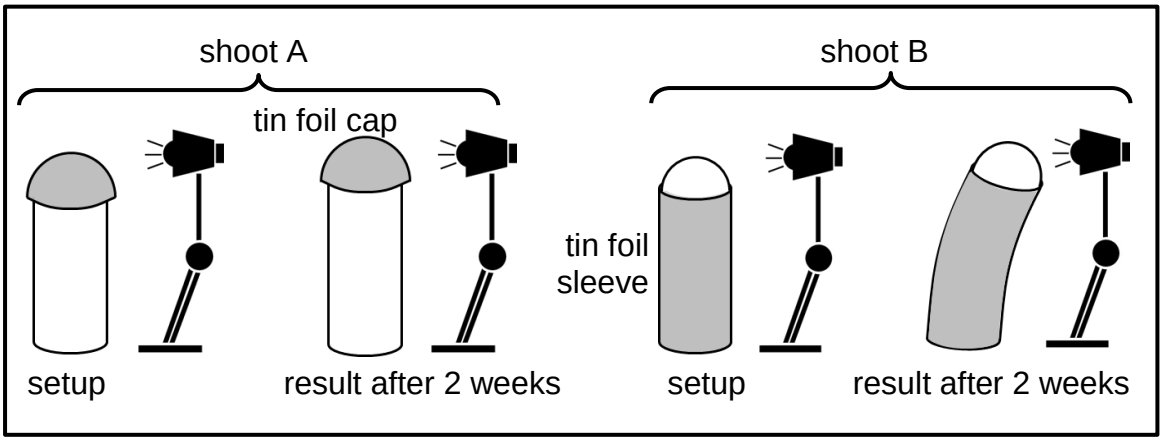
Activity 1: Phototropism

Lerato, a learner in Grade 12, is investigating how shoots respond to light. She used the following method.

Method

- Two shoots, labelled shoot A and shoot B were used.
- Both shoots were from the same plant species.
- The tip of shoot A was covered with a tin foil cap.
- The sides of shoot B were covered with a tin foil sleeve.
- Both shoots were exposed to unilateral light using two lamps.
- The lamps were placed at the same distance from the shoots.
- The apparatus was left for 2 weeks.
- After 2 weeks, she observed what happened to shoot A and shoot B.

The results of Lerato's investigation are shown in the diagram below.



1. Identify the

a) independent variable (1)

Position of the tin foil on the shoot ✓

b) dependent variable (1)

Shoot growth ✓

2. State three planning steps that Lerato considered in this investigation. (3)

the duration of the investigation ✓

the plant species to use ✓

the method of recording the results ✓

the apparatus to use ✓ (any three - mark first three only)

3. Explain the results observed on shoot B. (4)

Since the tip of shoot B was not covered ✓, the auxins produced at the tip moved to the shaded side ✓. This stimulated cell elongation on the shaded side ✓. The shaded side grew faster and bent towards the light source ✓

4. How did Lerato ensure validity in this investigation? (4)

by using the same plant species ✓

by placing the shoots the same distance from the lamp ✓

by ensuring that the shoots were both exposed to unilateral light ✓

by ensuring that both shoots were exposed to the light for the same length of time ✓

5. State three ways in which the reliability of the investigation can be improved. (3)

repeating the investigation ✓

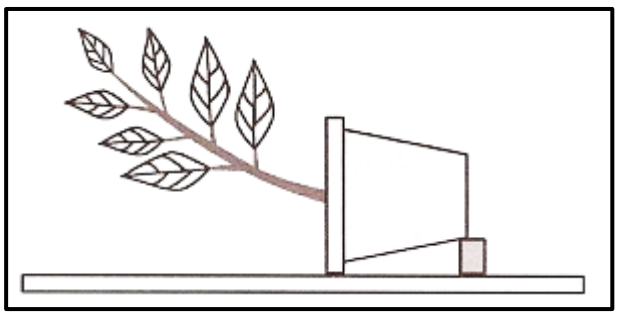
increasing the number of shoots used for each setup ✓

increasing the period of the investigation ✓

(16)

Activity 2: Geotropism

The pot plant in the diagram below was placed onto its side in a dark cupboard. After 2 weeks, the stem had started to grow upwards.



1. Give the term used to describe this phenomenon. (1)

   Geotropism ✓

2. Define the phenomenon identified in question 1. (1)

   Geotropism is the growth of a plant in response to gravity ✓

3. Discuss the role of auxins in the phenomenon mentioned in question 1 in respect of the roots of the plant. (6)

   The role of auxins in geotropism

   - When the root is placed horizontally, the auxin concentration will be high on the lower side of the root ✓
   - gravity attracts auxins ✓
   - More growth occurs on the upper side of the root ✓
   - because auxins on the lower side inhibit growth ✓
   - As a result the upper side of the root grows faster ✓
   - causing the root to bend downwards ✓

   (8)

Weed control

Discuss the role of plant hormones in inhibiting the growth of weeds whilst not affecting other plant or the plant itself. Teachers should remind the learners that weeds are harmful to commercial and subsistent farmers and that they need to be safely killed in order to improve crop yields. A description on how plant hormones are selective killers to weeds is given. No further information is required.

Plant defence mechanisms

Discuss the mechanisms by which plants are able to protect themselves from getting damage and eaten by insects and other larger herbivores. A brief discussion on how plants use both chemical and physical defences to deter herbivores. Teachers should not go in to too much detail, as this topic can be quite broad.

Summary

- Plants are able to respond to their environment with the help of chemical messengers called plant hormones.

- There are hormones that promote growth (auxin and gibberellins) and those that inhibit growth (abscisic acid).
- Plant hormones can be used to effectively kill weeds without damaging the commercially important crops.
- The response to a stimulus is call tropism.
- When parts of a plant grow towards a stimulus it is referred to as positive tropism.
- When parts of a plant grow away from a stimulus it is referred to as negative tropism.
- Shoots also grow towards the sun and against gravity, ensuring the leaves of a plant get maximum sunlight in order to photosynthesis.
- Roots always grow with gravity and away from the sun, ensuring the roots grow deep into the soil to absorb water and nutrients that plant needs for photosynthesis.

End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write only the letter (A- D) next to the question number (1.1.1 – 1.1.5) on your answer sheet, for example 1.1.6 D

1.1.1 Which ONE of the following plant hormones is responsible for the germination of seeds?

A Growth hormone
B Abscisic acid
C **Gibberellin ✓✓**
D Auxin

1.1.2 A gardener removes the apical buds from a rose bush in her garden regularly. As a result the rose bush will…

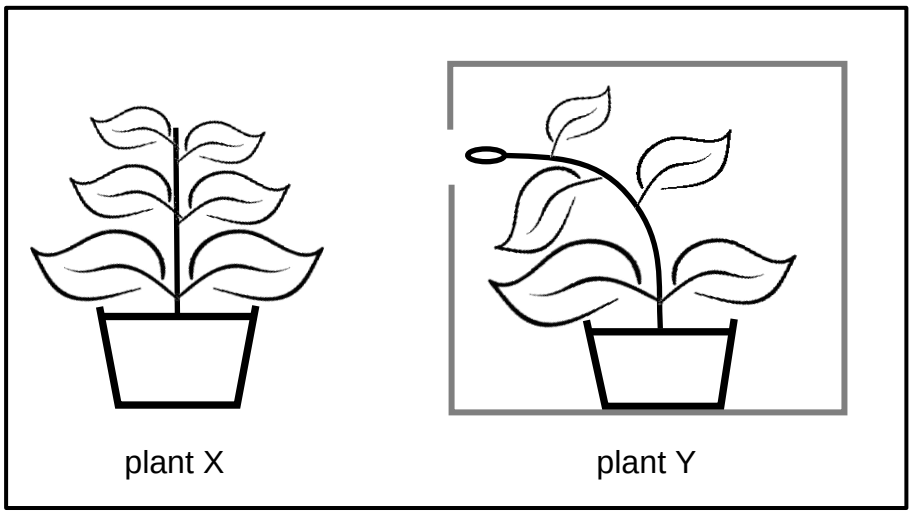
A **produce more lateral branches ✓✓**
B grow taller.
C remain the same size.
D produce fewer roses.

1.1.3 Which plant hormone promotes seed dormancy?

A Gibberellin
B Auxin
C **Abscisic acid ✓✓**
D Growth hormone

Questions 1.1.4 and **1.1.5** are based on the information and diagrams below:

Two identical potted plants X and Y, of the same age and size were placed in the light, but plant Y was placed in a box with a hole on one side. The diagram below shows the plant after 5 days.



1.1.4 Which combination of the following statements is correct?

i) The shoots of both plants have grown towards moisture.

ii) The shoot of plant Y has grown more than the shoot of plant X

iii) The shoot of plant Y has grown against the force of gravity

iv) The shoot of plant Y has grown towards light from one side but the shoot of plant X grew in response to uniform light.

v) The shoots of both plants have grown in the direction of the force of gravity.

A **(ii) and (iv)** ✓✓

B (i) and (ii)

C (iii) and (v)

D (i) and (v)

1.1.5 The reaction of plant Y is caused by growth hormones that…

A form only in the presence of light.

B cannot function in the dark.

C **stimulate cell elongation on the shaded sides**. ✓✓

D Inhibits cell division of the lighted side.

(5 x 2) = (10)

1.2 Give the correct **biological** term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The plant hormone that causes leaves to fall off trees in autumn.

Abscisic acid ✓

1.2.2 The movement of a part of a plant in response to gravity.

Geotropism ✓

1.2.3 A chemical substance that helps to coordinate the growth, metabolism or development of the plant.

Hormone ✓

1.2.4 Plant growth responses to external stimuli.

Tropisms ✓

1.2.5 A substance containing plant hormones used to kill unwanted plants.

Herbicide ✓

1.2.6 Animals that eat the leaves and twigs of trees.

Herbivores ✓ / Browsers

1.2.7 Plant hormones that promote the development of fruit.

Auxins ✓

1.2.8 The plant hormone that promotes seed dormancy.

Abscisic acid ✓

1.2.9 The response of a plant stem in reaction to light.

Phototropism ✓

1.2.10 Inhibition of the growth of lateral buds by the auxins present in apical buds.

Apical dominance ✓

(10 × 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 Plant defences	A: thorns B: chemicals
1.3.2 Chemicals used to kill weeds.	A: herbicides B: fungicides
1.3.3 Tropism involving movement of a plant in reaction to gravity.	A: phototropism B: hydrotropism
1.3.4 The young stem bearing leaves is called the…	A: shoot B: radicle
1.3.5 A stimulus coming from ONE direction only.	A: omnilateral B: unilateral

(5 x 2) = 10

1.3.1 **Both A and B ✓✓**

1.3.2 **A only ✓✓**

1.3.3 **None ✓✓**

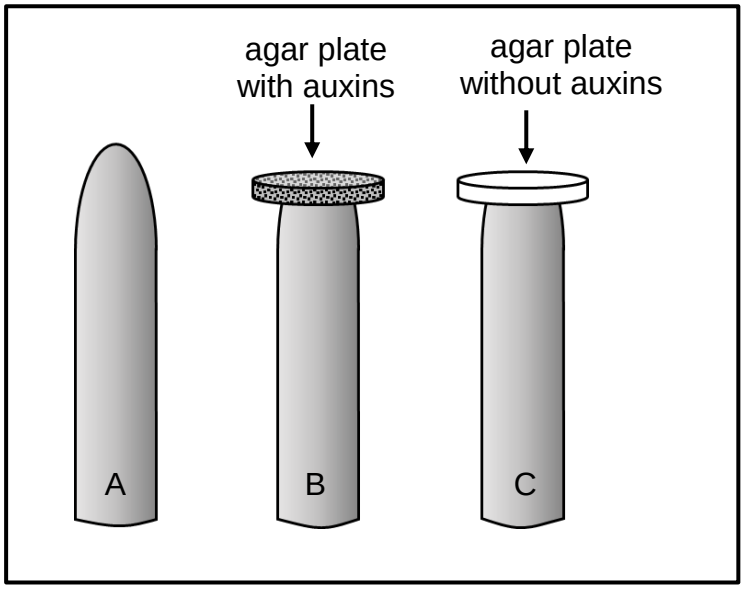
1.3.4 **A only ✓✓**

1.3.5 **B only ✓✓**

1.4 Thobeka investigated the effect of auxins on the growth of three plant shoots (**A**, **B** and **C**). The plant shoots were treated as follows:

- Shoot **A** – Not treated in any way
- Shoot **B** – Tip removed and agar plate with auxins placed on top.
- Shoot **C** – Tip removed and agar plate without auxins placed on top.

All shoots were exposed to the same light conditions. Note: Agar is a jelly-like substance that allows auxins to diffuse through it. The diagram below illustrates the set-up at the beginning of the investigation.



1.4.1 Identify the independent variable in this investigation. (1)

Presence or absence of auxin ✓ in the plant shoot

1.4.2 State two factors that must be kept constant in this investigation. (2)

- Same type of plant ✓
- Placed in the same environment ✓
- Same amount of treatment time ✓
- Tip removed at the same length ✓
- Same type of agar ✓
- Shoot of equal length ✓ (mark first two only)

1.4.3 Explain the results observed in:

a) Shoot **B** after a few days (3)

Shoot B would show upward growth ✓

Auxins in the agar gel diffused downwards ✓ into the shoot leading to cell elongation ✓

b) Shoot **C** after a few days (2)

No growth in shoot C ✓

Shoot tip contains no auxins ✓

1.4.4 Suggest two ways in which Thobeka could have improved the reliability of her investigation. (2)

Repeat the investigation ✓

Use more than one plant shoot per treatment / increase sample size ✓

(10)

1.5 A Grade 12 learner performed an investigation to determine the effect of light on the growth of plant shoots. The learner divided the plants that were used into three groups as follow:

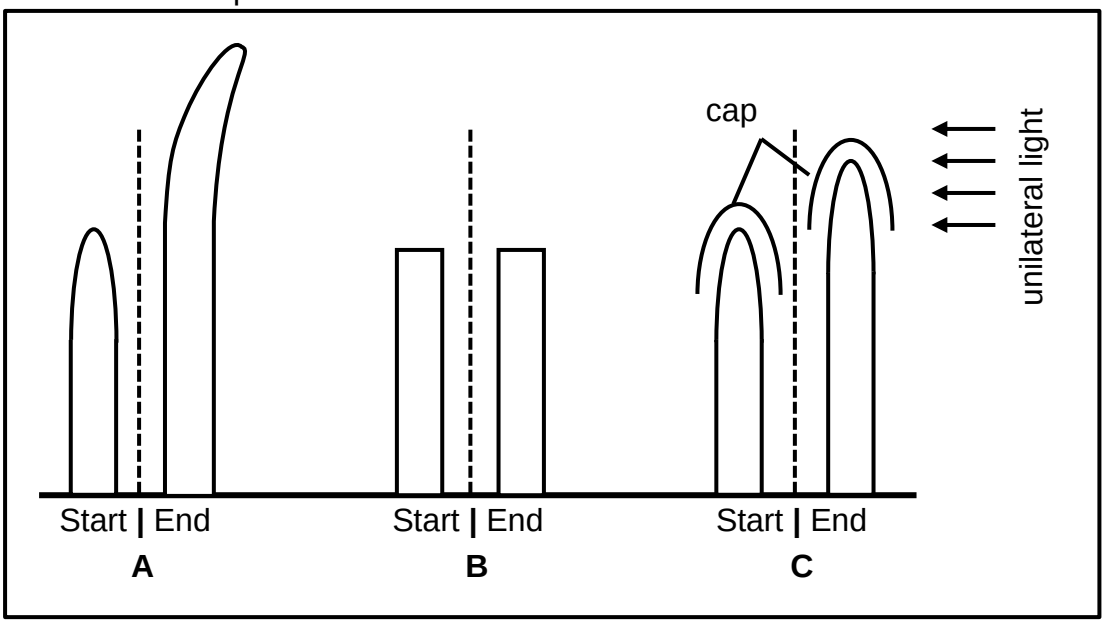
Group **A**: The tip of the shoot was intact.

Group **B**: The tip of the shoot was removed.

Group **C**: The tip of the shoot was covered by a cap that does not allow light to pass through.

The diagram in each group (**A**, **B**, **C**) below shows each shoot at the start of the investigation and next to each, the shoot at the end of the investigation.

The arrows indicate the direction of light to which each of the shoots **A**, **B** and **C** were exposed.



1.5.1 Name the dependent variable in this investigation. (1)

Growth of plant shoots ✓ / growth response / bending of the tip

1.5.2 Which plant hormone is being investigated in this experiment? (1)

Auxins ✓

1.5.3 State one factor that must be kept constant during this investigation. (1)

- Same environment in which shoots are placed ✓ / same intensity of light
- Same type of shoot used ✓
- Same age of shoot ✓ (any one – mark first one only)

1.5.4 Explain the results observed in:

a) investigation A (3)

- Light from the right ✓ / from one side / unilateral light
- Caused auxins to move to shaded side of the shoot ✓
- Leading to increased cell elongation and division ✓ on the shaded side / There was therefore greater growth of the shaded side.
- Thus bending the shoot in the direction of the source of light ✓

(any three × 1; mark first three only)

b) investigation C (3)

- Since there is no light stimulus ✓ from the side (because of the cap)
- there is no influence on the distribution of auxins ✓ / auxins evenly distributed below the cap
- therefore the shoot grew upright ✓

1.5.5 State one way in which the learner could improve the reliability. (1)

Repeat the investigation ✓

Use more than one plant shoot per treatment / increase sample size ✓ (any one × 1; mark first one only)

(10)

Section A: [50]

Section B

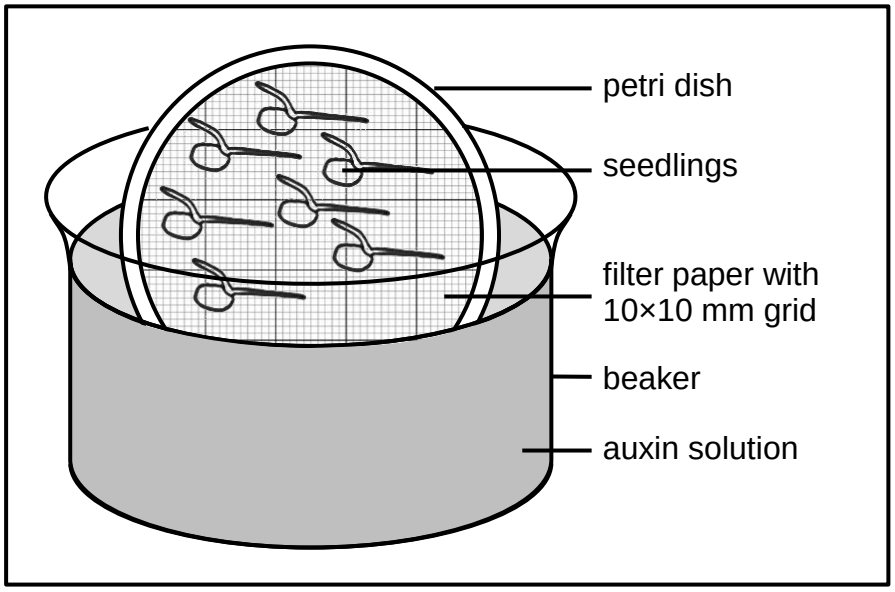
Question 2

2.1 A group of Grade 12 learners investigated the influence of different concentrations of auxins on plumule growth. A plumule is a young stem that grows from a seed.

The procedure was as follows:

- 35 bean seeds were germinated.
- The seedlings were then divided into five groups of seven seedlings.
- In each group the seven seedlings were attached with Prestik to filter paper on which a 10 mm x 10 mm grid was drawn.
- The filter paper with seedlings was then glued to the inside of a petri dish.
- Each of these five petri dishes was placed in a beaker containing a different concentration of auxins.

The diagram below shows the set-up of a single beaker.



- All five beakers were placed inside a dark cupboard for three days.
- After three days the increase in length of each plumule was measured.
- The average increase in length of the plumule in each beaker was calculated and recorded in the table below.

The table below shows the results of the investigation after three days.

Beaker number	Auxin concentration in parts per million (ppm)	Average increase in plumule length (mm)
1	0.1	1.5
2	1	3.2
3	10	4.8
4	50	2.3
5	100	0

2.1.1 For this investigation identify the:

a) independent variable (1)

Auxin concentration ✓

b) dependent variable (1)

Plumule growth ✓

2.1.2 State the purpose of the grid that was placed inside each petri dish. (1)

For measurement of plumule length ✓

2.1.3 Explain why the beakers were placed in a dark cupboard. (2)

To eliminate the effect of light ✓ so that only gravity is can affect the distribution of auxins ✓

2.1.4 State one way in which the learners ensured the reliability of this investigation. (1)

- They used seven seedlings in each group ✓ / 35 seeds in total / a large sample
- They calculated the average ✓ increase in plumule length

(any 1 × 1, mark first one only)

2.1.5 State three factors, not indicated in the procedure, that should be kept constant during this investigation. (3)

- Same species of beans ✓
- Seedlings of the same age ✓
- Seedlings of the same size ✓
- Same temperature ✓
- The same investigator ✓
- Identical apparatus (beakers / petri-dishes / graph paper / grid / volume of solution) ✓

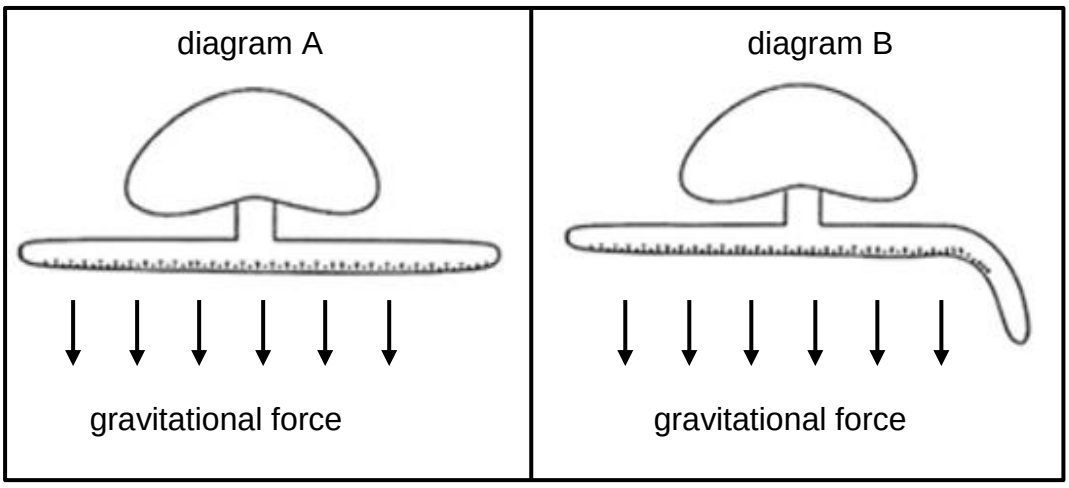
(any three × 1, mark first three only)

2.1.6 State the conclusion that can be made from the results in the table. (2)

An increase in auxin concentration up to an optimum stimulates the growth rate of the plumule / stem. With further increase in auxin concentration there is an inhibition of plumule / stem growth. ✓✓

(11)

2.2 An experiment was conducted by a learner to investigate growth movements in plants. A seedling was placed horizontally in the dark as shown in diagram A. Diagram B shows the results after 5 days.



2.2.1 Give the term for the movement of part of a plant in response to a stimulus. (1)

Tropism ✓

2.2.2 Which plant growth hormone stimulates the growth movement shown in diagram B? (1)

Auxins ✓

2.2.3 Give any other two functions of the hormone mentioned in question 2.2.2. (2)

- Brings about bending reaction in plants known as tropism ✓
- Promote cell division ✓
- Responsible for cell elongation ✓
- Responsible for apical dominance ✓
- Promote root development ✓

(any 2 × 1; mark first two only)

2.2.4 Does the accumulation of the hormone mentioned in question 2.2.2 inhibit or promote cell elongation in the growing tip of a stem? (1)

It promotes cell elongation ✓ at the growing tip of the stem

2.2.5 Explain why the part of the plant which showed a response as illustrated in the diagram B, will react as shown. (6)

- Under the influence of gravity ✓ the auxins tend to accumulate on the lower side of the root ✓
- The growth on the lower side is inhibited ✓ by the increased concentration ✓ of auxins
- On the upper side of the root the auxin concentration is less, ✓ these cells therefore elongate more ✓ causing
- The root to bend and grow downwards. ✓

(any 6 × 1)

(11)

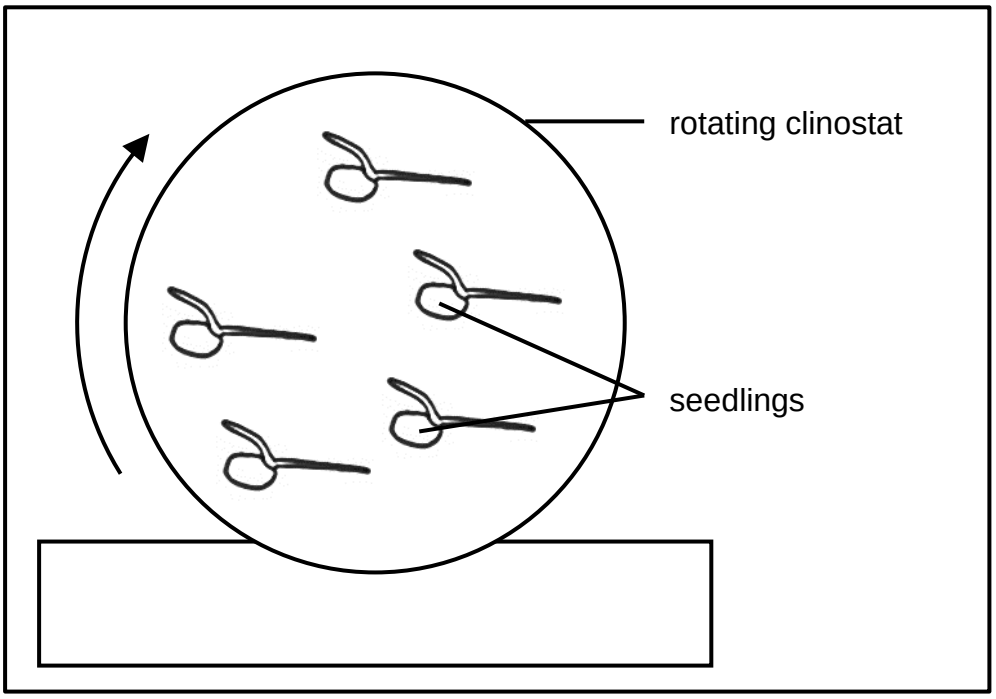
[22]

Question 3

3.1 A learner conducted an investigation to determine the effect of auxins and the effect of gravity on the root growth in pea seedlings. He used the following procedure:

- He germinated pea seeds for seven days.
- He then took a sample of 15 seedlings and divided them into 3 groups (A to C) of 5 seedlings each.
- In each group the 5 seedlings were placed **horizontally** on 3 different clinostats.

A clinostat is a device which has a disc that rotates at a constant speed. A diagram of a clinostat is shown below.



- He removed the root tips of all seedlings at the same length in group B.
- In groups A and B the clinostats were left stationary (no rotation).
- In group C the clinostat was allowed to rotate.
- All 3 clinostats were placed in a dark cupboard.

A summary of the learner's procedure is shown in the table below.

Group A	Group B	Group C
root tips present	no root tips	root tips present
stationary clinostat	stationary clinostat	rotating clinostat

After two days the direction of root growth was observed.

3.1.1 Which two groups were used to obtain information about:

a) The effect of auxins on root growth. (1)

A and B ✓

b) The effect of gravity on root growth. (1)

A and C ✓

3.1.2 Define the term *tropism.* (1)

Bending reaction of plants or parts of plant in response to an external stimulus.✓

3.1.3 Explain why the apparatus was placed in a dark cupboard. (2)

- To ensure that the results are attributed to gravity ✓
- And not to light ✓ / to eliminate the effect of light

3.1.4 Describe the expected results for each of groups **B** and **C** in this investigation. (2)

A – No growth will be observed ✓

B – Roots will grow **horizontally** / not change direction ✓

3.1.5 Explain the expected results for group **A.** (3)

- Auxins will move to the lower side of the root ✓ / attracted by gravity
- And a high concentration of auxins will inhibit growth on the lower side of the roots ✓
- While growth occurs faster on the upper side of the root ✓
- Causing the root to bend downwards ✓

(any 3 × 1)

3.1.6 State three ways in which the learner ensured a high level of validity for this investigation. (3)

- Used same type of plant ✓/ pea only
- Seedlings were the same age ✓ / germination period was 7 days
- All groups were exposed to the same environment ✓ / light intensity / placed in a dark cupboard
- Same number of seedlings in each group ✓
- Root tips were all cut at the same length ✓
- All seedlings placed in the same position ✓ / horizontally
- Allowed same amount of time for the 3 groups ✓
- Appropriate controls were set up ✓

(any 3 × 1; mark first three only)

(13)

3.2 Weeds are problematic to farmers because they invade farm fields and outcompete crop plants for space. This reduces crop yield.

Farmers spray their fields with chemicals, known as herbicides, to kill the weeds. Some weeds, however, have evolved to be resistant to herbicides.

Scientists investigated the time it took for a species of weed to develop resistance to five types of herbicides. The results are shown in the table below.

Types of herbicide	Time taken for weeds to develop resistance (years)
2,4 – D	9
Dalapon	9
Picloran	25
Dicloflop	7
Trifluralin	26

3.2.1 Refer to the passage above and state how weeds act to reduce crop yield. (1)

They outcompete crop plants for space ✓

3.2.2 Identify the:

a) independent variable (1)

The type of herbicide ✓

b) dependent variable (1)

Time taken for weed to develop resistance ✓

3.2.3 Name the herbicide:

a) to which the weeds developed resistance the fastest. (1)

Dicloflop ✓

b) that remained effective for the longest period of time. (1)

Trifluralin ✓

3.2.4 The scientists used the same weed species when investigating resistance to the different herbicides.

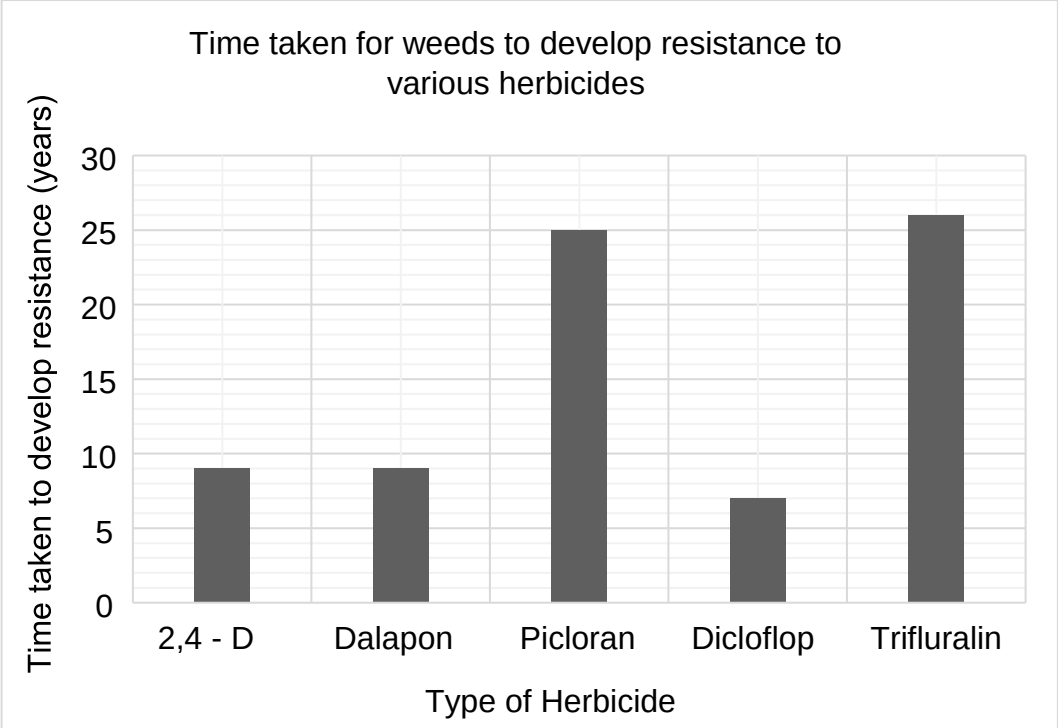
a) Describe how the scientists would have determined the resistance of the weeds to the herbicides. (2)

They would count the number of weeds that survived over a period of time.✓✓

b) Explain how the use of the same weed species improved the validity of this investigation. (2)

No other variable could have affected the weed species' survival.✓✓

3.2.5 Draw a bar graph to show the time taken for the evolution of resistance to the herbicides. (6)



Guidelines for marking graph

Criteria	Mark
Type of graph	✓
Caption	✓
Scale: Correct scale for X-axes (equal width of bars) and Y-axes	✓
Labels: Correct label for X-axes and correct label and unit of Y-axes)	✓
Plotting	✓: 1 – 4 bars correctly drawn ✓✓: All bars correctly drawn

NOTE:

- If the wrong type of graph is drawn, 1 mark will be lost for: "Correct type of graph".
- If labels of the axes are transposed then 2 marks will be lost for: " Correct label AND scale for x-and y-axes.

(15)

[28]

Section B: [50]

Total marks: [100]

Cognitive levels distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1	✓				2
1.1.2	✓				2
1.1.3	✓				2
1.1.4		✓			2
1.1.5	✓				2
	8	2			10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	10				10
1.3.1		✓			2
1.3.2		✓			2
1.3.3		✓			2
1.3.4		✓			2
1.3.5		✓			2
		10			10
1.4.1		✓			1
1.4.2		✓			2
1.4.3 a - b		✓✓			5 (3+2)
1.4.4				✓	2
		8		2	10
1.5.1		✓			1
1.5.2	✓				1

1.5.3		✓			1
1.5.4 a - b		✓✓			6 (3+3)
1.5.5		✓			1
	1	9			10
2.1.1 a - b		✓✓			2 (1+1)
2.1.2		✓			1
2.1.3		✓			1
2.1.4		✓			2
2.1.5		✓			3
2.1.6		✓			2
		11			11
2.2.1	✓				1
2.2.2	✓				1
2.2.3	✓				2
2.2.4	✓				1
2.2.5			✓		6
	5		6		11
3.1.1 a - b			✓✓		2 (1+1)
3.1.2	✓				1
3.1.3		✓			2
3.1.4			✓		2
3.1.5			✓		3
3.1.6			✓		3
	1	2	10		13
3.2.1	✓				1
3.2.2 a - b		✓			2 (1+1)
3.2.3 a - b	✓✓				2 (1+1)
3.2.4 a - b			✓✓		4 (2+2)
3.2.5		✓			6
	3	8	4		15
	28	50	20	2	100

CHAPTER 9: EVOLUTION BY NATURAL SELECTION

Overview

Time allocation**:** 2 weeks (8 hours)

This chapter consists of the following sections:

1. Introduction
2. Key concepts and terminology
3. Origin of ideas of evolution and evidence for evolution
4. Theories of evolution
5. Evolution by natural selection
6. Formation of a new species
7. Artificial selection
8. Mechanism for reproductive isolation
9. Evolution in present times
10. Summary
11. End of topic exercises

Introduction

Learners will be introduced to one of the greatest ideas in science: the theory of evolution by natural selection, formulated independently by Charles Darwin and Alfred Russel Wallace.

You will explain that species are not static but have changed over time through the process of evolution. Learners will review the various lines of evidence that support the theory of evolution, and investigate the mechanisms that drive evolution, such as natural selection.

They will develop an understanding of how a new species can arise (speciation) through genetic mutations, presence of geographic barriers and mechanisms of reproductive isolation.

Learners will learn that evolution requires a lot of time (often millions of year) in some populations and can occur relatively quickly in others, such as bacteria.

Key concepts and terminology

- Lamarck, Darwin and Wallace were the first to acknowledge that species are not static but change over time and therefore must have come from a common ancestor.
- There are multiple lines of evidence, from the fossil record, genetics, comparative anatomy and biogeography, to support that species have changed over time.
- Natural selection is one of the mechanisms that drive evolution and explains that individuals best adapted to their environment will leave the most offspring
- Variation due to gene mutations is central to the process of natural selection and natural selection only works on variation within a population.
- Humans have been changing organisms through selective breeding and artificial selection which mimics natural selection.
- New species are formed through a process called speciation by either being separated geographically or reproductively. When organisms of the same species do not mate with one another, they then become two different species.
- Speciation happens quickly followed by long periods of stasis (equilibrium) when no changes occur. This is referred to as punctuated equilibrium.
- Evolution is a very slow process but can happen quickly in microorganisms which rapidly reproduce resulting in many pathogens becoming resistant to pesticides and drugs, making it difficult to fight those infections.

biological evolution	any genetic change in a population that is inherited over several generations
biological species	a group of organisms with similar characteristics that interbreed with one another to produce fertile offspring
population	a group of individuals of the same species occupying a particular habitat
punctuated equilibrium	evolution characterised by long periods of little or no change followed by short periods of rapid change
natural selection	mechanism of evolution - organisms survive if they have characteristics that make them suited to the environment
artificial selection	human-driven selective force, e.g. breeding of plants and animals to produce desirable traits
inbreeding	mating of individuals that are closely related

outbreeding	mating of individuals that are not closely related
speciation	the formation of a new species
geographic speciation	formation of a new species when the parent population separated by a geographical barrier
reproductive isolation	a mechanism that prevents two species from mating with one another and making fertile hybrids

Origin of ideas about origins

A brief history of how the theory of evolution was determined should be taught.

Teachers should explain that religious explanations do not form part of the discussion on evolution.

Learners will be introduced to the main lines of evidence supporting the idea that species have changed and how they have changed. Learners should be made aware that the theory of evolution emerges from multiple lines of evidence e.g. fossils (taught in grade 10), genetics, biogeography, and comparative anatomy together with other forms of evidence.

Theories of evolution

In this section, a brief history of the development of the theory of evolution is discussed, including how long it takes for species to change (punctuated equilibrium).

Learners will be introduced to the two major contributors to the theory evolution, Jean-Baptiste Lamarck and Charles Darwin. Teachers should reiterate that there were a few other naturalists that had similar ideas, but Lamarck and Darwin developed their ideas further. It is important to remember that Lamarck did not provide any mechanisms of evolution (how the changes in species occurred) whereas Darwin's mechanism of evolution was natural selection (discussed in a separate section).

Teachers should focus the differences and similarities in Lamarckism and Darwinism. It is important that learners are able to apply ideas about how species changed to different scenarios according to different theories of evolution – the chapter activity is there to help build the learners understanding of how each theory works. Learners should also be taught why Lamarckism is not accepted today.

Evolution by natural selection

Darwin's theory of evolution by natural selection explains that organisms have evolved from previous organisms by natural selection. This section links very well to the Genetics chapter.

Teachers must emphasize the fact that natural selection only operates on variation in inherited characteristics and that most species are unable to survive in a new environment and become extinct, but some species have traits suitable to the new environment and thus go on to reproduce.

Teachers must ensure that learners are familiar with how natural selection works and should be taught how to apply the same steps to a different scenario – the activity on natural selection will help guide learners in applying what they have learnt to an unfamiliar organism.

Only one example of natural selection has been given. The peppered moth is a simple yet iconic example of how there is natural variation within a population and when the environment changes, the variation within the population allows it to survive.

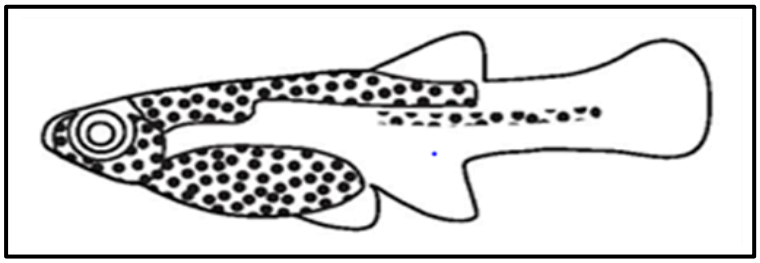
Activity 1: Natural selection

Question 1

A scientist used guppies (*Poecilia reticulata*) in an investigation to test Darwin's theory of natural selection. Male guppies have brightly coloured spots to attract females, but these spots also attract predators.

It was previously observed that males living in streams where there were many predatory fish tended to have fewer spots. This reduced their risk of being eaten.

Those males living in streams with fewer predators had more spots.



Guppy showing spots (adapted from www.decodedscience.org)

The **procedure** for the investigation was as follows:

- Equal numbers of male and female guppies were put into two ponds (pond 1 and pond 2).

- In pond 1, predatory fish that prey on guppies were introduced.
- In pond 2, predatory fish that do not feed on guppies were introduced.
- The guppies were allowed to breed for 20 months, representing several generations of guppies. (Guppies reproduce when they are about three months old.)

The **result** of the investigation:

The male guppies in pond 2 had significantly more spots than the male guppies in pond 1.

1.1 How could the validity of this investigation be increased? (2)

By ensuring that both ponds in an experiment have identical ✓ environmental conditions ✓ ; by ensuring that there were equal numbers ✓ of predatory fish in both ponds ✓ (any one correct answer)

1.2 Identify the:

(a) independent variable (1)

the type of predators ✓

(b) dependent variable (1)

average number of spots on each male guppy ✓

1.3 Explain why the scientist included pond 2 in this investigation. (3)

as a control ✓ , to compare the results between the ponds

to ensure that any changes that occurred ✓ were due to the presence of predators ✓ and not other environmental factors.

1.4 Describe how Darwin's theory of natural selection can be used to explain why the guppies in pond 1 had fewer spots. (5)

there is variation ✓ amongst the male guppies

some have more spots ✓ while others have fewer spots ✓

the ones that have more spots attract predators ✓ and are eaten ✓ by the predators.

the ones with fewer spots survived ✓ and reproduced to pass the gene for fewer spots on to the next generation ✓ (any five)

Question 2

2.1. What type of characteristics does nature select during evolution? (1)

Those that will benefit an organism and make it more successful ✓

2.2 In nature, there is always a fight for survival due to competition, predation and adverse weather conditions. Suggest a collective term for all these factors. (1)

Selective forces ✓

2.3 Why is the concept of natural selection so important? (2)

It provides a mechanism for evolution ✓ , explaining that animals are able to change to a changing environment and that these small changes over time can result in a new species being formed ✓ that is different to ancestral species.

2.4 Why is natural selection not a random process? (2)

The environment actively selects ✓ which organisms are best suited to their environment ✓ . The ways by which variation arises in a population may be random but natural selection is a very selective process.

2.5 In a population of mice, half were light in colour and half were dark.

a) If an owl, hunts in the area at night, which mice have the more favourable characteristic? Explain your answer in terms of natural selection. (3)

The dark coloured mice ✓ – they will be difficult to spot in the dark ✓ as they will be well camoflauged at night ✓ in their surroundings

b) If the predator was a snake that detects the body heat of its prey, which mice would probably have the more favourable variation? Explain your answer. (3)

The light coloured mice ✓ – lighter colours absorb less heat than darker colours ✓ . Darker coloured mice will absorb more heat and therefore will be more “visible” to the snake ✓ .

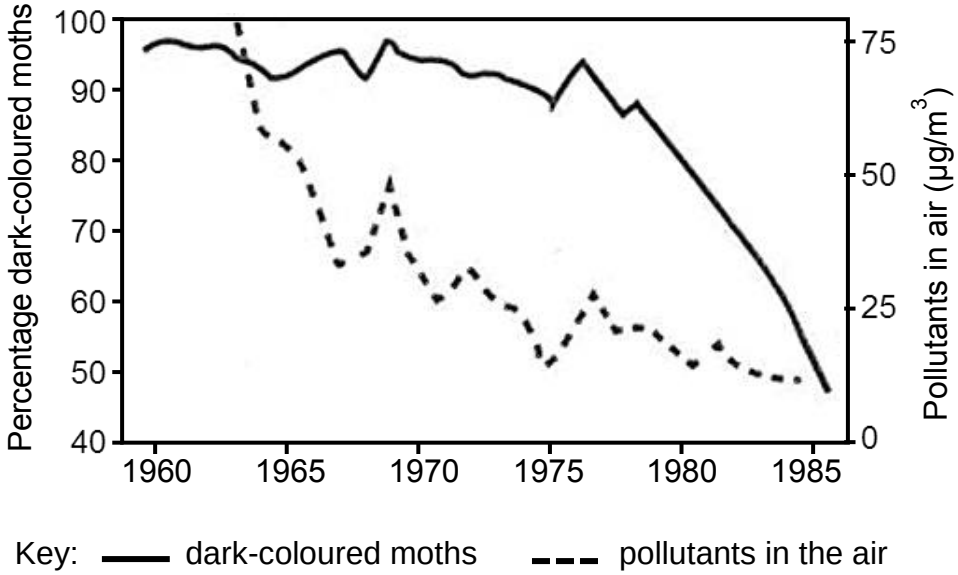
Question 3

Before the industrial revolution, light-coloured moths were far more common in England than dark-coloured moths. Trees were covered by a pale lichen which provided camouflage for the lighter moth. Dark moths were much more visible and were eaten by birds.

Due to pollution from factories in the 19th century, the environment changed. Lichen was killed off, and a black soot covered the bark on the trees. This provided good camouflage for the dark-coloured moths, but the light-coloured moths stood out from their background and were ready prey for birds.

The following is a graph showing the changes in the percentage of dark-coloured moths over a number of years.

Changes in the percentage of dark-coloured moths in relation to pollution over a period of time.



3.1 What is the general relationship between the dark-coloured moth population and the pollution from 1965 to 1985? (1)

Direct relationship ✓

3.2 Explain the relationship mentioned in question 3.1 (1)

As the air pollution decreased over time, the percentage of dark coloured moths also decreased ✓

3.3 Why did the population of the light-coloured moths decrease during the 19th century? (2)

The pollution caused a black ash to cover the lichen on the birch trees which made the light coloured moths more visible to predators ✓ and therefore the population numbers would decrease as predation increased ✓

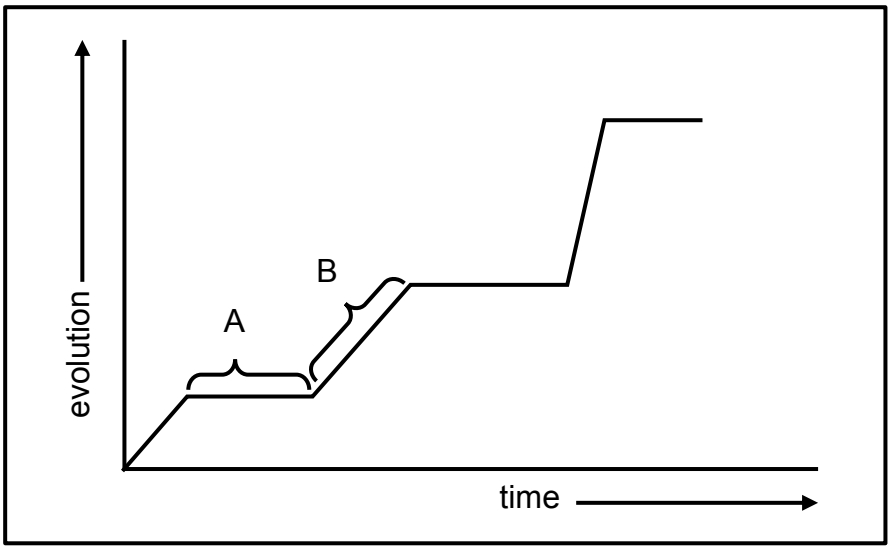
3.4 Once the air pollution had decreased, what do you think happened to the population of the light-coloured moths? Give a reason for your answer. (2)

The light coloured moth population would have increases since lower pollution levels resulted in less ash on the birch trees, allowing the lichen to grow again ✓ . Lighter coloured moths are more difficult to see on a light background and so would not be predated upon ✓.

(30)

Activity 2: Punctuated equilibrium

The graph below shows the speed at which evolution occurs in a species of butterfly.



1. Explain the trend in evolution represented by:

   a) phase A (2)

   No evolutionary change takes place in phase A ✓ – the species is in equilibrium with its environment ✓.

   b) phase B (2)

   Phase B points to an accelerated evolutionary change ✓ due to rapid environmental changes ✓.

2. In view of the trend represented by A and B, what type of evolution is represented by the graph? (1)

   Punctuated equilibrium ✓

3. Explain why the chances of speciation are great during phase B. (2)

   During phase B, species with advantageous characteristics, i.e. suitable to the new environment, survive and reproduce. ✓ Species that do not have advantageous characteristics die out. Thus the chances of speciation during phase B are much greater than during phase A ✓.

   (7)

Activity 3: Theories of evolution

1. Jean Baptiste de Lamarck was a French naturalist who proposed his theory of evolution in 1809.

   a) Name the two ideas on which Lamarck's theory was based. (2)

   The more a part was used, the larger and more dominant the trait became – the Law of Use and Disuse ✓ .

   Acquired changes were passed down to offspring – Law of Inheritance

of Acquired characteristics ✓

b) Why was his theory considered incorrect and therefore subsequently rejected? (1)

Lamarck's ideas were rejected since he suggested that the acquired characteristic which an organism gained through its life experience was transferred to it's offspring, which is not possible, since the acquired characteristic does not bring any change to an individuals set of genes ✓ .

c) Was Lamarck's work entirely without value because his theory had been rejected? (2)

No ✓ , it laid the foundation that traits could be passed on to offspring and he attempted to explain how and why species had changed from those in the fossil record ✓ .

2. Charles Darwin, a British naturalist, made his most important observations regarding evolution on the Galapagos islands.

a) List four observations his evolutionary theory was based on. (4)

- Populations can produce far more offspring than needed ✓
- Sizes of most natural population and resources remain relatively constant ✓ .
- Natural variation of characteristics among members of the same species are evident ✓
- Some characteristics are inherited and so are passed on to the next generation ✓

b) Describe how Darwin's theory of Natural Selection would have explained the development of long necks in giraffes. (7)

Organisms produce a large number of offspring ✓ .

There is a lot of variation among offspring as offspring differ from their parents in minor random ways – for example, in the length of their necks ✓ .

The offspring with traits / characteristics that make them better suited to the environment – i.e. with long necks to get to food sources others can't get to – will be most likely to survive and reproduce ✓ .

The organisms without the trait are less able to get to the food and so will die ✓ .

This means that more offspring in the next generation will have longer necks, a helpful difference. The next generation will have a higher proportion of individuals with the new trait – long necks ✓ .

These differences – the long necks – accumulate and eventually all

individuals in a population have the new trait ✓

Over time, together with other minor changes, this process leads to an entirely new species and evolution by natural selection will have take place ✓ .

c) Tabulate two differences between the theories of Charles Darwin and Lamarck. (5)

one mark for table, plus any two differences

Lamarckism	Darwinism
Members of a population are all the same ✓	Natural variation within the same population ✓
Individuals are able to transform during a life time ✓	Populations transform over time and only through genetic means ✓
Individual chooses which traits to pass on to offspring; changes are directed to meet survival ✓	Natural selection – the environment is the selective pressure causing change ✓

3. Below are statements referring to the evolution of species. Decide if the statement applies to Darwin, Lamarck or to both scientists.

a) Only the fittest individuals with the most advantageous characteristics survive in a changing environment. (1)

Darwin ✓

b) All members are slightly different and these differences accumulate over time, changing their appearance. (1)

Both ✓

c) A whale's hind limbs were severely reduced because they no longer used legs in the water. (1)

Lamarck ✓

d) Species acquire bigger and better structures by the increase in their use and pass these structures on to their offspring. (1)

Lamarck ✓

(25)

Formation of a new species (Speciation)

This section introduces learners to the concept of speciation (how a species is made). Teachers should ensure that learners understand the difference between a biological species and a population. The biological species concept defines a species as members of populations that actually or potentially interbreed in nature producing fertile offspring, not according to similarity of appearance. Teachers must

explain that although appearance is helpful in identifying species, it does not define species. Organisms may appear to be alike and be different species genetically.

Two main causes of variation in organisms 1 - mutations cause by changes in genes, and 2 - recombination of genes during prophase 1 of Meiosis and sexual reproduction. Teachers should ensure that learners understand that not all mutations in the genetics of an organism results in a physical change.

The two main mechanisms of speciation are sympatric speciation and allopatric (geographic) speciation. Learners must be taught that in order for change to occur, individuals of a population need to be isolated from one another. This is done either through a geographic barrier (allopatric speciation) or through reproductive strategies of different species, ensuring that two difference species do not interbreed with one another.

Activity 4: Speciation

Question 1

1. Bontebok are antelope that are found in the Western Cape. Two main populations exist, one at the Bontebok National Park and the other at Table Mountain National Park. These two national parks are hundreds of kilometres apart. Scientists believe that due to geographical separation, speciation **may** occur.

   1.1 Define the term “speciation”. (2)

   the formation of a new species ✓ ✓

   1.2 Define the term ‘species’. (3)

   A group of organisms ✓ that are closely related to each other ✓ , and are able to interbreed and produce viable offspring ✓

   1.3 Name the type of speciation that may occur in the bontebok populations. (2)

   Allopatric speciation or geographic speciation ✓ ✓

2. For each of the statements below, state whether the statement is TRUE or FALSE. Where false, correct the statement so that it is true.

   2.1 Genetic barriers cause divided populations to remain the same. (2)

   False – causes populations to diverge ✓ ✓

   2.2 Reproductive isolation prevents two or more populations from changing genes. (2)

   True ✓ ✓

2.3 Populations that become isolated by means of a geographic barrier will not differ from their ancestral species. (2)

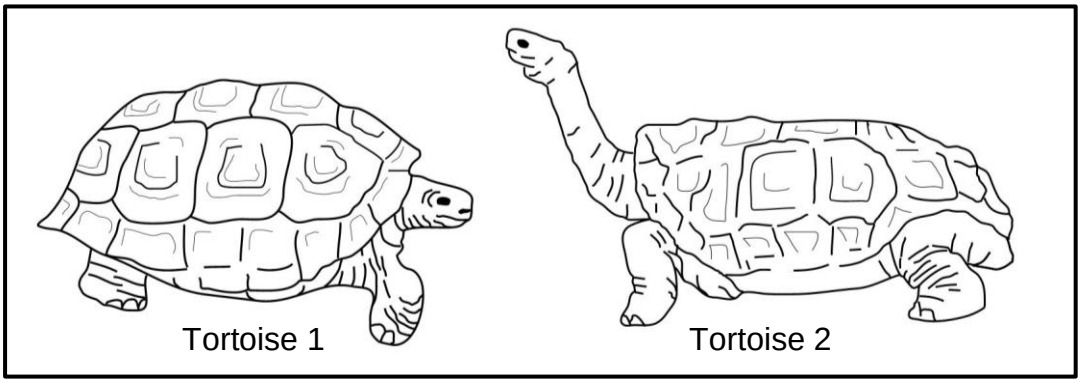
False – they will differ from ancestral species ✓ ✓

2.4 Competition, predation, climatic factors and disease are all selective forces / environmental pressures. (2)

True ✓ ✓

Question 2

Darwin discovered two different species of tortoises on two different island in the Galapagos. One had a domed shell and short neck, the other had an elongated shell and a longer neck. The two islands had very different vegetation. One of the islands (island X) was rather barren, dry and arid. It had no grass but rather short tree-like cactus plants. On the other island (island Y), there were no cactus plants but it had a good supply of water and grass grew freely. The diagram below shows the two main species of tortoise.



1.1 Which tortoise (1 or 2) would have been found on:

a) Island X Tortoise 2 ✓ (1)

b) Island Y Tortoise 1 ✓ (1)

1.2 Describe how the two tortoise species became different species. (5)

- The ancestral tortoise population was separated by a geographic barrier (the ocean) as they were found on the mainland and an islands ✓
- There was no gene flow between the populations ✓
- Each population was exposed to different climatic conditions and different vegetation types, so that natural selection occurs independently in both populations ✓
- The individuals in the populations become very different to each other both in their genes (genotypically) and their appearance (phenotypically) ✓
- Even if the populations were to mix again, they will not be able to

reproduce with one another ✓ , since they are now two different species.

1.3 Scientists believe that the variation in populations lead to the formation of new species. List four sources of variation in populations. (4)

crossing over during Prophase I of meiosis ✓ ; the random arrangement of maternal and paternal chromosomes ✓ ; random fertilisation of egg cells ✓ ; random mating ✓

(26)

Artificial selection

Artificial selection has been practiced by farmers since the first domesticated crops of maize and learners should be reminded about what they learnt about genetic engineering and how Mendel's laws allow farmers to manually manipulate genes. Teachers should make the learners aware that artificial selection and natural selection are the same process, carried out by different drivers and results in slightly different levels of variation.

Activity 5: Artificial selection and domestication

Question 1

1.1 List four ways in which artificial selection has been used in agriculture. (4)

any four, one mark ✓ each

- produce disease resistant crops
- improve yield of crops
- adapt old crops to grow in adverse conditions
- develop special breeds for particular purposes
- enhance nutritional value and flavour of crops

1.2 Copy the table below and complete it showing the differences between artificial selection and natural selection. (9)

	Artificial selection	Natural Selection
Driven by...	man ✓	nature ✓
Rate of change...	faster ✓	slower ✓
Amount of variation achieved	less ✓	more ✓
End result	improved crops and livestock ✓	suitable to changed environment ✓

1.3 Humans have been domesticating plants for years and today, most agricultural species come from domesticated varieties.

a) Define the term “domestication”. (2)

the selecting and breeding of organisms ✓ with desirable characteristics ✓

b) What was one of the first crops to be domesticated in the world? (1)

maize (*Zea mays*) ✓

c) Name two characteristics that were selected for in the domestication of the crop mentioned in (b) above. (2)

any two: reduced covering of the seed ✓ ; retention of seeds (kernels) on the cob ✓ ; erect habit with a single stalk ✓ ; larger ear structure ✓

Question 2

Decide if the statements below are TRUE or FALSE.

2.1 Cultivated plants show higher degrees of phenotypic variation than wild plants (1)

True ✓

2.2 Natural selection is a random process. (1)

False ✓

2.3 Artificial selection is similar to natural selection, except the process is driven by man and is a quicker process. (1)

True ✓

2.4 The final product of artificial selection is the adaptation of populations of organisms to their environment. (1)

False ✓

2.5 All hybrids are infertile. (1)

False ✓

2.6 Artificial selection has been used by humans to speed up evolution. (1)

False ✓

(24)

Mechanism for reproductive isolation

A brief discussion on various reproductive strategies in plants and animals is provided and how these strategies prevent different species from interbreeding. A short description is provided for various reproductive isolation strategies together with simple examples of each.

Evolution in present times

Evolution is always happening, however most of the time it is impossible to observe changes in population and species because evolution happens very slowly. This section demonstrates that evolution is constantly happening, even in this day and age. Learners should understand how gene mutations and sexual reproduction in organisms, such as viruses and bacteria, allow them to evolve very quickly over a short period of time. This has resulted in the evolution of many drug resistant pathogens, which is having negative impacts on communities in South Africa and the world. Teachers should facilitate a class discussion on the importance of finishing a course of antibiotics.

For enrichment

Evolution 101 - Understanding evolution (Berkley Education)
https://evolution.berkeley.edu/evolibrary/article/evo01

Summary

- Evolution is a constant change that takes place slowly.
- The process of change is called natural selection and the combined long-term change is called evolution.
- There is significant evidence that certain species have changed over time and yet share similar characteristics. This suggests that these species must have originated from a common ancestor.
- Evolution by natural selection is driven by changing environmental factors.
- Natural selection states that only those individuals with traits suitable to a new environment will survive and reproduce.

- Natural selection is one mechanism of evolution and only works on variation within a population that already exists. It does not explain how new structures appeared or why.
- Variation in a population arise due to gene mutations and through sexual reproduction.
- The process by which species change is call speciation and there are two main types — geographic (allopatric) speciation and sympatric speciation.
- Allopatric speciation is commonly known as geographic speciation. When a population is split by a geographical barrier and the populations are exposed to different environmental conditions and selective forces, natural selection will work independently on both populations simultaneously such that they become different from the original population, becoming different species.
- Sympatric speciation is which two species become separated in the same area through isolation in reproductive strategies and timings.
- Evolution takes a long time and it is impossible to observe changes in a species in one lifetime, however, in rapidly reproducing pathogens, evolution can happen quickly.
- Pathogens develop resistant to drug and pesticides because some of the pathogens are naturally resistant to the drugs. When the drugs kill the non resistant pathogens, only the resistant pathogens remain, resulting in a population of pathogens that cannot be killed by conventional drugs or pesticides.

End of topic exercises

Section A

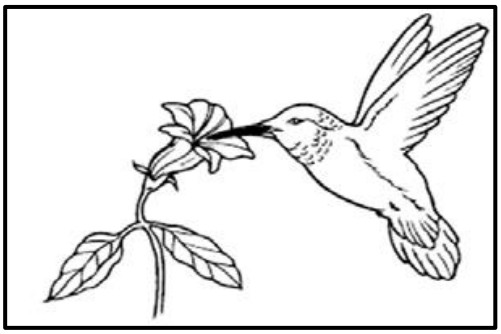
Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write the letter (A – D) next to the question number (1.1.1–1.1.5) for example 1.1.6 D.

1.1.1 The theory of evolution by natural selection was first described by …

A Gregor Mendel
B Watson and Crick
C Jean Baptiste de Lamarck
D **Charles Darwin ✓✓**

1.1.2 The reason that Lamarck would have provided for the long beak of the hummingbird is that:



A all hummingbirds have the same beak length
B there is natural variation in beak length and some birds are therefore better suited to feed on nectar
C **the more the hummingbird used its beak, the longer it grew ✓✓**
D hummingbirds with shorter beaks were more fit for survival

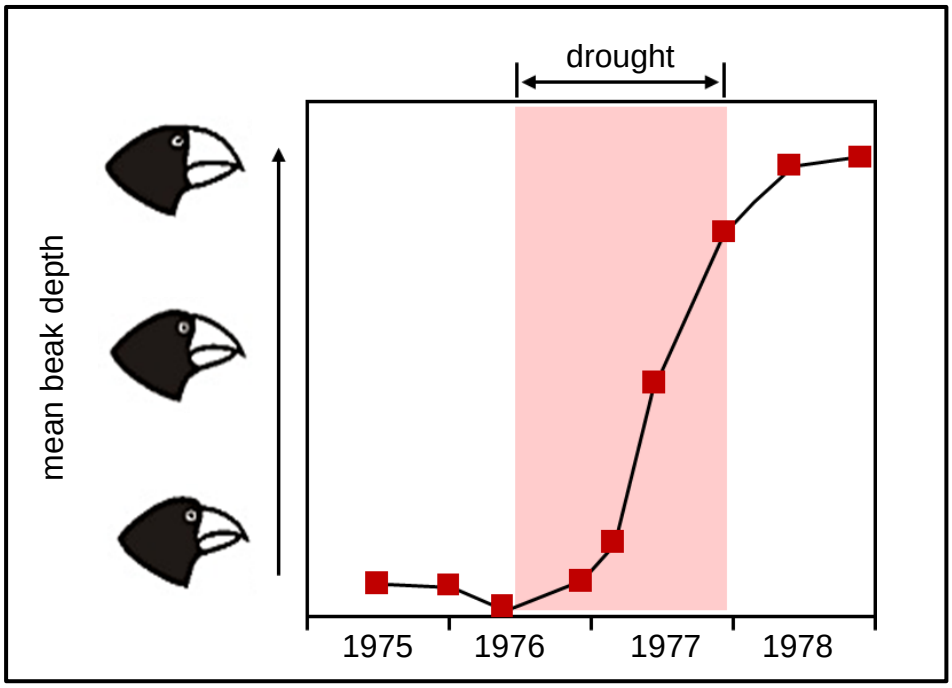
1.1.3 Lamarck's 'laws' of use and disuse and inheritance of acquired characteristics were:

A rejected, because only characteristics that benefit offspring can be inherited.
B not rejected, because evidence shows that acquired characteristics can be inherited

C **rejected, because only characteristics that are coded for in the DNA can be inherited ✓✓**

D not rejected, because Darwin's theory supports Lamarck's

1.1.4 During an investigation, researchers measured the beak size of a certain species of finch on the Galapagos Islands. The type of food available before and after a drought was a factor in the study of the evolution of the beaks of finches.



Which factor is the dependent variable?

A the amount of rain

B the type of food available

C **the beak size of finches ✓✓**

D the year

(4 x 2) = (8)

1.2 Give the correct biological term for each of the following descriptions. Write only the term next to the question number.

1.2.1 The permanent disappearance of a species from earth.

Extinction ✓

1.2.2 A tentative explanation of a phenomenon that can be tested.

Hypothesis ✓

1.2.3 The distribution of species in different parts of the world.

Biogeography ✓

1.2.4 Variation that results in distinct phenotypes.

discontinuous variation ✓

1.2.5 The explanation that species experience long periods without physical change, followed by short periods of rapid physical change.

Punctuated equilibrium ✓

1.2.6 An explanation for something that has been observed in nature and which can be supported by facts, laws and tested hypotheses.

Theory ✓

1.2.7 Formation of a new species when a physical barrier has divided a population.

Allopatric speciation ✓

1.2.8 The breeding of plants and animals to produce desirable characteristics.

Artificial selection ✓

1.2.9 The process whereby organisms better suited to their environment survive and produce more offspring.

Natural selection ✓

1.2.10 A group of similar organisms which interbreed successfully with each other to produce fertile offspring.

Species ✓

(10 × 1) = (10)

1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY, B ONLY, BOTH A AND** B or **NONE** of the items in Column II. Write **A only, B only, both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 The selection and breeding of organisms with desirable characteristics by humans	A: natural selection B: artificial selection
1.3.2 An example of discontinuous variation in humans	A: skin colour B: height
1.3.3 Example of a reproductive isolating mechanism	A: breeding at the same time of the year B: adaptation to different pollinators
1.3.4 A group of similar organisms that can interbreed to produce fertile offspring	A: species B: genus

1.3.5	Desired characteristics are passed on from parent to offspring	A: artificial selection B: natural selection

(5 x 2) = (10)

1.3.1 **B only ✓✓**
1.3.2 **None ✓✓**
1.3.3 **B only ✓✓**
1.3.4 **A only ✓✓**
1.3.5 **Both A and B ✓✓**

1.4 Since 1972, biologists Peter and Rosemary Grant from Princeton University in the USA have studied finch populations in the Galapagos. The table below shows their data collected on one island (Daphne Major), for a period of 7 years. They studied one finch population on Daphne Major.

Year	1974	1975	1976	1977	1978	1979	1980
rainfall (mm)	-	-	130	20	130	70	50
number of finches	1100	1300	1100	200	350	300	250
small seeds (mg/m^2)	-	800	600	90	300	70	50

1.4.1 In which year were the largest drop in rainfall, number of seeds and number of finches recorded? (1)

1977 ✓

1.4.2 Explain how the three events mentioned in question 1.4.1 are related to each other. (3)

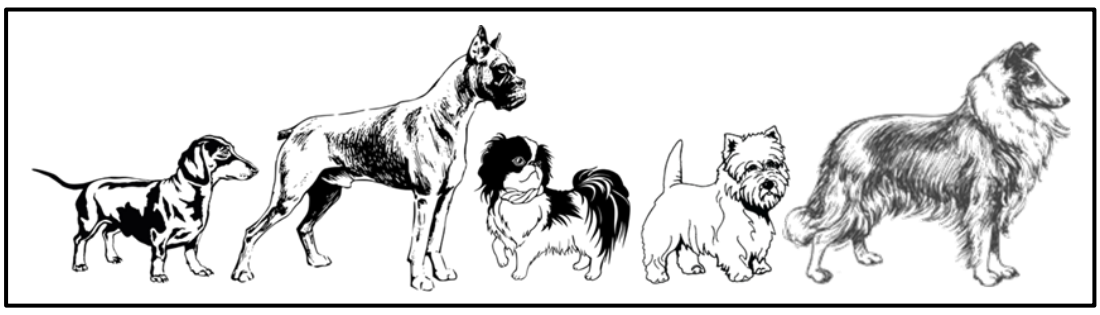
A drop in rainfall causes a drop in seeds / plants ✓ because of drought that causes a lack of seeds / food for finches ✓, therefore, fewer finches ✓

1.4.3 When the number of finches decreased, there were still plenty of large seeds on the island. What does this tell you about the seed-eating habits of the finches that died? (1)

These finches were not able to eat the large seeds ✓

(5)

1.5 Many dog breeds exist today as shown in the diagram below.



(a) Explain why all breeds of domestic dogs belong to the same species. (2)

They are able to interbreed with each other ✓ to produce fertile offspring ✓

(b) Describe how artificial selection has led to different breeds of domestic dogs. (3)

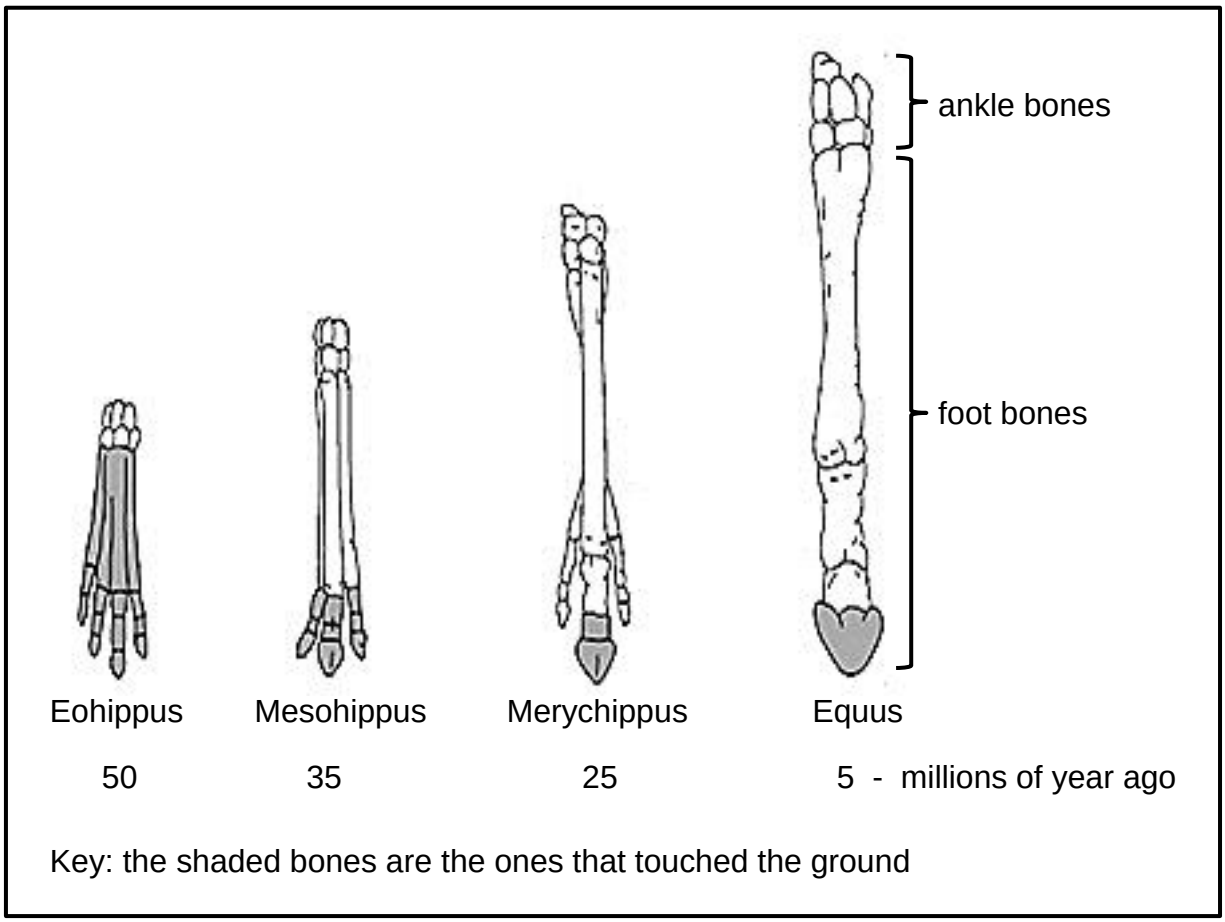
Humans chose characteristics that they like and bred dogs with those phenotypes and genotypes ✓ to create dogs that suit their needs, e.g. hunters, companions, helpers. ✓ The different breeds are bred for the different needs and therefore selected characteristics. ✓

(5)

1.6 This question applies to the diagram on the next page.

The ancestor of the modern horse had very differently shaped foot bones.

Scientists believed that the structure of the foot bones evolved as the environment changed from swampy areas with soft mud to drier and harder soil. This allowed the animals to move effectively in each habitat.



1.6.1 Describe two changes to the bones that have taken place over the past 50 million years. (2)

Bones became larger / longer / thicker ✓, there were fewer bones ✓, fewer bones touched the ground ✓ (any two)

1.6.2 Eohippus lived in swampy areas with soft mud. Explain one advantage to Eohippus of the arrangement of bones in its feet. (2)

Large/r surface / area in contact with the ground ✓ *compulsory

low / less pressure on the ground ✓, less likely to sink into ground / mud ✓, could run faster ✓, easier to escape predators ✓
(* compulsory + any one)

1.6.3 The changes in the arrangement of the foot bones of horses support Darwin's theory of evolution by natural selection. Explain how the arrangement of the foot bones of Eohippus could have evolved into the arrangement of the foot bones of Equus. (6)

There was a great deal of variation in the size, number, arrangement of foot bones ✓

some had larger / fewer bones and were suited to run faster on harder / drier ground ✓

some had smaller / many bones could not run fast and were more easily caught by predators / they died ✓

the ones that could run faster survived and reproduced ✓

passed the allele for larger / fewer bones to the next generation ✓

the next generation therefore had a higher proportion of individuals with larger / fewer bones. ✓

(10)

Section A: [48]

Section B

Question 2

2.1 An investigation was conducted by a scientist to determine if two plant populations, Population 1 and Population 2, belonged to the same species. The scientist collected seeds from each of the populations.

The procedure followed was :

- He planted 20 seeds from Population 1 and 20 seeds from Population 2 in two separate plots close to each other.
- The stamens of all the flowers of Population 1 were removed.
- Pollen from the flowers of Population 2 was used to pollinate the

flowers of Population 1.

- The scientist harvested the seeds of the plants in Population 1.
- He grew these seeds under ideal conditions in a laboratory.

Result: None of the seeds germinated.

2.1.1 Explain the advantage of removing the stamens from the flowers of Population 1. (2)

Stamens contain pollen grains in the anthers ✓

Removing stamens prevents self-fertilisation of Population 1. ✓

2.1.2 What evidence indicates that the two populations do not belong to the same species? (1)

Inability to produce fertile seeds / infertile seeds did not germinate ✓

2.1.3 State two factors that the scientist would have kept constant in the laboratory. (2)

Amount of water used on both populations must be the same ✓

Distance between the planted seeds must be the same ✓

The type of soils used must be the same ✓

The amount of light must be the same for both populations ✓

(any two)

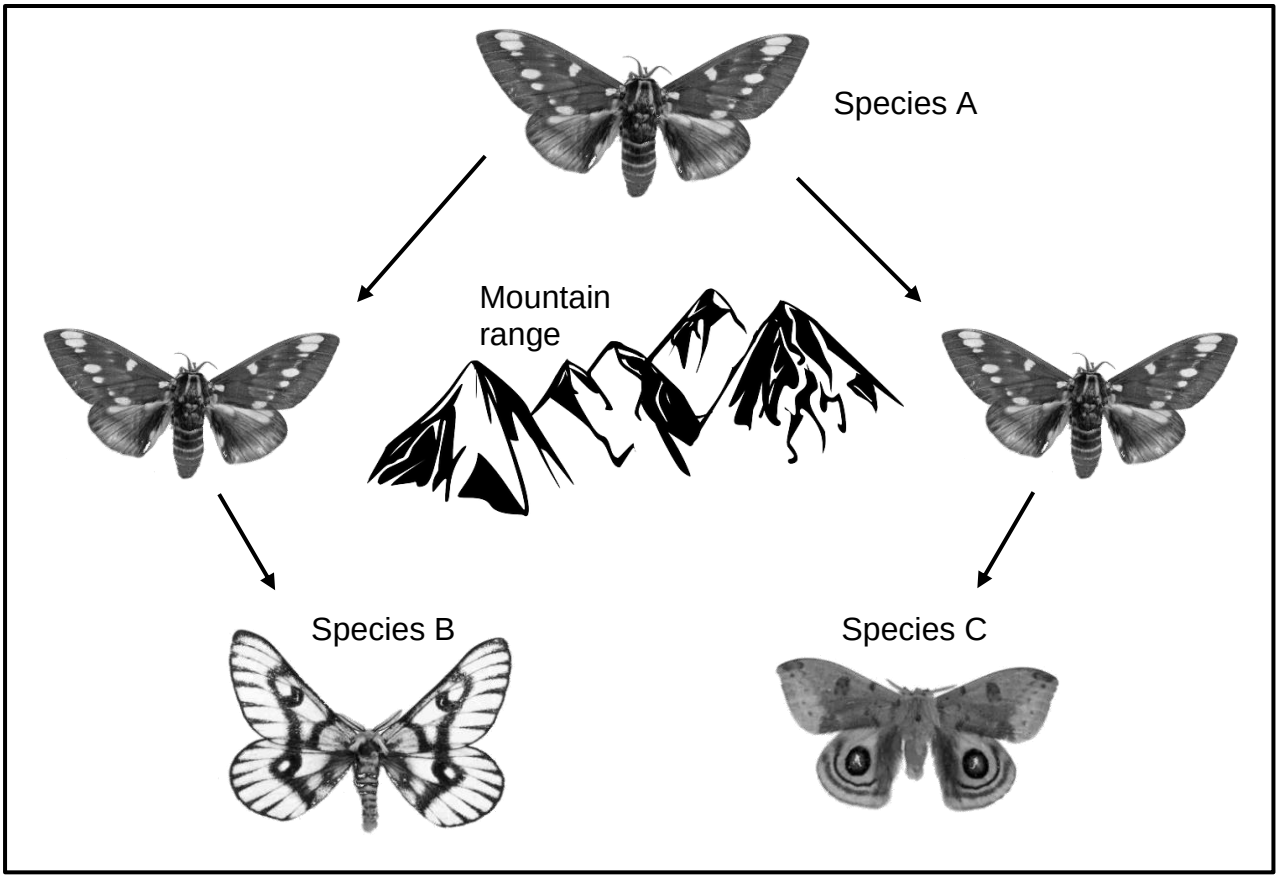
2.1.4 State one way in which the scientist could have increased the reliability of his results. (1)

Increase the sample size (more seeds) for each of the populations ✓

Repeat the investigation, and if the results are the same, it is reliable ✓ (any one)

(6)

2.2 Study the diagram below of the moth species that originally belonged to a single population but was later separated by a mountain into two groups.



2.2.1 Name the process which is illustrated in the diagram above. (1)

Speciation ✓

2.2.2 Explain the importance of the process you identified in question 2.2.1 above. (2)

Increases diversity of species / biodiversity ✓

Introduces reproductive isolation mechanisms ✓

Eliminates gene flow between different populations ✓

Decreases extinction rates of species ✓

(any two)

2.2.3 Why is species A the ancestor of species B and C? (2)

Species B and C ✓ evolved from species A. ✓

Species A existed prior to species B ✓, and species C evolved at the same time as species B ✓ (any one x 2)

2.2.4 Explain the above illustrated process in relation to the three species indicated in the diagram. (6)

Moth in species A belonged to a single population. The population of species A moths was split into two groups, one on each side of the mountain range. ✓

Gene flow / interbreeding between the two groups was completely eliminated / impossible ✓

Each group was exposed to unique environmental factors / selection pressures ✓

Natural selection occurred independently in each group on either side of the mountain. ✓

Each population became genotypically and phenotypically different from the other population. ✓

If the two groups were to mix again and attempt to interbreed, the offspring would be infertile. Thus two new species will then have been produced. ✓

(11)

2.3 Tabulate two differences between natural selection and artificial selection.

(3)

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 adaptations to the environment.

✓ - for table, ✓ - for each of two differences provided

(3)

2.4 Study the extract below which describes the evolution of the snake

> How snakes lost their limbs has long been a mystery to scientists: New research on a 90-million-year-old snake fossil suggests that snakes evolved to live and hunt in burrows as many snakes still do today.
>
> It is generally accepted that snakes and lizards are closely related, although very few transitional fossils have been found to support this generalisation.
>
> (adapted from https://www.ed.ac.uk/news/2015/snakes-271115)

a) Explain one characteristic that you would expect a transitional snake fossil to have. (1)

Smaller limbs than the ancestor compared to no limbs of modern snakes ✓

More vertebrae than the ancestor but less than the modern snake ✓ (any one)

b) Describe how Jean Baptiste de Lamarck would have explained the loss of limbs in snakes? (4)

Lizards crawled into burrows to find food / escape from predators ✓

They did not use their limbs anymore ✓

The limbs became smaller and eventually disappeared ✓

They passed on this characteristic to their offspring ✓

(5)

[25]

Question 3

3.1 Lizards of a certain species on an island are usually brown in colour. A mutation in one gene for body colour results in red or black lizards. Black lizards camouflage well against the dark rocks and warm up faster on cold days which will give them energy to avoid predators.

Scientists investigated the relationship between the colour of lizards in a population and their survival rate on an island.

They conducted the investigation as follows:

- They selected a group of lizards of a certain species in a habitat.
- They recorded the percentage of each colour (brown, red or black) in the selected group.
- They repeated the investigation over a period of 30 generations of offspring.

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

Colour of lizards	Percentage (%) of each colour In the population			
	Initial population	10th generation	20th generation	30th generation
Brown	80	80	70	40
Red	10	0	0	0
Black	10	20	30	60

(adapted from https//hhmi.org/bioInteractive)

3.1.1 State the:

a) independent variable (1)

colour of lizard ✓

b) dependent variable (1)

survival rate of the lizards ✓

3.1.2 Explain the effect of the mutation on the survival of red lizards. (2)

It decreases survival / lizards may die / is harmful / is lethal to the red lizards ✓ since they will be seen on the black rock by the predators ✓

OR They could not escape predators / catch prey on cold days ✓ as red lizards did not warm up fast on cold days ✓ (any one × 2)

3.1.3 Explain why the scientists had to conduct this investigation over 30 generations. (2)

To allow enough time for reproduction and survival ✓ to be able to calculate the percentage to ensure reliability of results ✓

OR A change in population proportions will not be seen over a shorter time period ✓ to ensure reliability of results ✓ (any one × 2)

3.1.4 State two ways in which the scientists could have improved the validity of the investigation. (2)

Conduct the investigation in the same habitat / environment ✓

Use the same sampling technique ✓

Capture the same number of lizards in each sampled generation ✓

Take each sample at the same time of day / weather conditions ✓

(Mark first two only – any 2)

3.1.5 Use the theory of natural selection to explain the higher percentage of black lizards in the population of the 30th generation. (6)

There is variation in colour amongst the lizards

* Red and brown lizards have a disadvantageous characteristic / trait and ✓

* are not camouflaged / cannot warm up fast enough to have energy to run away ✓

and are killed by predators ✓

* The black lizards have the advantageous trait and ✓

* are better camouflaged / warm up faster to have energy to avoid predators ✓

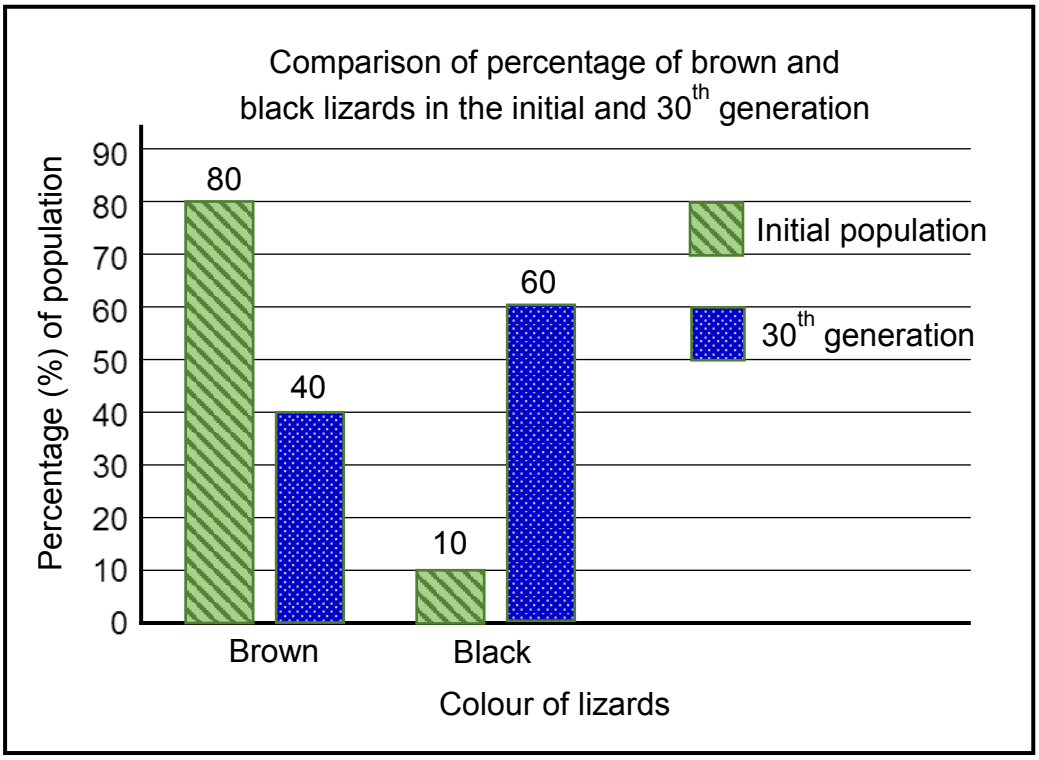
and survive / reproduce ✓

The allele for black colour is passed on to the next generation

to produce more black lizards in the next generation ✓

(any 2 + * 4 compulsory marks)

3.1.6 Draw a bar graph to compare the percentage of the brown and the black lizards in the initial population and the 30th generation. (6)



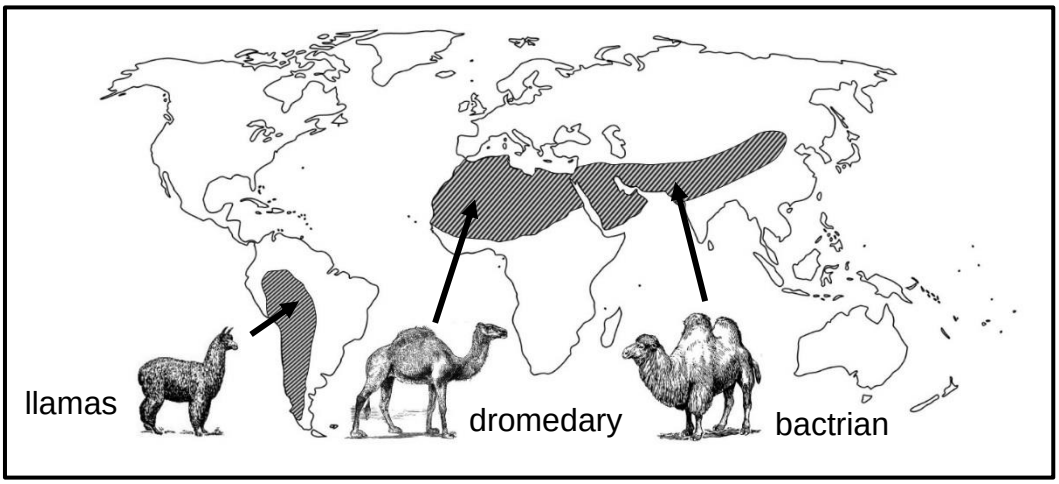
Guideline for assessing graph

Bar graph for the required data	✓
Title of graph	✓
Correct label and scale for X-axis	✓
Correct label and scale for Y-axis	✓
Drawing of bars	✓: 1 – 3 bars plotted correctly ✓✓: All 4 bars plotted correctly

If wrong type of graph, marks lost for Bar graph, and Drawing of bars.

(20)

3.2 The diagram shows the distribution of various camels on the different continents. The arrows indicate the current distribution of the animals.



(adapted from http://www.ck12.org)

Explain how speciation of camels may have occurred. (6)

The common ancestor / original camel population was separated into different populations by the sea / due to continental drift ✓
There was no gene flow between the populations. ✓
Each population was exposed to different environmental conditions / selection pressures ✓
Natural selection occurred independently in each of the populations ✓
The individuals of each of the separated populations became different from each other over time genotypically and phenotypically ✓
Even if the three populations were to mix again they would not be able to interbreed to produce fertile offspring. ✓

[26]

Section B: [51]

Total Marks: [99]

Cognitive level distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1	✓				2
1.1.2		✓			2
1.1.3		✓			2
1.1.4		✓			2
	2	8			8
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7	✓				1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	10				10
1.3.1		✓			2
1.3.2		✓			2
1.3.3		✓			2
1.3.4		✓			2
1.3.5		✓			2
		10			10
1.4.1		✓			1
1.4.2			✓		3
1.4.3		✓			1
		2	3		5
1.5 a		✓			2
1.5 b		✓			3
		5			5
1.6.1	✓				2
1.6.2		✓			2
1.6.3		✓			6
	2	8			10
2.1.1		✓			2
2.1.2	✓				1
2.1.3	✓				2

2.1.4	✓				1
	4	2			6
2.2.1	✓				1
2.2.2		✓			2
2.2.3			✓		2
2.2.4		✓			6
	1	8	2		11
2.3		✓			3
		3			3
2.4 a		✓			1
2.4 b		✓			4
		5			5
3.1.1 a - b		✓			2
3.1.2			✓		2
3.1.3			✓		2
3.1.4		✓			2
3.1.5		✓			6
3.1.6		✓			6
		16	4		20
3.2		✓			6
		6			26
	19	72	9		99

CHAPTER 10: HUMAN EVOLUTION

Overview

Time Allocation: 4 weeks (16 hours)

This chapter consists of the following sections:

1. Introduction
2. Key concepts and terminology
3. Our place in the animal kingdom
4. Characteristics that we share with African apes
5. Lines of evidence that support the idea of common ancestors for living hominids including humans
6. 'Out of Africa' hypothesis
7. Fossil sites in Africa and South Africa
8. Alternatives to evolution
9. For enrichment
10. Summary
11. End of topic exercises

Introduction

This chapter focusses very specifically on human evolution by considering three major phases of hominin evolution starting from approximately 6 million years ago to the present day. As a first step, we consider the place of humans in the animal kingdom, as part of the Order Primates, and the Family Hominidae, which includes us modern humans, chimpanzees, bonobos, gorillas and orangutans.

We consider the notion of a common ancestor for the Family Hominidae, by exploring what we share with other hominids, represented by chimpanzees. We also look at differences between us and chimps – anatomical differences as a result of bipedalism and a larger brain

The next step is to the lines of evidence supporting the notion of a common ancestor. We consider the fossil evidence, genetic and cultural evidence.

This leads us to the consideration of the Out of Africa hypothesis – the theory that early humans evolved in Africa, and over time, spread all across the world. This will be done by evaluating the fossil evidence in eastern and southern Africa and what mitochondrial DNA studies have shown.

We briefly delve into South Africa's contribution to an understanding of human evolution by considering our numerous fossil sites, e.g., the Cradle of Humankind. And in the last section to this chapter, we briefly consider some of these alternatives.

Key concepts and terminology

- In the fossil record, there is considerable evidence for a common ancestor for living hominids, including humans.
- There are distinct similarities between African apes and humans, as there are clear anatomical differences.
- There is genetic evidence linking modern humans to a common ancestor in East Africa approximately 60 000 years ago.
- According to the Out of Africa hypothesis, modern humans originated in Africa and then migrated out of Africa into the rest of the world.
- South African fossil sites, particularly the area known as the Cradle of Humankind, are rich in fossil records that together with the Rift Valley fossils, trace a 6 million-year-long evolutionary development from an ape-like ancestor to modern humans.
- The theory of evolution is not universally accepted, and a number of alternative theories have been developed to account for the diversity of life.

Key terminology

hominids	Hominids are a biological group that includes modern humans, our early human ancestors, chimpanzees and bonobos, gorillas and orangutans, sometimes collectively referred to as apes.
hominins	Hominins are a sub-group of the hominids, and includes only modern humans and early human ancestors.
homo	This is a Latin term meaning ‘human’.
Homo sapiens	*Homo sapiens* means ‘wise human’. All humans living today belong to the same species of *Homo sapiens*.
primates	A biological grouping that includes lemurs, baboons, chimpanzees, apes, and humans. Primates share a number of characteristics as will be detailed shortly.
phylogenetic diagram	A branching diagram or "tree" showing the evolutionary relationships among various biological species

Our place in the Animal Kingdom

Discussing the scientific theory of evolution, and particularly human evolution, can quickly lead to very defensive reactions based on a misunderstanding of what human evolution is actually saying. This is minimised when placing the human within a classification of living things (the Kingdom Animalia), and part of a large family, the *Family Hominidae*.

Learners must be able to situate the *Family Hominidae* within the Order Primates using a phylogenetic tree, and to interpret it.

They must be able to determine the position and dating of a common ancestor for a particular taxon, and be able to explain what a 'common ancestor' is in the context of the scientific study of human evolution.

Activity 1: Phylogenetic trees

1. To what Order and what Family do modern humans belong? (2)

   The Order Primates ✓ and the Family Hominidae ✓

2. Name two species that belong to the same Family humans belong to. (2)

   Gorillas, chimpanzees, orangutans, bonobos ✓✓ any two

3. According to the phylogenetic tree in Figure 2, when did the most recent common ancestor for humans and gorillas exist? (1)

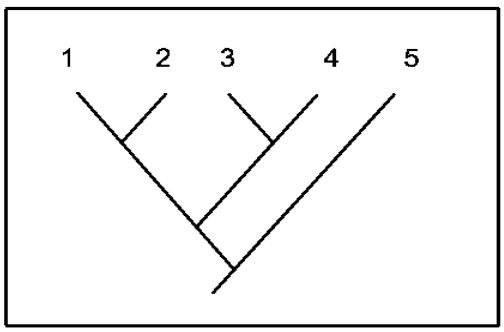
   About 10 million years ago ✓

4. Distinguish hominids from hominins. (4)

   Hominids are members of the Family Hominidae ✓ and include humans and early humans, chimpanzees, bonobos, gorillas and orangutans ✓.

   Hominins form a sub-group (tribe) within the Family Hominidae ✓, and include only modern humans and early human ancestors ✓.

5. Study the phylogenetic tree below.



   Which ONE of the following is a reasonable conclusion based on the phylogenetic tree?

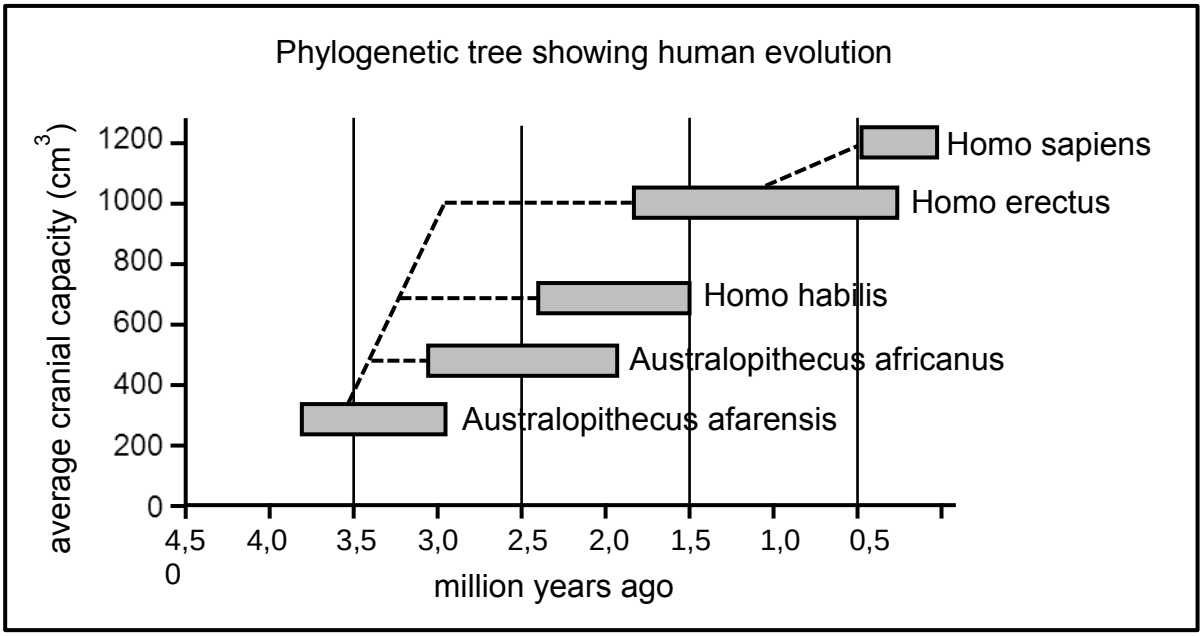
A **1** and **2** belong to the same species

B **3 is more closely related to 4 than to 5** ✓✓

C **1** and **5** do not have a common ancestor

D The DNA of 1 will be more similar to **4** than to **2** (2)

6. Study the phylogenetic tree below and answer the questions that follow.



a) Define a phylogenetic tree. (2)

a branching diagram or "tree" ✓ showing the evolutionary relationships among various biological species ✓

b) Which organism is considered to be the common ancestor of all species shown above? (1)

Australopithecus afarensis ✓

c) Which organism has the biggest cranial capacity? (1)

Homo sapiens ✓

d) Name TWO species that lived between 1,5 and 2 million years ago. (2)

Homo habilis ✓ , *Australopithecus africanus* ✓ and *Homo erectus* ✓ (any two)

e) Calculate the time difference between the evolution of *Homo erectus* and *Homo sapiens*. (Show your working.) (3)

Homo sapiens: emerges around 0,5 mya ✓ ; *Homo erectus* emerged around 1,8 mya ✓ . Time difference = 1,8 – 0,5 = 1,3 million years ago ✓

f) Which organism – *Homo erectus* or *Homo habilis* − is more closely related to modern day humans? (1)

Homo erectus ✓

(21)

Characteristics that humans share with African apes

Having a common ancestor that lived 10 million years ago implies that the descendants of that ancestor will, to a greater or lesser extent, share some of the ancestor's characteristics. We explore the characteristic shared by humans and other primates (i.e. how we are alike), by humans and the other members of the *Family Hominidae* (having a more recent common ancestor 6 mya).

But the process of evolution is an ongoing process, so there will be significant differences that have developed in the interceding years. We explore these differences as they apply to:

- bipedalism and related anatomical adaptations,
- increasing brain size and its morphological implications,
- dentition and palate shape,
- prognathism, cranial ridges and brow ridges.

This is done by comparing the above characteristics in a modern human with those in chimpanzees. Learners should be able to identify the characteristics and their changes, and apply these to make relevant judgements about what type of fossil they are looking at.

Key terminology

opposable thumb	a thumb that can be placed opposite the fingers of the same hand
sexual dimorphism	distinct differences in size or appearance between the sexes of an animal in addition to the sexual organs themselves
bipedalism	ability to walk on two legs
quadrupedalism	use of four limbs for locomotion (quadrupeds)
foramen magnum	hole in the base of skull through which the spinal cord passes
cranial ridge	ridge running across the top of the skull that served to attach large jaw muscles to the head
prognathous	protruding (projecting forward) upper / lower jaw

A summary of the differences between modern humans and African apes …

Feature	Humans (*Homo sapiens*)	African apes
cranium	large cranium / brain	small cranium / brain
brow ridges	not well developed	well developed, prominent
spine	more curved (S-shaped)	less curved (C-shaped)
pelvic girdle	short and wide	long and narrow
canines	small	large
arrangement of teeth	small gaps between teeth	big gaps between teeth
palate shape	small, semi-circular	long, rectangular
jaws	small, less prognathous	large, more prognathous
cranial ridges	none	across top of cranium
foramen magnum	in a forward position	in a backward position

Activity 2: Anatomical differences and similarities between African apes and modern humans

1. Name five characteristics that all hominids share, and name three differences between humans and chimpanzees. (8)

   Shared characteristics: Large brain, eyes in front of head, opposable thumbs, bare fingertips / nails instead of claws, upright posture, freely rotating arms, sexual dimorphism ✓ for any five

   Differences (human vs chimpanzee): Forward vs backward position of foramen magnum, curved vs straighter spine, short, wide vs long, narrow pelvis, no vs prominent brow ridges, C-shaped or semi-circular vs long, rectangular palate, small vs large canines, orthognathic vs prognathous jaws ✓ for any three

2. Explain the meaning of the term ‘opposable thumb’ in your own words. (2)

   The thumb is opposable if it can touch and exert pressure on the finger pad of another finger ✓ on the same hand ✓

3. Explain bipedalism in your own words. Is bipedalism simply the ability to stand on two feet? (3)

   Bipedalism or habitual bipedalism is the ability to stand erect and walk comfort-ably on two feet ✓ , placing one foot in front of the other, slight apart ✓. It is more than simply standing on two feet ✓ – many animals can do that for a short period

4. Name four advantages of bipedalism. (4)

✓ for any four: Hands are free to pick or carry food, to use tools or weapons; Standing upright, with eyes higher off the ground, gives a better and wider view of surroundings, a timelier warning of approaching predators or of potential prey; Movement becomes easier and more energy-efficient; A more vertical posture reduces the body's exposure to sunlight when in an open area; In courtship behaviour, the sex organ is readily displayed

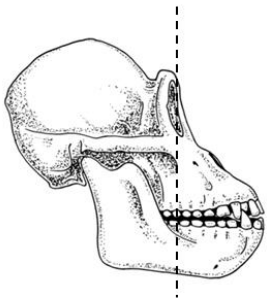
5. Explain the meaning of binocular vision and depth perception. (4)

Binocular vision: having two eyes ✓ in the front of the head ✓ to view an object. Depth perception is a function of the brain ✓ that interprets what the eyes see and recognises shape, distance, etc. ✓ – this is known as stereoscopic vision

6. Use a sketch to illustrate the meaning of the term 'prognathous'. (3)

prognathous means protruding, as in sketch, the jaws of the chimpanzee skull extend far beyond the vertical line running through the eye-socket.

✓ - for sketch, ✓✓ - showing jaws protruding

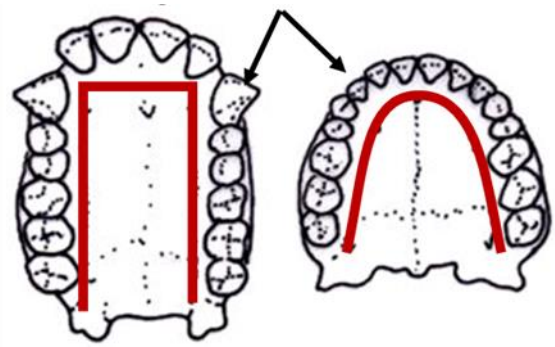


7. Draw a labelled diagram to illustrate the evolution of the palate shape and teeth from chimpanzee to modern human. The diagram should include at least three visible differences. (6)

Diagram illustrating the evolution of palate shape ✓✓✓

change in canines ✓, smaller human teeth ✓, changing palate shape ✓

Canines – humans canines differ



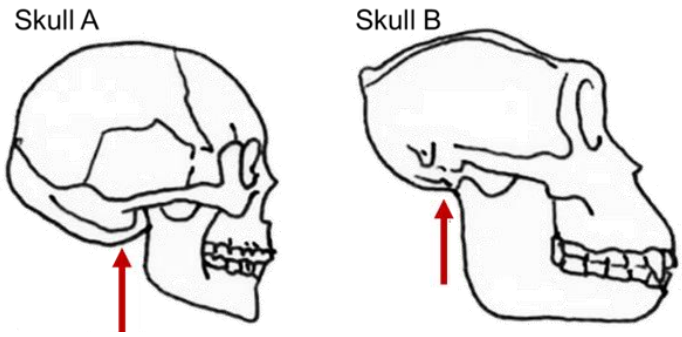
Changing palate shape

Humans have smaller teeth generally

Chimpanzee vs human palate

8. The diagram shows the skulls of two different primate species.

The arrows point to the position of a crucial part of the skull. Answer the questions below.



a) What part of the skull are the arrows pointing to in both cases? (1)

foramen magnum ✓

b) Which species, A or B, is more likely to be a quadruped? Explain. (3)

Species B ✓ . When walking as quadruped, on all fours, the back is almost horizontal ✓ . To look forward comfortably, the spine needs to go into the skull towards the back of the base ✓

c) Tabulate 4 directly observable differences between the two skulls. (5)

✓ - for table, each observable difference – any four

	Skull A (human)	**Skull B (gorilla)**
Brain size	large	Much smaller
Jaws	Orthognathous / flat face	Prognathous
Teeth	Small, small canines	Large, large canines
Cranial ridge	none	Present
Brow ridge	none	prominent

d) Explain how the change in the skulls pictured above might indicate a change in intelligence. (3)

The larger the cranium ✓ , the larger the brain is can house / accommodate ✓ . A larger brain suggests greater intelligence ✓

9. The diagram below gives parts of the skeletons of a human and an ape.

a) Which letter, A or B, best represents a bipedal organism? (1)

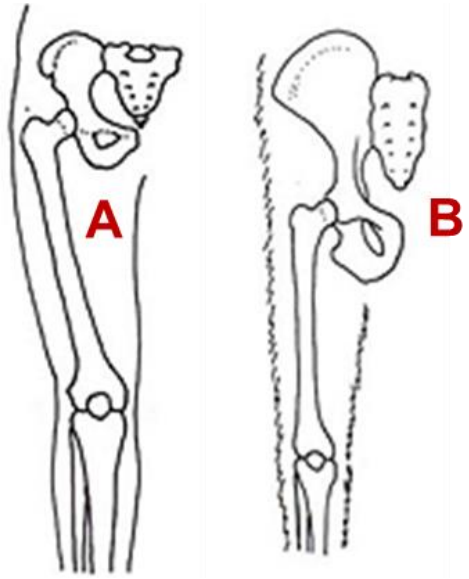
A ✓

b) Explain how the shape of the pelvis contributes to bipedalism. (2)

The pelvis is A is shorter and wider (more cup-shaped) than the pelvis in B ✓ . It is better able to support the weight of vertically stacked organs ✓ , as in a human.

c) Which other characteristic shown in the diagram below contributes to bipedalism? (2)

The shape of the pelvis in A and the direction of the hip socket angle



the femur inwards ✓ for maximum load bearing and an efficient, comfortable bipedal gait ✓

(47)

Lines of evidence that support the idea of common ancestors for living hominids including humans

In this section learners explore very specifically human evolution – the development of modern humans from a very early human-ape-like organism, *Ardipithecus ramidus*. From there, the process of human evolution is traced through the genus Australopithecus and early Homo species.

Learners should be able to name / identify the various species mentioned, and give information about them with regard to the fossil sites where they were found, the scientists who discovered them, and discuss the evolutionary trends provided by the fossils of the three genera.

Learners should be able to interpret and draw a time-line for the existence of the three genera, and be able to tabulate the most significant changes that took place in the evolution of modern humans.

As part of this, learners are encouraged to explore various phylogenetic trees, and recognize that such trees are hypotheses, not definitive answers. Relationships between fossilised species are inferred, and often strongly debated / argued about.

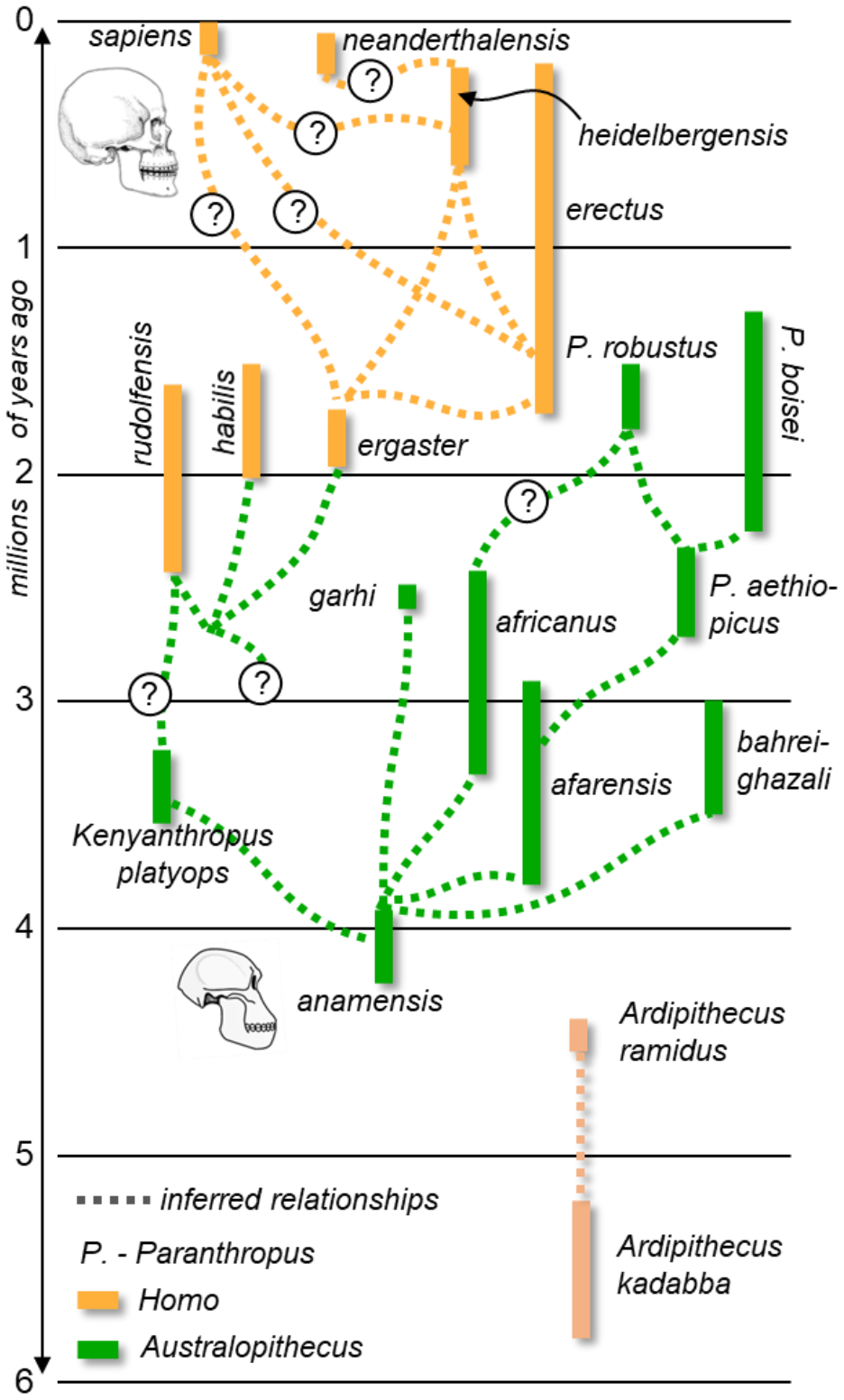
Key terminology

hominin	The group consisting of modern and early humans
pithecus	Greek word of 'ape'
genus	Biological classification ranking between family and species, consisting of structurally or phylogenetically related species
species	A group of organisms that are genetically similar, can interbreed and produce fertile offspring
For all entries below, the first name: *Ardipithecus*, *Australopithecus* and *Homo* refers to the genus, the second name, e.g. *ramidus*, refers to the species.	
Ardipithecus ramidus	Ardipithecus – *ardi* means 'ground', or 'floor', and *ramidus* means 'root': the name refers to the closeness of this species to the roots / origins of humanity
Australophitecus	*Australis* is the Latin for 'southern', thus southern ape.
A. afarensis	*afarensis* – from Afar, a location in Ethiopia
A. africanus	*africanus* – from Africa (thus southern ape of Africa)
A. *sediba*	*Sediba* – Sotho word, meaning 'natural spring' or 'well'
A. *robustus*	*robustus* – meaning robust, strong, sturdy, heavy set.
Homo	Latin word for human
H. *habilis*	*habilis* – meaning skilful, or handy
H. *erectus*	*erectus* – meaning erect, walking upright
H. *sapiens*	*Sapiens* – wise, thus H. sapiens the wise human (a reference to the large brain)
H. *ergaster**	*ergaster* – the Greek word for 'work', thus working man
H. *heidelbergensis** **H. *neanderthalensis****	The names of these species are derived from two towns in Europe where these species were first discovered
H. *naledi**	*naledi* – meaning star.

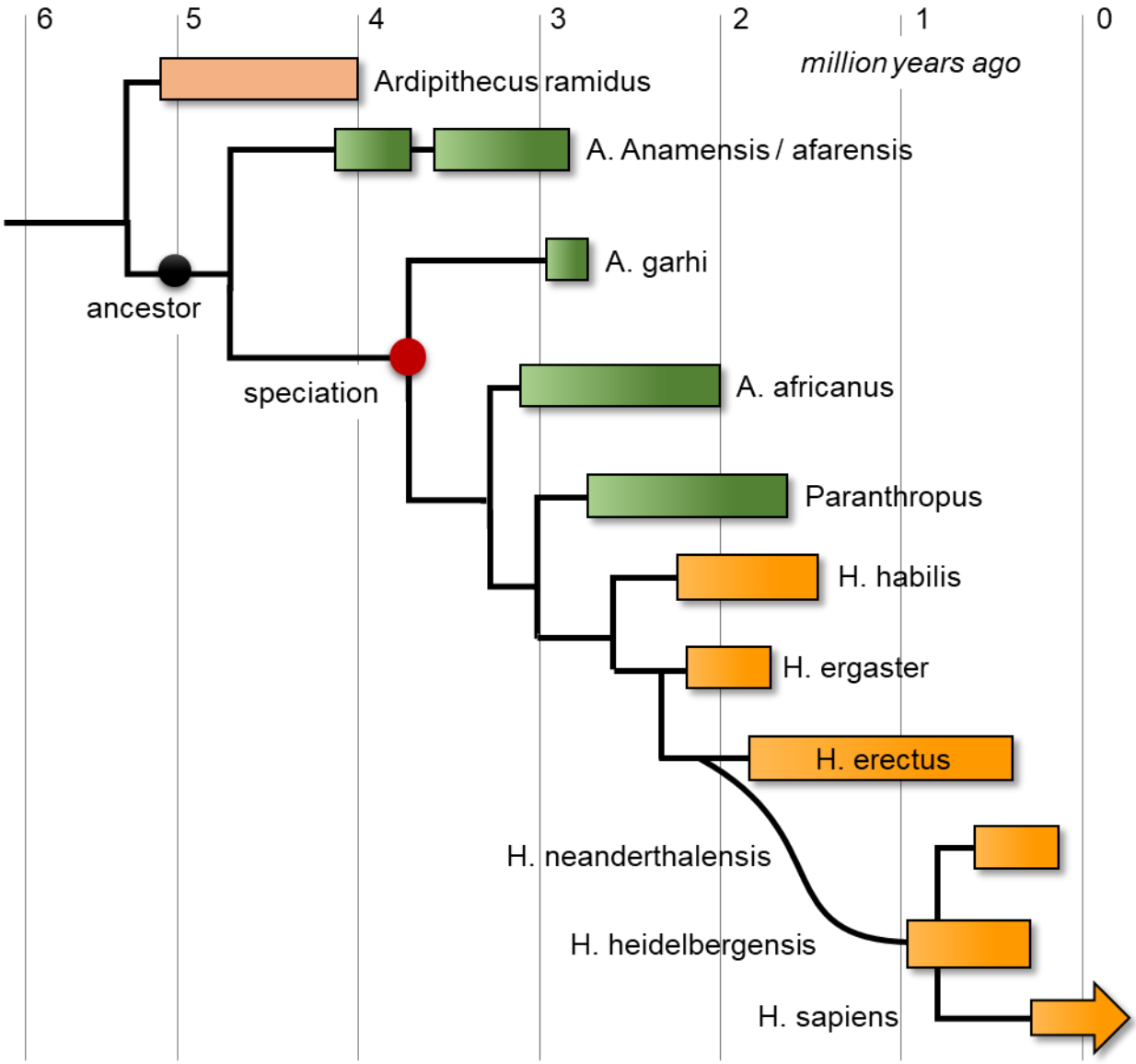
Phylogenetic trees of hominin evolution

Phylogenetic trees seek to provide some order into the story of human evolution. To generate a phylogenetic tree, scientists analyse characteristics of the species involved. This may include anatomical similarities and differences evident in the fossil record. But given the scarcity of fossils and other data, "phylogenetic trees are hypothesis, not definitive answers" (Khan Academy, Phylogenetic trees).

Here are two alternative phylogenetic trees.



This phylogenetic tree emphasizes the fact that the story of human evolution is very complex. Paleo-anthropologists infer relationships between different hominin species based on shared traits. In some cases, identified by the question mark, there is significant debate among scientists about the exact nature of the relationships.



Activity 3: Fossil evidence

1. Explain why our understanding of the sequence of human evolution based on fossil evidence might change in the future. (2)

   While numerous fossils have been found, most have only been discovered in the last 50 years or so. Every fossil find requires study and interpretation, to find out how it fits into the overall picture ✓ . This is not an easy task, particularly if you have few pieces of the puzzle ✓ . New discoveries can change our understanding radically, as has happened in the past already.

2. The image below is of Mrs. Ples.

a) Name three ape-like features of this skull.(3)

Brow ridge , strongly projecting upper jaw bone , smaller cranium / brain size ✓ - for any three

b) What clues are there in the image to the brain size of Mrs. Ples. (2)

the size of the cranium ✓✓

c) Where was Mrs. Ples found, and by whom? (2)

by Robert Broom ✓ , in 1947, near Sterkfontein ✓

d) What species did Mrs. Ples belong to, and when did this species live? (2)

Australopithecus africanus ✓ , lived in Africa between 3,2 and 2 million years ago ✓

e) The species Mrs. Ples belonged to is extinct. What does this mean? (1)

Extinct means to no longer exist, no member of the species is still alive ✓

3. Which genus of early human lived on Earth for the longest time span? How does this relate to the time span for the other two genera considered? (3)

The genus *Australopithecus* lived on Earth between 4 and 1,2 million years ago – a total of 2,8 million years ✓ , much longer than the genus *Homo* (about 2,2 million years) ✓ , and very much longer than the *Homo sapiens* species (200 000 years) ✓ . The genus *Ardipithecus* probably lived for about 1,5 million years.

4. Name three Australopithecine species that lived. For each species, give the timeframe in which they lived, an example / specimen of the species, and where, when and by whom the specimen were found. (12)

Australopithecus afarensis ✓ : 3,9 – 2,8 million years ago ✓ , Lucy – discovered 1974 ✓ , by Donald Johansen at Hadar, Ethiopia ✓

Australopithecus africanus ✓ : 3,2 – 2 million years ago ✓ , Taung child – discovered by Raymond Dart in 1924 ✓ , at Taung, North West Province, South Africa ✓ .

Australopithecus sediba ✓ : 2 – 1,7 million years ago ✓ , Karabo – discovered in 2009 ✓ , by Lee Berger, at Malapa, South Africa ✓

5. If asked to decide whether a complete skull with jaw-bones was that of *Ardipithecus* or *Australopithecus*, what four features would you examine? (8)

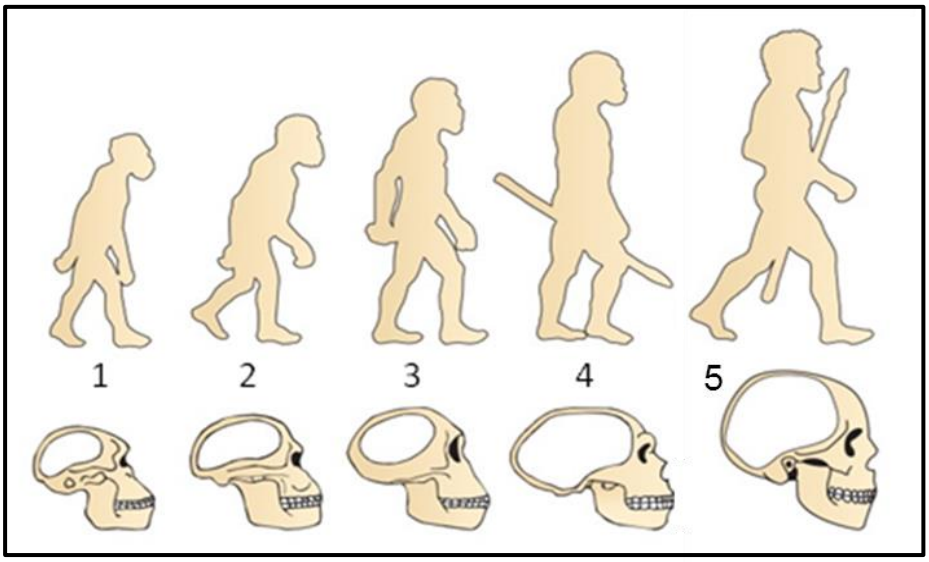
Cranium size / brain size ✓ : *Ardipithecus* had a smaller brain size (350 mL as against 435 – 530 mL) ✓

The position of the foramen magnum ✓ : for *Ardipithecus*, it would not be as forward as for *Australopithecus* ✓ .

Considering the dentition, examine palate shape, and the size of canines ✓ . *Australopithecus* would have a slightly rounder arch ✓ .

The size of the canines ✓ : larger in *Ardipithecus* than in *Australopithecus* ✓

6. Study the skulls shown in the image below.



a) Identify the species represented. Species include: *H. habilis*, *A. afarensis, A. robustus, H. sapiens, H. erectus.* (5)

1 – *A. afarensis*, 2 – *A. robustus*, 3 – *H. habilis*, 4 – *H. erectus*, 5 – *H. sapiens* – one mark ✓ for each correct specification

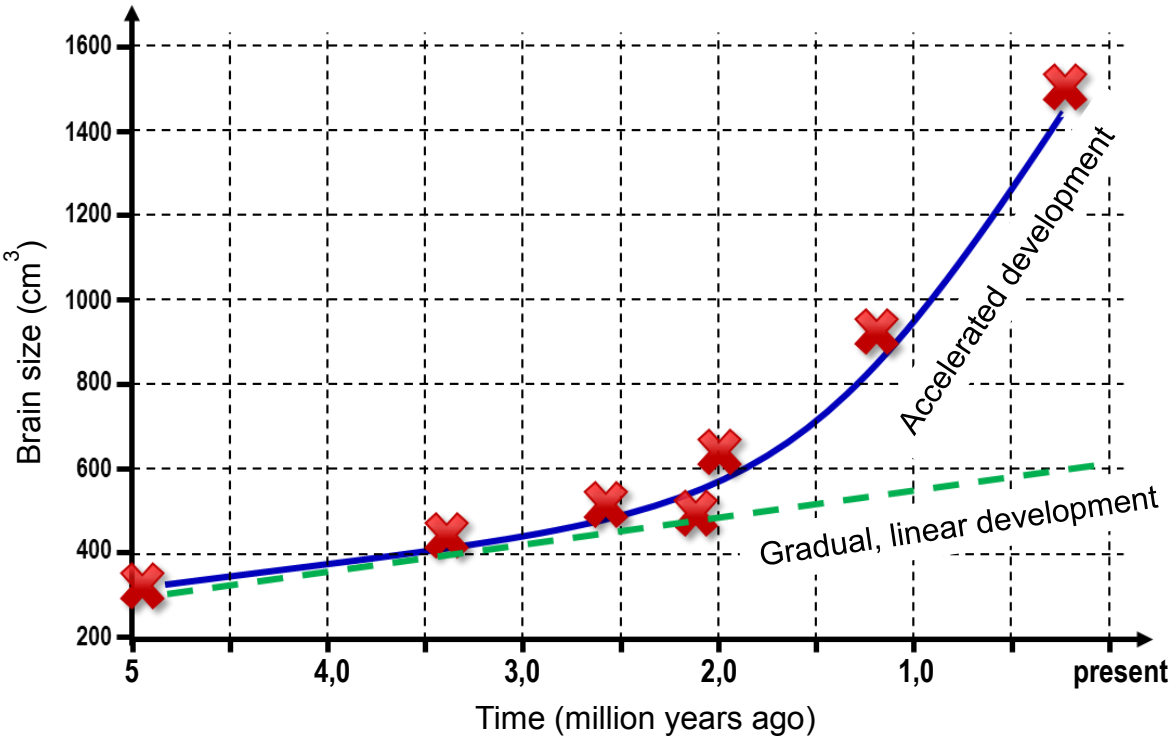
b) List four characteristics of the skull and brain size that you used to make your selection. (4)

Brain size: the larger the brain, the further the species in the stage of evolution, generally speaking; brow ridges / the shape of the forehead / how prognathous the jaw is / the size of the jaw – one mark ✓ for each correct specification

7. Draw a line graph to show the development of brain size from *Ardipithecus* through to *Homo sapiens*. Use the following data.

Species	Time frame (mya)	Brain size (mL)
Ardipithecus ramidus	5	350
Australopithecus afarensis	3,4	460
A. afarensis	2,6	520
A. sediba	1,9	420
Homo habilis	2	650
H. erectus	1,2	950
H. sapiens	0,2	1500

What conclusion/s can you draw from the graph? (8)



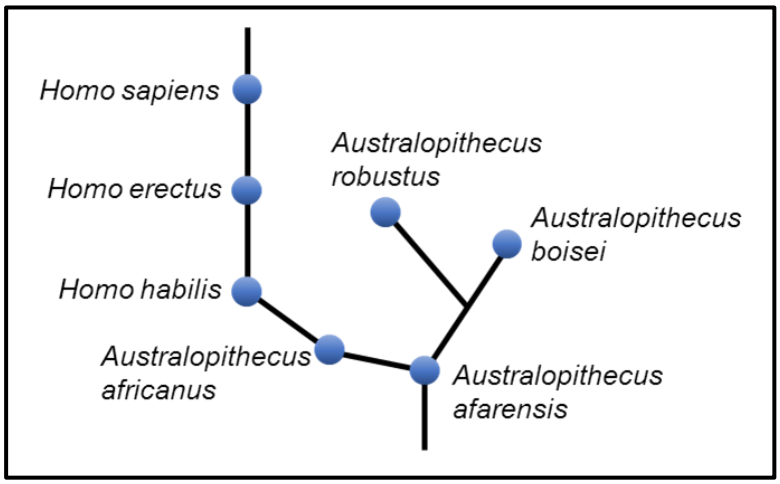
Conclusion: the initial brain size development is slow, and then speeds up exponentially as one approaches the present. ✓ ✓

(this is clearly illustrated by the two lines of best fit drawn through the scatter plots: the line representing a gradual, more linear brain size development, and the line showing accelerated development)

✓✓ - for correctly drawn graph – scatter plot, position of dots/crosses

✓✓ - for correct labelling, axes

8. The diagram below shows possible relationships between members of the family Hominidae. Study the diagram, then answer the questions that follow.



a) What is the name given to this type of diagram? (1)

phylogenetic tree ✓

b) How many genera, and how many species, are represented? (2)

two genera *Australopithecus, Homo* ✓ and seven species ✓

c) Explain why *A. robustus* and *A. boisei* are more closely related than *A. boisei* and *A. afarensis*. (2)

A.robustus and *A. boisei* share a more recent common ancestor ✓✓

(57)

'Out of Africa' hypothesis

In this section, the evidence supporting the Out of Africa hypothesis is examined.

We explore the evidence presented by mitochondrial DNA studies. We examine the fossil evidence: fossils of Ardipithecus found only in Africa, fossils of Australopithecus (including Karabo, Little Foot, Taung child, Mrs Ples) also only found in Africa, of Homo habilis (Africa only) and the oldest fossil of modern Homo sapiens.

Learners should be able to argue for this hypothesis, and list the various reasons for it in some detail.

Fossil sites in Africa and South Africa

The Cradle of Humankind is a veritable treasure trove of hominin fossil, and as such, has played a very significant part in elaborating the evolution of humans. We explore the various cave complexes in the Cradle, what was found there, and by whom and when. Learners should be able to explain the significance of the Cradle, and list some of the details shared in the text. Other South African sites are also explored, highlighting South Africa's contribution. Finally the fossil evidence found in other parts of Africa is explored.

Activity 4: Out of Africa hypothesis

1. State the 'Out of Africa' hypothesis. (3)

   All modern humans (*Homo sapiens*) ✓ originated in Africa ✓ and migrated to other parts of the world ✓

2. Explain why we speak of an 'Out of Africa' *hypothesis*, not theory. (4)

   It is a hypothesis, since it relies on currently available fossil evidence that has been studied and from which relationships etc. are inferred ✓ . Fossil evidence yet to be discovered can contradict the presently generally accepted Out of Africa hypothesis ✓ . This has happened a few times in the

past. Some scientists argue for a multi-regional origin ✓ . A theory is more definitive than a hypothesis ✓ , hence the Out of Africa hypothesis, not theory

3. What evidence is there to support the 'Out of Africa' hypothesis? (9)

   Genetic evidence ✓ – mitochondrial DNA is inherited from the mother ✓ . Analysis of mutations / markers on the mtDNA shows the oldest female ancestors ✓ were living in Africa ✓ , and that all currently living humans are descended from her ✓ .

   Fossil evidence ✓ – the fossils for *Ardipithecus*, for *Australopithecus* and for *Homo habilis*, have been found only in Africa ✓ . The oldest *Homo erectus* fossil ✓ and the oldest *Homo sapiens* fossil ✓ have also been found in Africa.

4. What is mitochondrial DNA? (3)

   Mitochondrial DNA is the small circular chromosome ✓ found inside mitochondria ✓ . The mitochondria, and thus mitochondrial DNA, are passed only from mother to offspring through the egg cell ✓

5. What factors make mtDNA a useful tool in the exploration of human evolution? (4)

   Scientists look for mutations in the mtDNA ✓ . The mutations (called markers) occur at a steady and known rate ✓ . Those with the greatest number of markers are the oldest human populations (all from Africa) ✓ . Comparing markers allows scientists also to determined when populations separated from each other ✓

6. In your own words, describe the importance of the Cradle of Humankind. (4)

   The importance of the Cradle of Humankind derives from the abundance of hominin fossil (40% of all world-wide) ✓ found here. The fossil species found only here ✓ : *Australopithecus africanus, Paranthropus* ✓ . The first African fossils of *Homo erectus* were found here ✓

7. List two sites in South Africa, but not part of the Cradle of Humankind, where important fossils remains were discovered. Provide some detail of the fossils found. (4)

   Makapansgat Valley ✓ : this cave complex has a significant fossil record, and 40 individuals of the species *A. africanus* that is only found in South Africa ✓.

   Florisbad ✓ : an almost complete skull of an early *Homo sapiens* (or of *H. heidelbergensis*) – with a cranial volume of 1400 mL – was found there ✓

(31)

Alternative to evolution

This section of the chapter is not examinable in the final matric exam (see the Life Sciences Examination Guidelines for Grade 12 published in 2017). As such, only a

period (or two) should be devoted to this section. Its purpose should not be to argue for or against any religious convictions, but to emphasis the scientific nature of the theory of evolution. Learners should learn how to argue in favour of evolution without denigrating someone else's religious beliefs.

For enrichment

Watch some of these videos to further explore the concepts and materials dealt with in this chapter on Human Evolution. Video length is given in brackets. Also explore the websites listed below.

Family Hominidae

- Bonobo Chimpanzees: More human-like than you think: https:IIwww.youtube.comlwatch?v=yEY15TI_D4c

Bipedalism

- Why Do We Walk on Two Legs? https:llwww.youtube.comlwatch?v=G1iYLds2NcY
- Why Do We Walk Upright? The Evolution Of Bipedalism https:llwww.youtube.comlwatch?v=LzEOYgXodGI

Early Humans

- Early Humans...in five minutes or less: https:llwww.youtube.comlwatch?v=JLblq9ZvutE
- How 'Lucy' Got Her Name: https:llwww.youtube.comlwatch?v=SKYjpetqYWI
- Lucy IN SEARCH OF HUMAN ORIGINS PART ONE: https:llwww.youtube.comlwatch?v=PR_9_5gxvxg
- Laetoli Footprints: Protecting Traces of our Earliest Ancestors: https:llwww.youtube.comlwatch?v=0EZi_EAyIoQ

Out of Africa hypothesis

- First Peoples I PBS I Out of Africa https:llwww.youtube.comlwatch?v=2mpkn7AEAvU
- The Ancient World Unit: Multiregional Theory or Out of Africa Theory? https:llwww.youtube.comlwatch?v=zP2OhDOv7bE

Cradle of Humankind

- Introducing the Cradle of Humankind https:llwww.youtube.comlwatch?v=iqBtAunhQ04

- Cradle of Humankind World Heritage Site
  https:llwww.youtube.comlwatch?v=HZ442VxB15A

Homo naledi

- New Human Ancestor Discovered: Homo naledi
  https:llwww.youtube.comlwatch?v=oxgnlSbYLSc

Modern humans

- DNA Research Show Modern Humans Benefit From Neanderthal DNA
  https:llwww.youtube.comlwatch?v=0dLaOdveDGs

Alternative theories

- 5 Theories On The Creation Of Humans
  https:llwww.youtube.comlwatch?v=11hJal7qAtU

Longer videos

- The First Human (Evolution Documentary) I Timeline
  https:llwww.youtube.comlwatch?v=vJybfmbrOCE
- Evolution The Evolution of humans documentary 2014
  https:llwww.youtube.comlwatch?v=MsHEAnPX59Y

Websites worth exploring

- Australian Museum (Human Evolution)
  https:llaustralianmuseum.net.aulhuman-evolution
- The Knowledge Project: Evolution
  https:llwww.nature.comlscitablelknowledgelevolution-13228138
- Smithsonian: National Museum of Natural History: Introduction to Evolution
  http:llhumanorigins.si.eduleducationlintroduction-human-evolution
- Bradshaw Foundation (extensive review of human evolution)
  http:llwww.bradshawfoundation.comloriginslindex.php

Summary

Our place in the Animal Kingdom

- Humans are part of the Animal Kingdom in the Family *Hominidae*.
- A common ancestor to the Family Hominidae lived about 10 mya, while the common ancestor to humans and chimpanzees lived about 6 mya.
- The term hominid refers to all members of the Family Hominidae. Hominin are modern day humans and all early human ancestors.

Lines of Evidence for a Common Ancestor for Living Hominids.

- **Similarities** – with primates, humans share …
    - An opposable thumb, nails on fingers with sensitive pads, hind limbs stronger than forelimbs (arms), two eyes in the front of the head, a brain relatively large in proportion to body size.
    - With other hominids, humans share a diurnal character, the ability to raise forelimbs above the head, and the absence of a tail.
- **Differences**
    - Modern humans stand erect and have a bipedal gait (bipedalism).
    - Advantages to bipedalism: hands are free to pluck, carry or hold; it is more energy efficient, and reduces exposure to sunlight.
    - Bipedalism resulted in the following anatomical changes: Humans have
        - the foramen magnum in a forward position, a short, wide pelvis, a more curved spine.
        - a larger brain, no brow ridges or cranial ridges, no prognathous jaws, smaller teeth in a semi-circular palate.
- Genetic evidence points to a close relationship between humans and chimpanzees, sharing 98,8% of genetic material. mtDNA studies suggest that the most recent common ancestor for humans and chimpanzees lived 5 – 6 mya.
- Cultural evidence: Humans are distinguished from other hominids in that they are the only species that have manufactured tools. The simplest stone tools (Oldowan tools) appeared 2,6 mya, made by *Homo habilis*.

Out of Africa hypothesis

- The Out of Africa hypothesis – that modern humans originated in Africa, is supported mitochondrial DNA studies and the fossil record.
- Evidence from the fossil record:
    - *Ardipithecines*, *Australopithecines*, and *Homo habilis* , all ancestors of modern humans, have only been found in Africa.
    - *Homo sapiens* emerged in Africa. The oldest *Homo sapiens* fossils, dated 195 – 160 000 years ago, were discovered in Ethiopia.

Major phases in hominin evolution from 6 mya to the present

- The 3 major phases are: *Ardipithecus*, *Australopithecus* and *Homo*.
- *Ardipithecus ramidus*, the earliest hominin species, lived 4,5 mya. It was mainly arboreal, and had a relatively small brain size at 350 mL.

- Fossils of the genus *Australopithecus* have only been found in Africa. This genus had larger brains (430 – 530 mL) than *Ardipithecines* and walked erect most of the time.
- Species of *Australopithecines* include:
    - *A. afarensis* (3,9 – 2,8 mya, Lucy was found in Ethiopia in 1974)
    - *A. africanus* (3,2 – 2 mya, Taung child – by R. Dart in 1924 – Taung)
    - *A. sediba* (2 – 1,7 mya, Karabo was found by Lee Berger in 2009)
    - *A. robustus,* renamed *Paranthropus*, was found by R. Broom in 1938, at Kromdraai.
- The genus *Homo*. Fossils for 15 – 20 different, extinct species of *Homo* have been found. The only currently living species is *Homo sapiens*.
    - *Homo* species stood erect, with a height between 1,3 and 2 m.
    - *Homo* evolved a large brain, with average brain size for *Homo sapiens* approximately 1500 mL.
- The phases of hominin development within the genus *Homo* are represented by *Homo habilis* (2,4 – 1,6 mya), *Homo erectus* (2,0 – 1,4 mya) and *Homo sapiens* (200 000 years ago to the present).

Important fossil sites in South Africa / Africa.

- The Cradle of Humankind is one of the most important fossil sites in the world. Almost 40% of all hominin fossils found world-wide have been discovered here. It has contributed greatly to our understanding of human evolution.
- The Cradle includes a number of caves complexes (specimen and date found)
    - Sterkfontein (Mrs Ples - 1947, Little Foot - 1997 and Naledi - 2013)
    - Swartkrans, Kromdraai, Malapa (Karabo – 2009) and others
- Other SA sites:
    - Taung (Taung child – 1924), Makapansgat Valley, Florisbad.
- Famous SA palaeontologists (or working in SA): Raymond Dart, Robert Broom, Phillip Tobias, Ron Clarke, Lee Berger, Charles K. Brain.
- Sites in the rest of Africa – in Ethiopia, Kenya and Tanzania, explored by Louis and Mary Leakey, Richard Leakey, Tim White and Donald Johansen.

End of topic exercises

Section A

Question 1

1.1 Various options are provided as possible answers to the following questions. Choose the correct answer and write the letter (A–D) next to the question number (1.1.1–1.1.5) for example 1.1.6 D.

1.1.1 A possible explanation for an observation that can be tested is known as a

A fact
B law
C theory
D **hypothesis** ✓✓

1.1.2 The most dramatic change in the evolution of *Homo sapiens* is traced in

A loss of body hair
B shortening of the jaws
C shorter legs
D **the increase in brain size** ✓✓

1.1.3 How were the first modern humans (*Homo sapiens*) different from any of the other hominid species?

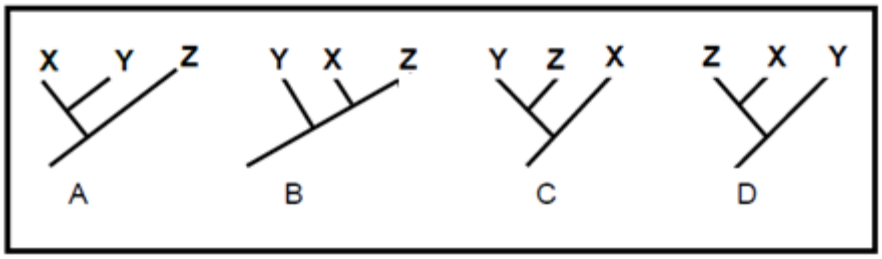
A They lived outside Africa
B They lived longer in Africa than any of the other hominids
C They used tools
D **They used symbolic thought, represented in language and art.** ✓✓

1.1.4 Which one of the following serves as evidence of cultural evolution in early *Homo* species?

A The size of a *Homo erectus* cranium relative to a *Homo sapiens* cranium.
B **The presence of ancient stone tools** ✓✓
C Male and female skeletons in the same area
D Animal fossils mixed with hominin fossils.

1.1.5 Three related species, X, Y and Z, share a common ancestor. Species Y and Z share the most recent common ancestor.

Which phylogenetic tree most accurately represents their evolutionary relationship?



C ✓✓

(5 × 2) = (10)

1.2 Give the correct term / phrase for each of the following descriptions. Write only the term next to the question number.

1.2.1 Living primarily in tree
Arboreal ✓

1.2.2 The type of vision shared by apes and humans that allows for depth perception
binocular vision (accept stereoscopic vision) ✓

1.2.3 The family to which humans belong
Family Hominidae ✓

1.2.4 The hypothesis which supports migration of human ancestors from the point of origin
Out of Africa hypothesis ✓

1.2.5 The ability of an organism to walk on two feet
bipedalism ✓

1.2.6 Having a face with protruding jaws
prognathous ✓

1.2.7 The first hominin that used stone tools for cutting meat
Homo habilis ✓

1.2.8 The genus to which modern humans belong
Homo ✓

1.2.9 The permanent disappearance of a species from Earth
extinction ✓

1.2.10 Genetic material used to trace female ancestry.
mitochondrial DNA ✓

(10 × 1) = (10)

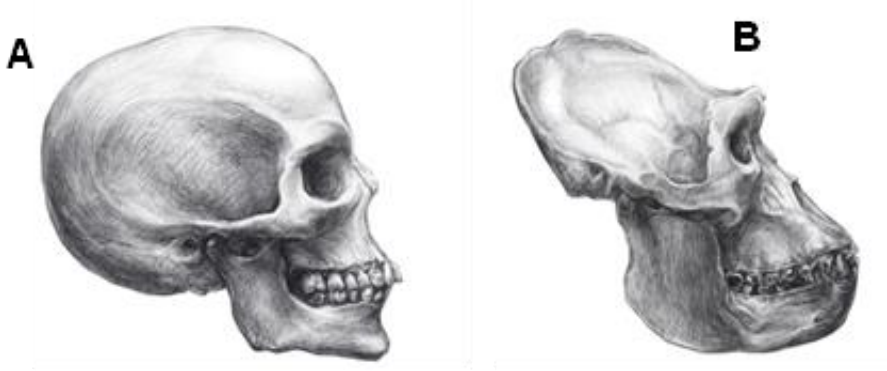
1.3 Indicate whether each of the descriptions in Column I applies to **A ONLY**, **B ONLY**, **BOTH A AND B** or **NONE** of the items in Column II. Write **A only**, **B only**, **both A and B** or **none** next to the question number.

Column I	Column II
1.3.1 Found in apes and humans	A: claws B: nails and an opposable thumb
1.3.2 Fossils found in South Africa	A: Mrs Ples B: Lucy
1.3.3 Fossil evidence found in Ethiopia	A: *Ardipithecus ramidus* B: *Australopithecus africanus*
1.3.4 Study of fossils	A: fossilisation B: palaentology
1.3.5 Discovered the fossil called 'Little Foot'	A: Raymond Dart B: Ronald Clarke

1.3.1 **B only** ✓✓ – hominids (apes and hominin) don't have claws
1.3.2 **A only** ✓✓ – Lucy was discovered in Ethiopia
1.3.3 **A only** ✓✓ – *A. africanus* only found in South Africa
1.3.4 **B only** ✓✓ – fossilisation is the process of becoming a fossil (rare)
1.3.5 **B only** ✓✓ – Raymond Dart discovered the Taung child

(5 × 2) = (10)

1.4 The diagram shows the skulls of two organisms; a human and a gorilla. Study the diagrams (drawn to scale) and answer the questions that follow.



1.4.1 Which diagram (A or B), represents the skull of a gorilla? (1)

B ✓ – humans don't have brow ridges or a large jaw as in B

1.4.2 Which organism (A or B), is bipedal for most of its adult life? (1)

A ✓ – modern humans are bipedal, except in early infancy

1.4.3 Name and explain two possible advantages of bipedalism for an organism. (4)

Fast movement ✓ – to get away from danger ✓
Ability to survey surroundings ✓ – to see where the dangers are ✓
Freedom of forearm and hand ✓– for tool use or for defence ✓
Exposed to less sunlight ✓ – for temperature regulation ✓
Display of genitals ✓ – to attract a mate ✓
(any two ✓ for name, ✓ for explanation)

1.4.4 Tabulate two observable differences between the skull of organism A and B (5)

Skull A	**Skull B**
non prognathous	prognathous
no cranial ridge (accept no sagittal crest)	cranial ridge present
big cranium / brain cavity	small cranium
small canines	large canines

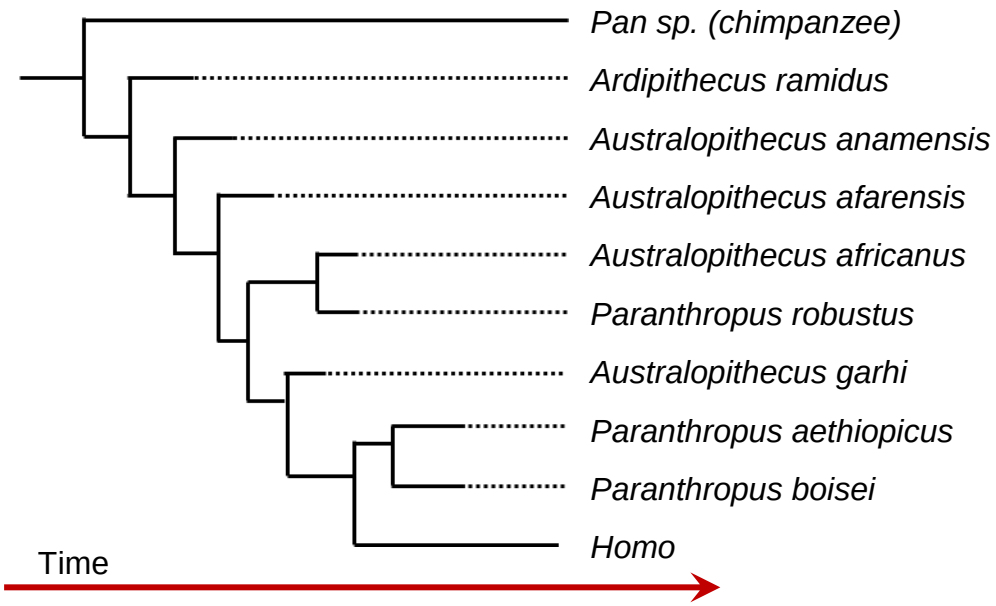
table - ✓, any two differences ✓✓

1.4.5 Name one similarity between organism A and B which is a characteristic of primates. (1)

anyone of: eyes in front, large brain, upright posture ✓

(12)

1.5 The diagram below shows possible evolutionary relationships between hominids. A dotted line indicates the species is extinct.



1.5.1 What is this type of diagram called? (1)

Phylogenetic diagram ✓

1.5.2 List the different hominin genera shown in the diagram. (4)

Ardipithecus ✓, *Australopithecus* ✓, *Homo* ✓ and *Paranthropus* ✓

1.5.3 According to this diagram, which …

a) genus is most recently evolved? (1)

Homo ✓

b) genus of hominin is the oldest? (1)

Ardipithecus ✓

c) hominin species shares a common ancestor with *Australopithecus africanus*? (1)

Paranthropus robustus ✓

1.5.4 Give two examples of an *Australopithecus africanus* fossil found in South Africa. (2)

Taung child (Taung), Mrs Ples and Little Foot (both Sterkfontein) - ✓ - one mark each

1.5.5 Name two *Homo* species, besides *Homo sapiens*, that have been found in Africa. (2)

H. erectus, H. habilis, H. ergaster, … ✓ - one mark each

(12)

Section A: [54]

Section B: Question 2

2.1 Read the following passage, then answer the questions based on it.

Australopithecus sediba

According to those who discovered the fossil remains of *Australopithecus sediba,* this species shared many characteristics with *Australopithecus africanus*, from which it descended. The species however also reveals a number of early *Homo* features, more so that any other *Australopithecus* species. This suggests that *A. sediba* is possibly ancestral to *Homo*, though it may also be an evolutionary dead end.

Like other species from the genus *Australopithecus*, *A. sediba* had a relatively small brain size. The length of the legs, arms adapted for climbing trees, and details of the teeth also resemble earlier Australopithecines. On the other hand, the species' hand with the precision grip of a toolmaker, and its facial features closely resemble those of early *Homo* species. Remarkably, *A. sediba* had a more human-like pattern of movement than a fossil attributed to *Homo habilis*.

The pelvic structure of *A. sediba* suggests this species walked upright on a regular basis. The legs and feet however point to a previously unknown way of walking upright. With each step, *Australopithecus sediba* turned its foot inward with its weight focused on the outer edge of the foot.

(adapted from Australopithecus Sediba, https://factsanddetails.com/world/cat56/2215.html)

2.1.1 Who discovered *Australopithecus sediba*, and where? (2)

Lee Berger ✓, at the Malapa caves ✓

2.1.2 *A. sediba* is described as having a relatively small brain size. What was the average brain size for this species? (1)

420 mL

2.1.3 Define the term 'transitional fossil'. (2)

Shows the characteristics of two different genera or species ✓✓

2.1.4 *A. sediba* is described as possibly an "evolutionary dead end". What is an evolutionary dead end? (3)

A dead end implies the species became extinct ✓ and that this species did not evolve any further ✓✓

2.1.5 According to the passage, *Australopithecus sediba* had a previously unknown way of walking upright. What does this suggest for the evolution of bipedalism? (2)

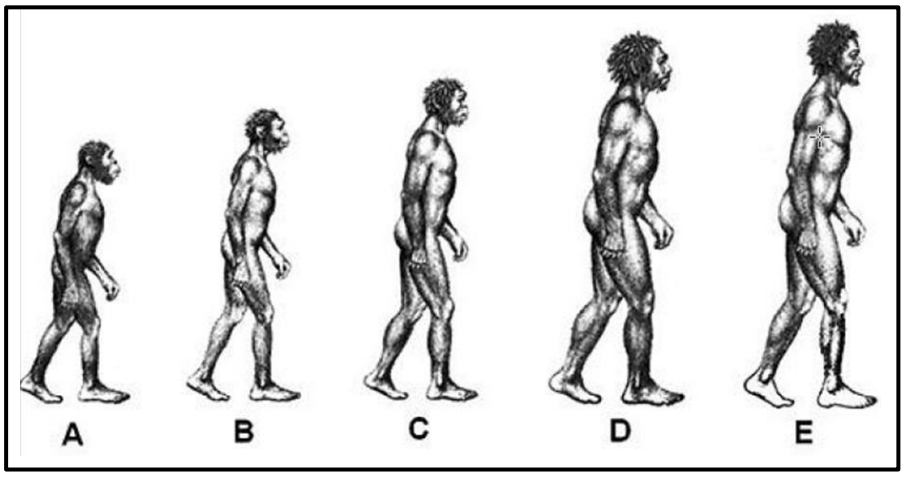
It suggests that upright walking (bipedalism) evolved on more than one path during human evolution. ✓✓

2.1.6 What is the difference between bipedalism and standing upright? Use examples to explain. (5)

No ✓. Bipedalism means to habitually walk erect ✓, on two feet, the way a human being ✓ normally walks. Many animals (e.g. a chimpanzee ✓) can stand upright on two legs, but generally walks on all fours ✓

(15)

2.2



The diagram above shows the progression of human evolution. Study the diagram of some early hominin A, B, C, D and E which represent *Homo erectus*, *Homo sapiens*, *Australopithecus*, *Homo habilis* and *Homo neanderthalensis*, in no particular order.

2.2.1 Identify each of the above hominid members (A – E) correctly from the list given above. (5)

A – *Australopithecus*, B – *H. habilis*, C – *H. erectus*, D – *H. neanthal-ensis*, E – *Homo sapiens* (✓ for each correct answer)

2.2.2 Mention any three common characteristics which are shared by the members represented in the above diagram. (3)

(Any 3 of these - 1 mark for each)

freely rotating (movable) long upper limbs

elbow joints allowing rotation of the forearm

flat nails instead of claws / bare, sensitive finger tips.

flexible wrists that are capable of rotating at least 180°

eyes in front

opposable thumbs for precision grip

larger brain than other hominids

binocular vision / stereoscopic vision

sexual dimorphism

upright posture / bipedal

2.2.3 Name the family the above group belongs to, and the collective name for these members (2)

Family Hominidae ✓and the Tribe: Hominini ✓

2.2.4 Supply any three characteristics that make the organism, labelled E different from other primates. (3)

(any three of these: one mark each)

bipedalism

curved spine

flat (non-prognathous) face

c-shaped / semi-circular dental palate

small teeth and canines (canines not large, pointed)

larger brain (average size 1450 – 1500 ml)

(13)
[28]

Question 3

3.1

3.1.1 A larger brain size is often associated with a greater intelligence. Accordingly, *Homo neanderthalensis*, with a larger brain than *Homo sapiens*, should have been more intelligent, and thus better able to adapt to climate changes. Yet *H. neanderthalensis* is extinct, while *H. sapiens* flourishes. What other factor related to the brain could explain this? (2)

Intelligence is related to brain size. It is also related to the complexity and structure of the brain. ✓ The structure of the *Homo sapiens* brain probably allowed the species to adapt better than the *H. neanderthalensis*. ✓

3.1.2 Explain the relationship between the decrease in the jaw size of evolving hominin species and their increasing brain size. (3)

The large jaws of early hominin species required strong jaw muscles attached to the skull (particularly the cranial ridge). As the need for large jaws slowly disappeared (due to cooked food) ✓, so did the need for strong jaw muscles ✓. Freed from the muscle constraints, the cranium could more easily expand in size ✓.

(5)

3.2 Scientists use fossils as evidence for human evolution. The brain volume of some extinct primates has been estimated from their fossils and have been compared to the brain volumes of living primates. The results are shown in the table below (figures in brackets give mid-point of existence).

Hominid	Period of Existence (million years ago)	Average Brain Volume (mL)
Ardipithecus ramidus	5,8 to 4,4 (5,1)	400
Australopithecus afarensis	4 to 2,7 (3,4)	450
Australopithecus africanus	3 to 2 (2,5)	450
Homo habilis	2,2 to 1,6 (1,9)	750
Homo erectus	2 to 0,4 (1,2)	1 000
Homo neanderthalensis	0,3 to 0,23 (0,27)	1 500
Homo sapiens	0,2 to present (0,1)	1 400
Modern apes	0,2 to present (0,1)	500

3.2.1 Apart from fossil evidence, give two other types of evidence for human evolution? In each case, give a brief explanation of how the evidence is used to support the notion of human evolution. (4)

Genetic evidence ✓ – scientists use mitochondrial DNA to determine the degree of relationship between species, and how long ago the species separated. ✓

Cultural evidence, specifically tool making ✓ – stone tools, manufactured by various hominids, with more careful working becoming sharper, is evidence of evolution. ✓

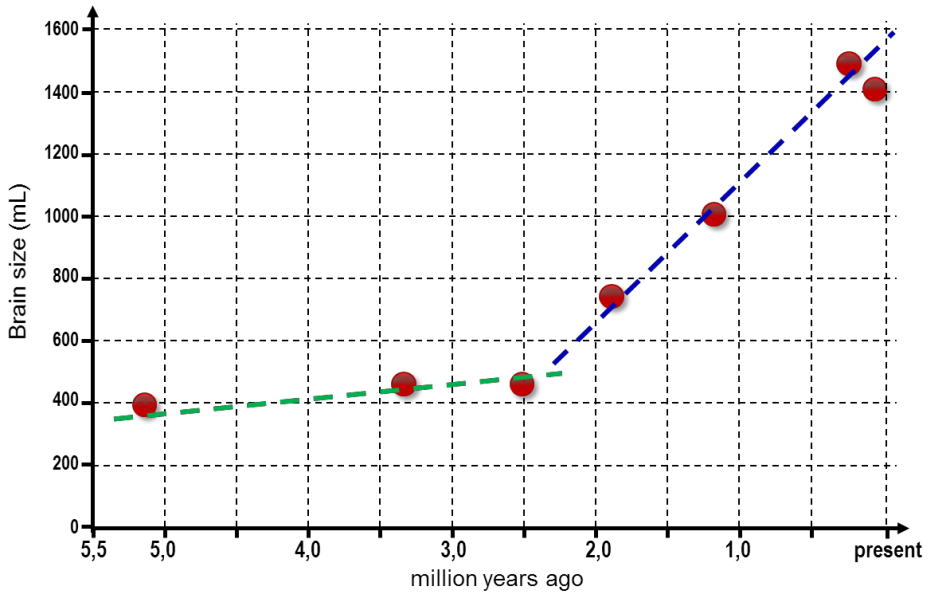
3.2.2 The brain of an organism is not preserved as fossil. How do experts determine the average brain volume of extinct species? (2)

Scientists make a cast of the inside of a fossil cranium and measure its volume ✓. They do this for all fossil craniums of a particular species to calculate the average size of the brain. ✓

3.2.3 Calculate the difference in brain volume (in mL) between the two living primates. Show all calculations. (3)

Pick correct specimen ✓: 1400 – 500 ✓ = 900 mL ✓

3.2.4 Draw a line graph to show the evolution of brain size across all hominin species listed in the table. Use the mid-point of the period of existence on one axis. Once the points have been plotted, interpret the graph. (8)



Interpretation: for the period 5,5 – 2,5 million years ago (3 million years), brain size develops very slowly. Thereafter, there is a rapid increase in brain size, for various reasons.

Right vertical (brain size) & horizontal (time) axes ✓
Correct labels ✓ Appropriate and correct scale ✓
Correct plotting of points ✓✓✓ Interpretation ✓✓

(17)

[22]

Section B: [50]

Total marks: [104]

Cognitive levels distribution

Question	Level 1	Level 2	Level 3	Level 4	Marks
1.1.1	✓				2
1.1.2	✓				2
1.1.3	✓				2
1.1.4	✓				2
1.1.5	✓				2
	10				10
1.2.1	✓				1
1.2.2	✓				1
1.2.3	✓				1
1.2.4	✓				1
1.2.5	✓				1
1.2.6	✓				1
1.2.7		✓			1
1.2.8	✓				1
1.2.9	✓				1
1.2.10	✓				1
	9	1			10
1.3.1		✓			2
1.3.2		✓			2
1.3.3		✓			2
1.3.4		✓			2
1.3.5		✓			2
		10			10
1.4.1	✓				1
1.4.2	✓				1
1.4.3		✓			4
1.4.4		✓			5
1.4.5	✓				1
	3	9			12

1.5.1	✓				1
1.5.2	✓				4
1.5.3 a - c	✓				3
1.5.4	✓				2
1.5.5	✓				2
	12				12
2.1.1	✓				2
2.1.2	✓				1
2.1.3		✓			2
2.1.4			✓		3
2.1.5				✓	2
2.1.6			✓		5
	4	2	8	2	15
2.2.1			✓		5
2.2.2	✓				3
2.2.3	✓				2
2.2.4		✓			3
	7	3	5		13
3.1.1				✓	2
3.1.2				✓	3
				5	5
3.2.1		✓	✓		4 (2 + 2)
3.2.2			✓		2
3.2.3			✓		3
3.2.4		✓		✓	8 (3 + 5)
		5	7	5	17
	42	30	20	12	104