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### Teacher’s Guide

1.1 Curriculum overview  
1.2 The Life Sciences curriculum  
1.3 Syllabus  
1.4 Assessment  
1.5 Assessment Tools

<table>
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<th>Section</th>
<th>Page</th>
</tr>
</thead>
<tbody>
<tr>
<td>1.1</td>
<td>6</td>
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<tr>
<td>1.2</td>
<td>8</td>
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<tr>
<td>1.3</td>
<td>13</td>
</tr>
<tr>
<td>1.4</td>
<td>25</td>
</tr>
<tr>
<td>1.5</td>
<td>31</td>
</tr>
</tbody>
</table>
Dear educator, welcome to the force of educators that make a difference by unlocking the marvels of the Life Sciences to learners. What a privilege you have to guide the learners in becoming critical thinkers! The Life Sciences is a subject that will enrich the lives of all who study it. It not only helps learners understand themselves better, but it will enable them to develop a deep appreciation of the world around them, and guide them to make wise decisions about their own health, and the health of the planet.

The CAPS curriculum

From the beginning of January 2012, all learning and teaching in public and independent schools in South Africa is laid down in the National Curriculum and Assessment Policy Statements (January 2012) (CAPS) document. National Curriculum and Assessment Policy Statements were developed for each subject. This policy document replaces all old Subject Statements, Learning Programme Guidelines and Subject Assessment Guidelines in Grades R - 12. All educators should make themselves familiar with the CAPS document.

How the national curriculum can serve the national agenda:

(a) The knowledge, skills and values worth learning for learners in South Africa are clearly set out in the National Curriculum and Assessment Policy Statement for Life Sciences. The content links to the environment of the learners and is presented within local context, with awareness of global trends.

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

- equip all learners, irrespective of their socio-economic background, race, gender, physical ability or intellectual ability, with the knowledge, skills and values necessary for self-fulfilment to participate meaningfully in society as citizens of a free country
- provide access to higher education
- facilitate the transition of learners from education institutions to the workplace
- provide employers with a sufficient profile of a learner’s competencies
(c) The key principles (fuller described in the document) of the National Curriculum Statement for Grades R - 12 are:

- social transformation: making sure that the educational differences of the past are put right
- providing equal educational opportunities to all
- active and critical learning: encouraging an active and critical approach to learning, not only rote learning of given facts
- high knowledge and high skills: specified minimum standards of knowledge and skills are set to be achieved at each grade
- progression: content and context of each grade shows progression from simple to complex
- human rights, inclusivity, environmental and social justice: being sensitive to issues such as poverty, inequality, race, gender, language, age, disability and other factors
- 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 themselves and their activities responsibly and effectively
- collect, analyse, organise and critically evaluate information
- communicate effectively using visual, symbolic and/or language skills in various modes
- 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 become a central part of the organisation, planning and teaching at each school. Educators need to:

- have a sound understanding of how to recognise and address barriers to learning
- know how to plan for diversity
• address barriers in the classroom
• 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

1.2 The Life Sciences curriculum

Life Sciences orientation

The first section of the Grade 10 Life Sciences curriculum is designed to orientate learners to the study of Life Sciences in the FET stage. This introduction should create continuity between what learners studied in the GET (Natural Sciences) and what they will be learning in the FET (Life Sciences). The Life Sciences subject builds on knowledge and skills acquired from various strands in the GET Natural Sciences curriculum. This introduction to Life Sciences will describe the scientific approach. It is important that learners understand how knowledge is built and constructed in science. In order to accomplish this goal, this introduction should focus on providing learners with the range of skills that they will develop throughout their scientific endeavours.

Life Sciences Content Framework

The Life Sciences content framework is organised into four Knowledge Strands which are developed progressively over the three years of FET. The four Knowledge Strands are:

- 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 retain the sequence of Knowledge Strand 1 before Knowledge Strand 2 and Knowledge Strand 3 before Knowledge Strand 4. It is up to individual teachers to decide whether to start the school year with Knowledge Strand 1 or Knowledge Strand 3.
The purpose of studying Life Sciences can be summarised as follows:

- The attainment of scientific knowledge and understanding
- The development of scientific investigative skills
- An appreciation of the role of science in society

The DBE has established a number of subject-specific aims in order to meet the purposes outlined above.

According to CAPS, these aims are as follows:

- Specific Aim 1: knowing of the subject content ('theory').
- Specific Aim 2: conducting science or practical work and investigations.
- Specific Aim 3: understanding the applications of Life Sciences in everyday life, as well as understanding the history of scientific discoveries and the relationship between indigenous knowledge and science.

**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.

1.1 **Acquire knowledge:** Acquire and recall knowledge

<table>
<thead>
<tr>
<th>Learners must be able to:</th>
<th>Verbs that can be used by teachers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>Access information</td>
<td>State</td>
</tr>
<tr>
<td>Select key ideas</td>
<td>Name</td>
</tr>
<tr>
<td>Recall facts</td>
<td>Label</td>
</tr>
<tr>
<td>Describe concepts, processes</td>
<td>List</td>
</tr>
<tr>
<td>theories etc.</td>
<td>Define</td>
</tr>
<tr>
<td></td>
<td>Describe</td>
</tr>
</tbody>
</table>
1.2 Comprehension: Understand, comprehend and make connections between ideas and concepts.

<table>
<thead>
<tr>
<th>Learners must be able to:</th>
<th>Verbs that can be used by teachers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Write summaries</td>
<td>• Explain</td>
</tr>
<tr>
<td>• Develop flow charts, diagram and mind maps</td>
<td>• Compare</td>
</tr>
<tr>
<td>• Recognise patterns and trends</td>
<td>• Rearrange</td>
</tr>
<tr>
<td></td>
<td>• Give an example</td>
</tr>
<tr>
<td></td>
<td>• Illustrate</td>
</tr>
<tr>
<td></td>
<td>• Calculate</td>
</tr>
<tr>
<td></td>
<td>• Interpret</td>
</tr>
<tr>
<td></td>
<td>• Suggest a reason</td>
</tr>
<tr>
<td></td>
<td>• Make a generalisation</td>
</tr>
<tr>
<td></td>
<td>• Interpret information or data</td>
</tr>
<tr>
<td></td>
<td>• Predict</td>
</tr>
<tr>
<td></td>
<td>• Select</td>
</tr>
<tr>
<td></td>
<td>• Differentiate</td>
</tr>
</tbody>
</table>

1.3 Application: Apply knowledge in new and unfamiliar contexts.

<table>
<thead>
<tr>
<th>Learners must be able to:</th>
<th>Verbs that can be used by teachers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Use information in a new way</td>
<td>• Demonstrate</td>
</tr>
<tr>
<td>• Apply knowledge to new and unfamiliar contexts</td>
<td>• Interpret</td>
</tr>
<tr>
<td></td>
<td>• Predict</td>
</tr>
<tr>
<td></td>
<td>• Compare</td>
</tr>
<tr>
<td></td>
<td>• Differentiate</td>
</tr>
<tr>
<td></td>
<td>• Illustrate</td>
</tr>
<tr>
<td></td>
<td>• Solve</td>
</tr>
<tr>
<td></td>
<td>• Select</td>
</tr>
</tbody>
</table>

1.4 Synthesis: Analyse, evaluate, and synthesise Scientific Knowledge, concepts and ideas.

<table>
<thead>
<tr>
<th>Learners must be able to:</th>
<th>Verbs that can be used by teachers:</th>
</tr>
</thead>
<tbody>
<tr>
<td>• Analyse information and data</td>
<td>• Appraise</td>
</tr>
<tr>
<td>• Recognise relationships between existing knowledge and new ideas</td>
<td>• Argue</td>
</tr>
<tr>
<td>• Critically evaluate scientific information</td>
<td>• Judge</td>
</tr>
<tr>
<td>• Identify assumptions</td>
<td>• Select</td>
</tr>
<tr>
<td>• Categorise information</td>
<td>• Evaluate</td>
</tr>
<tr>
<td></td>
<td>• Defend (a point of view)</td>
</tr>
<tr>
<td></td>
<td>• Compare</td>
</tr>
<tr>
<td></td>
<td>• Contrast</td>
</tr>
<tr>
<td></td>
<td>• Criticise</td>
</tr>
<tr>
<td></td>
<td>• Differentiate</td>
</tr>
<tr>
<td></td>
<td>• Distinguish</td>
</tr>
</tbody>
</table>
Specific Aim 2: Investigating phenomena in Life Sciences

Practical investigations involve a specific range of skills, which are listed under Specific Aim 2. However, knowledge and understanding of conducting scientific investigations should also be assessed within the context of the cognitive domains of Specific Aim 1.

<table>
<thead>
<tr>
<th>Specific Aim 2: Skills</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.1 Follow instructions</td>
<td>• Learners to be given a set of instructions to follow</td>
</tr>
<tr>
<td></td>
<td>• Adherence to safety rules</td>
</tr>
<tr>
<td>2.2 Handle equipment or apparatus</td>
<td>• Knowledge of apparatus (naming, handling and what it is used for)</td>
</tr>
<tr>
<td></td>
<td>• Use of chemicals</td>
</tr>
<tr>
<td></td>
<td>• Using equipment appropriately and safely</td>
</tr>
<tr>
<td></td>
<td>• Use of chemicals taking the necessary precautions</td>
</tr>
<tr>
<td>2.3 Make observations</td>
<td>• Drawings</td>
</tr>
<tr>
<td></td>
<td>• Descriptions</td>
</tr>
<tr>
<td></td>
<td>• Grouping of materials (similarities and/or differences)</td>
</tr>
<tr>
<td></td>
<td>• Measurements</td>
</tr>
<tr>
<td></td>
<td>• Comparing materials before and after treatment</td>
</tr>
<tr>
<td></td>
<td>• Observing results of an experimental investigation and recording information in the appropriate manner</td>
</tr>
<tr>
<td></td>
<td>• Counting</td>
</tr>
<tr>
<td>2.4 Record information or data</td>
<td>• Simple tables</td>
</tr>
<tr>
<td></td>
<td>• Drawings</td>
</tr>
<tr>
<td></td>
<td>• Descriptions</td>
</tr>
<tr>
<td></td>
<td>• Constructing a pie chart</td>
</tr>
<tr>
<td></td>
<td>• Line graph</td>
</tr>
<tr>
<td></td>
<td>• Histogram or bar chart as suited to the data and choosing suitable axes and scales</td>
</tr>
</tbody>
</table>
## Specific Aim 2: Skills

<table>
<thead>
<tr>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>2.5 Measure</td>
</tr>
<tr>
<td>- Reading linear and two-dimensional scales</td>
</tr>
<tr>
<td>- Scaling by choosing a correct date for axes</td>
</tr>
<tr>
<td>- Measuring quantities</td>
</tr>
<tr>
<td>- Making valid measurements of variables, repeating measurements to obtain an average where necessary in all quantitative work</td>
</tr>
<tr>
<td>- Recognising, or supplying the correct units for common measurements</td>
</tr>
<tr>
<td>- Counting systematically</td>
</tr>
<tr>
<td>2.6 Interpret</td>
</tr>
<tr>
<td>- Convert information into an appropriate graph, table etc. and extract data</td>
</tr>
<tr>
<td>- Apply knowledge</td>
</tr>
<tr>
<td>- Analyse and recognise patterns or trends</td>
</tr>
<tr>
<td>- Acknowledge limitations of experimental procedures</td>
</tr>
<tr>
<td>- Make deductions based on evidence to reach a conclusion</td>
</tr>
<tr>
<td>2.7 Design/Plan Investigations or Experiments</td>
</tr>
<tr>
<td>- Identifying a problem and formulate a question that will guide the investigation</td>
</tr>
<tr>
<td>- The aim of the investigation</td>
</tr>
<tr>
<td>- The Hypothesis</td>
</tr>
<tr>
<td>- Selecting the correct apparatus or equipment and/or materials and chemicals</td>
</tr>
<tr>
<td>- Identifying variables</td>
</tr>
<tr>
<td>- Adhere to laboratory safety procedures</td>
</tr>
</tbody>
</table>
Specific Aim 3: Appreciating and understanding the history, importance and applications of Life Sciences in society

<table>
<thead>
<tr>
<th>Specific Aim 3: Skills</th>
<th>Description</th>
</tr>
</thead>
<tbody>
<tr>
<td>3.1 Understanding the history and relevance of discoveries</td>
<td>The history of scientific discoveries provide the context of learning and forms the relevant baseline for society.</td>
</tr>
<tr>
<td>3.2 Relationships of Indigenous Knowledge Systems to Life Sciences</td>
<td>Learners are required to understand the different cultural contexts in which Indigenous Knowledge Systems were developed. Examples of the Indigenous Knowledge Systems are required to be linked directly to specific areas in the Life Sciences subject content.</td>
</tr>
<tr>
<td>3.3 Value and application of knowledge in industry, career opportunities and in everyday life</td>
<td>Learners need to be able to analyse and evaluate the application of biotechnology in everyday life. Learners must have the skill to evaluate and summaries the positive and negative effects of biotechnology on the environment. Learners should be made aware of careers in Life Sciences.</td>
</tr>
<tr>
<td>3.4 Developing language skills (reading and writing)</td>
<td>The teaching of language across the curriculum. Teachers need to provide learners with opportunities to develop and improve their language skills in the context of learning Life Sciences. It is critical to give learners the opportunity to read scientific text, writing of reports, paragraphs, and short essays as part of the assessment.</td>
</tr>
</tbody>
</table>

Time allocation

The time allocation for Life Sciences in Grade 10 is 4 hours per week.

The curriculum for Grade 10 has been designed to be completed within 32 weeks out of 40 weeks in the school year. This provides a time buffer of 8 weeks for examinations, tests and disruptions due to other school activities.

1.3 Syllabus

<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>Orientation to Life Science</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Life Sciences orientation</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• How sciences works</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Scientific Skills</td>
<td></td>
</tr>
<tr>
<td>Week</td>
<td>Content</td>
<td>Assessment</td>
</tr>
<tr>
<td>------</td>
<td>---------</td>
<td>------------</td>
</tr>
<tr>
<td>2-4</td>
<td>Organic molecules made up of C, H, O and N, P</td>
<td>- Food tests for starch</td>
</tr>
<tr>
<td></td>
<td><strong>Inorganic compounds</strong></td>
<td>- Food tests for reducing sugars</td>
</tr>
<tr>
<td></td>
<td>• Water: 2 H and 1 O</td>
<td>- Food tests for lipids</td>
</tr>
<tr>
<td></td>
<td>• Minerals: e.g. Na, K, Ca, P, Fe, I, nitrates, phosphates. Macro and micro elements. Main functions and deficiency diseases</td>
<td>- Food tests for proteins</td>
</tr>
<tr>
<td></td>
<td>• Need for fertilisers in over utilised soils</td>
<td>- Investigation to test the working of a “biological” washing powder</td>
</tr>
<tr>
<td></td>
<td>• Eutrophication</td>
<td>- Investigating the effect of catalase from chicken liver on hydrogen peroxide</td>
</tr>
<tr>
<td></td>
<td><strong>Organic compounds</strong></td>
<td>- Compare Recommended Daily Allowance (RDA) with usual diet of individual learners</td>
</tr>
<tr>
<td></td>
<td>• Carbohydrates - monosaccharide’s (single sugars) e.g. glucose, fructose; disaccharides (double sugars) e.g. sucrose, maltose; polysaccharides (many sugars) e.g. starch, cellulose, glycogen</td>
<td><strong>Food tests</strong></td>
</tr>
<tr>
<td></td>
<td>• Lipids (fats and oils) - 1glycerol and 3 fatty acids: unsaturated and saturated fats. Cholesterol in foods. Heart disease</td>
<td>for starch</td>
</tr>
<tr>
<td></td>
<td>• Protein - amino-acids (C, H, O and N and some have P, S, Fe). Proteins are sensitive to temperature and pH; loss of structure and function</td>
<td>for reducing sugars</td>
</tr>
<tr>
<td></td>
<td>- Role of enzymes in breaking down/synthesizing molecules</td>
<td>for lipids</td>
</tr>
<tr>
<td></td>
<td>- Influence of temperature and pH on enzyme action</td>
<td>for proteins</td>
</tr>
<tr>
<td></td>
<td>- Lock and key model of how enzymes work</td>
<td>Investigation to test the working of a “biological” washing powder</td>
</tr>
<tr>
<td></td>
<td>- Enzymes in everyday life, e.g. washing powders.</td>
<td>Investigating the effect of catalase from chicken liver on hydrogen peroxide</td>
</tr>
<tr>
<td></td>
<td>• Mention of Nucleic acids: DNA and RNA - Consisting of C, H, O, N and P (No details of structure required)</td>
<td>Compare Recommended Daily Allowance (RDA) with usual diet of individual learners</td>
</tr>
<tr>
<td></td>
<td>• Vitamins e.g. A, one of B vitamins, C, D and E</td>
<td><strong>Food tests</strong></td>
</tr>
</tbody>
</table>

14

1.3. Syllabus
<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td>4-7</td>
<td><strong>Cell structure</strong></td>
<td>• Calculate magnification and scale</td>
</tr>
<tr>
<td></td>
<td>• Relate structure and location of organelles to their functions</td>
<td>• Observing diffusion</td>
</tr>
<tr>
<td></td>
<td>• Cells differ in size, shape and structure in order to carry out specialised functions</td>
<td>• Predicting the direction of osmosis</td>
</tr>
<tr>
<td></td>
<td>• Molecular make-up: Cells are mostly made of proteins, carbohydrates, lipids, nucleic acids and water</td>
<td>• Examining plant cells under the microscope</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Examining animal cells under the microscope</td>
</tr>
<tr>
<td></td>
<td></td>
<td>• Research on a cell organelle</td>
</tr>
<tr>
<td></td>
<td><strong>Cell structure and function: roles of organelles</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cell wall - support structure in plant cells only</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cell membrane - fluid mosaic model; boundaries and transport; movement across membranes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Nucleus, chromatin material, nuclear membrane, nucleopores, nucleolus: the control centre, heredity.</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Cytoplasm - storage, circulation of materials</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Mitochondria - release of energy during cell respiration</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Ribosomes - protein synthesis</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Endoplasmic reticulum (rough and smooth) - transport systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Golgi-body - assemble secretion</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Plastids - production and storage of food, pigments</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Vacuole, lysosomes, vesicles - storage, digestion, osmoregulation</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Differences between plant and animal cells</strong></td>
<td></td>
</tr>
<tr>
<td>Week</td>
<td>Content</td>
<td>Assessment</td>
</tr>
<tr>
<td>------</td>
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<td>------------</td>
</tr>
</tbody>
</table>
| 8-11 | **Cell division - mitosis**  
- Cell cycles including mitosis: interphase, mitosis (with names of phases) cytokinesis, growth  
- Continuous process of mitosis: division of cell to form two identical cells  
- Chromosomes: in nuclei of all cells, two chromatids, centromere  
- Difference in telophase between plant and animal cells  |
|       | **Role of mitosis**: growth and repair.  
Reproduction in some simple organisms  
**Cancer**  
- Uncontrolled cell division and growth  
- Causes of cancer  
- Brief discussion of beliefs and attitudes concerning cancer  
- Treatments of cancer  
- Medical biotechnology e.g. radiotherapy, chemotherapy (no detail required)  |
|       | • Activity on smoking and cancer  
• Research and present information on a type of cancer |
| 12-13 | **Tissues**  
- Group of similar cells adapted for a particular function  
- Emphasis on the relationship between basic structure and function  
- Plant tissues: xylem, phloem, parenchyma, collenchyma, sclerenchyma, epidermis and meristematic tissue  
- Animal tissues: epithelial, connective, muscle, nerve  |
|       | **Application of IKS and Biotechnology**  
- Traditional technology e.g. traditional medicines and healers  
- Medical biotechnology e.g. immunity, vaccines, antibiotics, blood transfusion  
- Cloning of plant and animal tissues and stem cell research; ethics and legislation  |
|       | Select from the following activities:  
- Investigate leaf epidermis under a microscope  
- Observing Parenchyma cells  
- Observing sclerenchyma cells in pears  
- Investigating sclerenchyma fibres  
- Observing secondary walls in xylem of fresh plant tissue |
<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
</tr>
</thead>
<tbody>
<tr>
<td>14</td>
<td><strong>Organs: Leaf structure</strong>&lt;br&gt;Cross section of a dicotyledonous leaf to demonstrate and explain its structure in terms of its functions i.e. Photosynthesis, gas exchange and transport</td>
</tr>
</tbody>
</table>

**Life Processes in Plants and Animals (9 weeks)**<br>**Support and Transport Systems in Plants (3 weeks)**

| 15-18 | **Anatomy of dicotyledonous plants**<br>• root and stem: distribution of different tissues<br>• structure of cells in different tissues<br>• secondary growth; annual rings in a tree trunk to assess age and to infer climate change<br>**Transpiration**<br>• Relationship between water loss and leaf structure<br>• Factors that affect the rate of transpiration:<br>  – temperature<br>  – light intensity<br>  – wind<br>  – humidity<br>  – Wilting and guttation<br>**Transport in Plants**<br>• Uptake of water and minerals into xylem in roots in xylem<br>• Transport of water and minerals to leaves<br>• Translocation of manufactured food from leaves to other parts of plant | **Assessment**<br>• Examining the structure of the dicotyledonous root and stem<br>• Observe annual tree rings and to assess age and climatic conditions<br>• Determine the effect of environmental conditions on transpiration rate<br>• Determining the effect of light intensity on transpiration<br>• Examining water uptake by the stem |

**Support Systems in Animals (3 weeks)**

<p>| 19-21 | <strong>Skeletons:</strong>&lt;br&gt;Advantages and disadvantages&lt;br&gt;• hydrostatic skeleton&lt;br&gt;• endoskeleton&lt;br&gt;• exoskeleton&lt;br&gt;<strong>Evolution of skeleton</strong>&lt;br&gt;related to the need for support linked to a terrestrial lifestyle |</p>
<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Life Processes in Plants and Animals (9 weeks)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Support Systems in Animals (3 weeks)</strong></td>
<td></td>
</tr>
</tbody>
</table>
| Human skeleton | • the axial skeleton: mention of facial bones, cranium, foramen magnum, vertebral column  
• appendicular skeleton: arms and legs | • Draw the structure of a long bone (longitudinal section)  
• Optional Investigation: Investigating organic and inorganic components of bones  
• Dissection of animal tissue  
• Observe and describe movement at joints |
| Functions of skeleton | • movement, protection, support, storage of minerals, hearing |          |
| Structure of a long bone |          |          |
| Relationship between structure and function of: |          |          |
| • bone |          |          |
| • cartilage |          |          |
| • tendons |          |          |
| • Joints |          |          |
| • ligaments |          |          |
| Joints | • fixed |          |
| • partly movable |          |          |
| • freely movable (synovial). Structure of synovial joints: ball and socket, hinge, pivot and gliding |          |          |
| Roles of the following in human locomotion | • bones |          |
| • joints |          |          |
| • ligaments |          |          |
| • tendons |          |          |
| • antagonistic muscles (e.g. biceps/triceps) |          |          |
| Structure of voluntary skeletal muscle: | myofibrils and muscle contraction |          |
| Diseases that affect the skeleton | • rickets in children |          |
| • osteoporosis |          |          |
| • arthritis |          |          |
Circulatory systems
- open, closed, single and double

Human double closed circulation system:
- pulmonary and systematic (double, closed) circulatory systems
- heart and associated blood vessels
- heart: internal and external structure related to functioning
- Direction of blood flow: difference between oxygenated and deoxygenated blood in different parts of the system (diagram or schematic drawing)
- major organs and systematic system: associated major blood vessels of brain, small intestine, liver kidney

Cardiac cycle: flow of blood through the heart
- Mechanisms for controlling cardiac cycle and heart rate (pulse)

Blood vessels
- structure and functioning of arteries, veins with valves and capillaries

Lymphatic system
- Relationship between blood system and lymphatic system. Functions of lymphatic system

Diseases of heart and circulatory system
- high and low blood pressure, heart attacks, strokes

Treatment of heart diseases
- stents, valve replacements, bypass surgery, pacemakers, heart transplant
<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
<th>Assessment</th>
</tr>
</thead>
</table>
| 22-27 | **Biosphere**  
  - Concept of the biosphere. Inter-connectedness with and components of global ecosystems: hydrosphere, lithosphere, atmosphere | Learners may do a selection of the following:  
  - Effects of burning grassland  
  - Role players in forest ecosystem  
  - Discovering fynbos in South Africa  
  - Biomes advertisement  
  - Biomes project  
  - Investigating the water-retaining properties of soil  
  - Understanding Food Chains  
  - Understanding food chains and food pyramids |
|       | **Biomes**  
  - Terrestrial and aquatic biomes of Southern Africa: how climate, soils and vegetation influence the organisms found in each. Location of different biomes in South Africa:  
    - grassland, savanna, succulent karoo, Nama karoo, forest, fynbos, desert, thicket | |
|       | **Environment**  
  - Concept of environment to show human activities in and interactions with the natural environment | |
|       | **Ecosystems**  
  - Concept of ecosystem  
  - Structure and ecosystem functioning  
  - **Abiotic factors**  
    - physiographic factors (aspect, slope, altitude)  
    - soil (pH, humus content, texture, water retention capacity, air content)  
    - light (day length, seasonal changes)  
    - temperature (effect of day/night, seasons)  
    - water (water cycle, importance of wetlands)  
    - atmospheric gases  
    - wind  
  - **Biotic factors**  
    - producers  
    - consumers  
    - decomposers | |

**COMPULSORY** Term project and fieldwork:  
- Studying a terrestrial ecosystem
<table>
<thead>
<tr>
<th>Week</th>
<th>Content</th>
<th>Assessment</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td><strong>Biospheres to Ecosystems (5 weeks)</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Energy flow</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Energy flow through ecosystems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Trophic structure: food chains, food pyramids, food webs</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Trophic levels: producers, consumers (herbivores, carnivores, omnivores, decomposers)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Cycles</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Flow charts of the following nutrients:</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- water</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- oxygen</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- carbon</td>
<td></td>
</tr>
<tr>
<td></td>
<td>- nitrogen cycles</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Ecotourism:</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Economics, ethics and opportunities</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Biodiversity (1 week)</strong></td>
<td></td>
</tr>
<tr>
<td>28</td>
<td><strong>Enormous biodiversity</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• large variety of species, different ecosystems, genetic differences</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• indigenous and endemic species in South Africa</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Classification schemes a way of organising biodiversity</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Brief history of classification</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• scientist attempt to classify organisms based on shared features</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• as information increases classification changes</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• Linnaeus (Carl von Linne) and his role in classification systems</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• naming things in science: species concept and binomial system</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Classification activity</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Constructing a mnemonic to remember the sequence of the classification system</strong></td>
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</tr>
<tr>
<td>Week</td>
<td>Content</td>
<td>Assessment</td>
</tr>
<tr>
<td>------</td>
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<td>------------</td>
</tr>
<tr>
<td>28</td>
<td><strong>Five-kingdom system</strong>&lt;br&gt;• Diagnostic features of each of the following:&lt;br&gt;  – Animalia&lt;br&gt;  – Plantae&lt;br&gt;  – Fungi&lt;br&gt;  – Protista&lt;br&gt;  – Monera (Bacteria)&lt;br&gt;&lt;br&gt;<strong>Differences between prokaryotes and eukaryotes</strong>&lt;br&gt;<strong>Classification schemes and dichotomous keys</strong></td>
<td>• Investigate examples of life forms from each kingdom&lt;br&gt;• Activity: Identifying arthropods using a dichotomous naming key</td>
</tr>
<tr>
<td>29-34</td>
<td><strong>Different representations of the history of life on Earth</strong>&lt;br&gt;<strong>Geological timescale</strong>&lt;br&gt;• Meaning and use of timescales-eons, eras and periods&lt;br&gt;&lt;br&gt;<strong>Continental drift</strong>&lt;br&gt;• Changes in climate (e.g. increase in oxygen levels, ice ages)&lt;br&gt;• Geological events (e.g. movement of continents, continental drift)&lt;br&gt;• Biogeography (e.g. location of life on the planet)&lt;br&gt;&lt;br&gt;<strong>Natural selection</strong>&lt;br&gt;• Life-forms have gradually changed to become present life-forms&lt;br&gt;&lt;br&gt;<strong>Fossil formation and methods of dating</strong>&lt;br&gt;• How fossils are formed&lt;br&gt;• Radiometric dating and relative dating&lt;br&gt;&lt;br&gt;<strong>Scientists use deductive reasoning</strong>&lt;br&gt;• Deductive reasoning (inference) to understand fossils and the history of life on Earth using evidence from multiple sources</td>
<td>• Construct a timeline showing the history of life on Earth</td>
</tr>
<tr>
<td>Week</td>
<td>Content</td>
<td>Assessment</td>
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<tr>
<td>------</td>
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</tr>
<tr>
<td></td>
<td><strong>History of Life on Earth... continued (5 weeks)</strong></td>
<td></td>
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<tr>
<td></td>
<td><strong>Cambrian explosion</strong></td>
<td>• Comparing the skeleton of a modern bird to the Archaeopteryx</td>
</tr>
<tr>
<td></td>
<td>• Origins of early forms of all animal groups</td>
<td>• Is the Coelacanth the missing link between fish and amphibians?</td>
</tr>
<tr>
<td></td>
<td><strong>Paleozoic, Mesozoic and Cenozoic eras</strong></td>
<td>• What caused the mass extinctions? Comparing theories</td>
</tr>
<tr>
<td></td>
<td>• each era divided into periods (names of periods not to be memorized)</td>
<td>• Observing fossils</td>
</tr>
<tr>
<td></td>
<td>• major climate changes and evolution of species and plants</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Evolution of humans in the last four million years</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• in the last four million years significant changes have occurred in species occurring in Africa (e.g. humans)</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Mass extinctions</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• There have been five mass extinctions in Earth’s history</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 250 mya - resulted in the extinction of about 90% of all life on Earth</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• 65mya - resulted in the extinction of many species, including the dinosaurs</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>The Sixth extinction</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• The rate extinction on the Earth at present is higher than at any time in the past</td>
<td></td>
</tr>
<tr>
<td></td>
<td><strong>Causes of mass extinctions</strong></td>
<td></td>
</tr>
<tr>
<td></td>
<td>• impact events - meteorites</td>
<td></td>
</tr>
<tr>
<td></td>
<td>• volcanic events</td>
<td></td>
</tr>
</tbody>
</table>
### Key events in the life’s history for which there is evidence from southern Africa

- origins of the earliest forms of life: evidence of single-celled fossilized bacteria (stromatolites) from many parts of South Africa
- bivalves and ammonites on the Makhatini flats in northern KwaZulu-Natal
- trilobites in the Karoo
- Soft-bodied animals in Namibia, Northern Cape
- early land plants in the Grahamstown area
- forests of primitive plants such as Glossopteris near Mooi River and Escourt
- location of coal deposits in South Africa (map only)
- the Coelacanth as a “living fossil” of the group that is ancestral to amphibians (Northern KwaZulu-Natal coast)
- mammal-like reptiles in the Karoo (e.g. Lystrosaurus and Thrinaxodon)
- dinosaurs (Drakensberg and Maluti mountains) (Euskylosaurus from Ladybrand in the Free State) and cone-bearing plant
- whale fossils in the Sahara
- first mammals (Eastern Cape and Lesotho)
- humans and pre-humans (Gauteng, North West, Free State, KwaZulu-Natal, Limpopo)

### Impact of humans on biodiversity and the natural environment

**Fossil Tourism**

- source of income and employment in some fossil localities

### Assessment

- Understanding evolutionary history based on evidence from South Africa
- How do we manage the impact of humans on the planet?
Dear Educator, as the Programme of Assessment (PoA) is the driving force of teaching and learning in the classroom, you need to familiarise yourself with the requirements specified in the National Curriculum and Assessment Policy Statement for Life Sciences (CAPS) document.

Assessment is a tool which enables learners to gauge their progress and test their understanding of the knowledge and skills gained. It is also useful for teachers to see where learners are struggling, and to intervene where necessary to reinforce understanding.

Assessment is a continuous planned process of identifying, gathering and interpreting information about the performance of learners, using various forms of assessment.

It involves four steps:

- generating and collecting evidence of achievement
- evaluating this evidence
- recording the findings
- using this information to understand and assist the learner’s development to improve the process of learning and teaching

Assessment should be both informal (Assessment for Learning) and formal (Assessment of Learning). To enhance the learning experience, learners need regular feedback from both informal and formal assessment.

Assessment is a process that measures individual learners’ attainment of knowledge (content, concepts and skills) in a subject by collecting, analysing and interpreting the data and information obtained from this process to:

- enable the educator to make reliable judgements about a learner’s progress
- inform learners about their strengths, weaknesses and progress
- assist educators, parents and other stakeholders in making decisions about the learning process and the progress of the learners

Assessment should be mapped against the content, concepts and skills and the aims specified for Life Sciences and in both informal and formal assessments. It is important to ensure that in the course of a school year:

- all of the subject content is covered
- the full range of skills is included
- a variety of different forms of assessment are used
**Types of assessment**

**Informal or daily assessment**

Assessment for learning has the purpose of continuously collecting information on a learner’s achievement, that can be used to improve their learning. Informal assessment is a daily monitoring of learners’ progress. This is done through observations, discussions, practical demonstrations, learner-educator conferences, informal classroom interactions, etc.

**Informal assessment tasks can consist of:**

- homework, class work, practical investigations, experiments and informal tests

**Informal assessment tasks will assess:**

- structured problem solving involving calculations, include problem-solving exercises that do not involve calculations, practical investigations, experiments, projects, scientific arguments, ability to predict, observe and explain

Learners or educators can mark these assessment tasks.

Self-assessment and peer assessment actively involves learners in assessment. This is important as it allows learners to learn from and reflect on their own performance. The results of the informal daily assessment tasks are not formally recorded unless the educator wishes to do so. The results of daily assessment tasks are not taken into account for promotion and certification purposes. Informal, on-going assessments should be used to structure the gaining of knowledge and skills, and should precede formal tasks in the Programme of Assessment.
Formal assessment tasks form part of a year-long formal Programme of Assessment in each grade and subject. Examples of formal assessments include tests, examinations, practical tasks, projects, oral presentations, demonstrations, performances, etc. Formal assessment tasks are marked and formally recorded by the educator for progression and certification purposes. All Formal Assessment tasks are subject to moderation for the purpose of quality assurance and to ensure that appropriate standards are maintained. Formal assessment provides educators with a systematic way of evaluating how well learners are progressing in a grade and in a particular subject.

**Formal assessment: Control Tests and Examinations**

Control tests and examinations are written under controlled conditions within a specified period of time. Questions in tests and examinations should assess performance at different cognitive levels with an emphasis on process skills, critical thinking, scientific reasoning and strategies to investigate and solve problems in a variety of scientific, technological, environmental and everyday contexts.

The following section deals with the recommended weighting of cognitive levels for formal assessment in the Life Sciences for Grade 10.

**Weighting of cognitive demands for assessment**

The cognitive demands in assessment tasks should appropriate for the age and cognitive-level of the learners. The assessment tasks should cater for a range of cognitive levels and abilities, and should be designed to cover the subject content, skills and cognitive demands that have been identified in the Specific Aims.

To guide educators in the design of assessment tasks, the following two tables show the desired weighting of cognitive demands and Specific Aims.

<table>
<thead>
<tr>
<th>Specific Aims 1.1 and 3.2 (knowing, remembering)</th>
<th>Specific Aims 1.2 and 3.1 (understanding, applying)</th>
<th>Specific Aims 1.3 and 3.3 (analysing, evaluating, creating)</th>
</tr>
</thead>
<tbody>
<tr>
<td>40%</td>
<td>30%</td>
<td>30%</td>
</tr>
</tbody>
</table>
Weighting of Cognitive Demands for the Assessment of Content Grades 10.

<table>
<thead>
<tr>
<th>Aim</th>
<th>Weighting %</th>
<th>Examples of verbs</th>
</tr>
</thead>
</table>
| **Knowing Science**                    | 40%         | • State  
• Name  
• Label  
• List  
• Define  
• Describe and others                     |
| **Understanding Science**              | 25%         | • Explain  
• Compare  
• Rearrange  
• Give an example of  
• Illustrate  
• Calculate  
• Make a generalisation and other       |
| **Applying Scientific Knowledge**      | 20%         | • Predict  
• Apply  
• Use knowledge  
• Demonstrate  
• Solve  
• Implement  
• Judge and others                       |
| **Evaluating, analyzing and synthesising Scientific Knowledge** | 15%         | • Select  
• Differentiate  
• Analyse  
• Infer  
• Suggest a reason  
• Discuss  
• Categorise and others}
The programme of assessment as per the CAPS document is designed to spread formal assessment tasks in all subjects in a school throughout a term.

Types of formal assessment to be used throughout the year are as follows:

- **Tests:** Four tests (minimum of 50 marks each).
- **Mid-Year Examination:** One midyear examination (2.5 hours; 150 marks).
- **Project Assignment:** One project/assignment (can be done in any term, but must be out of 100 marks and will count towards the fourth term’s marks).
- **Practical Tasks:** A selection of three representative practical tasks, which cover the range of skills, must be marked and recorded. (The marks allocated for a practical task should range from 20 to 40 marks).
- **End of year examinations:** These exams tests knowledge on content, concepts and skills across all topics.
- **Practical Examination:** Knowledge of practical work as well as some of the skills related to practical work must be assessed in the written examination. This exam tests practical knowledge and skills. This should be set by each teacher taking into account the resources that are available for practical examination.

The schedule of formal assessment is as follows:

<table>
<thead>
<tr>
<th>Formal term-based assessments 100%</th>
<th>End of year internal examination 75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Term 1 -1 test -1 practical task</td>
<td>Term 4 -End of year examination: Paper 1 (2 1/2 hours)</td>
</tr>
<tr>
<td>Term 2 -1 test -1 practical task</td>
<td>Term 4 -End of year examination: Paper 2 (2 1/2 hours)</td>
</tr>
<tr>
<td>Term 3 -1 test -1 practical task involving environmental studies fieldwork</td>
<td>Term 4 -End of year examination: Practical Exam (1 hour)</td>
</tr>
<tr>
<td>Term 4 -1 test -1 project / assignment</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>25%</th>
<th>25%</th>
<th>25%</th>
<th>25%</th>
<th>75%</th>
</tr>
</thead>
<tbody>
<tr>
<td>Convert to 25%</td>
<td></td>
<td></td>
<td></td>
<td>100%</td>
</tr>
<tr>
<td>75%</td>
<td></td>
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</tr>
</tbody>
</table>

Chapter 1. Teacher’s Guide
The end of year examinations consists of:

- Two examinations papers of 2.5 hours and 150 marks each.
- One Practical Examination of 1.5 hours of 50 marks.

The weighting and assess of topics in Paper 1 and Papers 2 are as follows:

### Paper 1

<table>
<thead>
<tr>
<th>Topic</th>
<th>Time (weeks)</th>
<th>Weighting (%)</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Chemistry of Life</td>
<td>2.5</td>
<td>16</td>
<td>23</td>
</tr>
<tr>
<td>Cells: basic units of life</td>
<td>3</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>Cell division: Mitosis</td>
<td>2</td>
<td>12</td>
<td>18</td>
</tr>
<tr>
<td>Plant and animal tissues</td>
<td>1</td>
<td>5</td>
<td>9</td>
</tr>
<tr>
<td><strong>Term 2</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Plant and animal tissues</td>
<td>2</td>
<td>13</td>
<td>20</td>
</tr>
<tr>
<td>Plant organs (leaf)</td>
<td>0.5</td>
<td>3</td>
<td>5</td>
</tr>
<tr>
<td>Support and transport systems in</td>
<td>3</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td>plants</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Support systems in animals</td>
<td>3</td>
<td>17</td>
<td>25</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>17</td>
<td><strong>100%</strong></td>
<td><strong>150</strong></td>
</tr>
</tbody>
</table>

### Paper 2

<table>
<thead>
<tr>
<th>Topic</th>
<th>Time (weeks)</th>
<th>Weighting (%)</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>Transport systems in mammals</td>
<td>3</td>
<td>20</td>
<td>30</td>
</tr>
<tr>
<td>Biosphere to Ecosystems</td>
<td>6</td>
<td>40</td>
<td>60</td>
</tr>
<tr>
<td><strong>Term 4</strong></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Biodiversity and Classification</td>
<td>1</td>
<td>7</td>
<td>10</td>
</tr>
<tr>
<td>History of Life and Earth</td>
<td>5</td>
<td>33</td>
<td>50</td>
</tr>
<tr>
<td><strong>Totals</strong></td>
<td>15</td>
<td><strong>100%</strong></td>
<td><strong>150</strong></td>
</tr>
</tbody>
</table>

The weighting per topic must serve as a guideline for teachers: minor deviations in respect of the number of marks allocated to a topic are acceptable. The purpose of providing the weighting is to ensure that all topics are covered according to the correct weighting as far as possible.
1.5 Assessment Tools

You use an assessment tool to record information during an assessment. Assessment tools allow an educator to systematise the marking, undertake quality assurance, check that content and specific aims are covered and allow for easier moderation. It enables a more objective analysis of a learner’s achievement and also enables both learner and educator to identify the areas at which the learner excelled, and which require intervention. Assessment tools can be:

- Check lists
- Assessment grids/sheets
- Rubrics
- Observation books or notebooks
- Completed tasks, assignments of worksheets
- Conferencing or interviews
- Self or Peer Assessment Sheets
- Recordings, photographs, written descriptions
- Portfolios

Before you use the tool the learners must know:

- When he/she is to be assessed
- How she/he will be assessed
- The consequences of the assessment
- The expected mode for response (written, spoken, practical)

After using the tool, the educator needs to answer the following question:

- Were the criteria used adequate to assess the outcome, and were the levels appropriate?
- Is appropriate feedback given to learners?
- Are learning difficulties identified and action planned?
- What happens to the product?
- What feedback follow-up action is needed?
- Has the integrating function been addressed?
- What learner appeal process exists?
- How will assessment inform further teaching/learning?
A rubric is an assessment tool which defines different levels of performance. It can be used for assessing concepts and process skills during informal and formal assessment, and for practical work. Rubrics aim to make assessment more objective and consistent. Some of the advantages of using rubrics are:

- Learners become aware of the expectations of educators
- Educators become aware of learners’ progress and potential
- Enhance greater learner involvement
- Learners are more focused and self-directed

Below are a number of rubrics that may be used to evaluate a number of different activities and tasks. The various rubrics provided are:

- **Assessment Rubric 1: Practical activity**
  - To be used for any practical task where learners are required to follow instructions to complete the task.

- **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 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 Rubric 4: Table**
  - To be used when learners have to draw their own table and you would like to assess it.

- **Assessment Rubric 5: Scientific drawing**
  - To be used when learners have to do a drawing, particularly in Life and Living.

- **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 Rubric 7: Model**
  - To be used when learners have to design and build their own scientific models.

- **Assessment Rubric 8: Poster**
  - To be used when learners have to make a poster, either individually or in a group.

- **Assessment Rubric 9: Oral presentation**
  - To be used when learners have to give an oral presentation to the class on a selected topic.

- **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 Rubric 1: Practical activity

Name:  
Date:  
Task:  

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Following instructions</td>
<td>Unable to follow instructions</td>
<td>Instructions followed with guidance</td>
<td>Able to work independently</td>
<td></td>
</tr>
<tr>
<td>Observing safety precautions</td>
<td>Unable to observe safety precautions</td>
<td>Sometimes does not follow safety precautions</td>
<td>Able to follow safety precautions completely</td>
<td></td>
</tr>
<tr>
<td>Ability to work tidily</td>
<td>Cannot work tidily</td>
<td>Can work tidily</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Cleans up afterwards</td>
<td>Does so once reminded</td>
<td>Does so without reminding</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Organisation</td>
<td>Disorganised</td>
<td>Fairly organised</td>
<td>Organised and efficient</td>
<td></td>
</tr>
<tr>
<td>Use of apparatus, equipment and materials</td>
<td>Always used incorrectly and materials wasted</td>
<td>Sometimes used correctly and aware of material usage</td>
<td>Apparatus and materials used correctly and efficiently</td>
<td></td>
</tr>
<tr>
<td>Results or final product</td>
<td>No result or final product</td>
<td>Partially correct results or product</td>
<td>Results or product correct</td>
<td></td>
</tr>
<tr>
<td>Answers to questions based on activity</td>
<td>No answers provided or most are incorrect</td>
<td>Can answer questions and at least 60% are correct</td>
<td>Can answer application and questions correctly</td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
<td></td>
<td>Total /15</td>
</tr>
</tbody>
</table>
## Assessment Rubric 2: Investigation

Name:  
Date:  
Task:  

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim</strong></td>
<td>Not stated or incorrect</td>
<td>Not clearly stated</td>
<td>Clearly stated</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Hypothesis or prediction</td>
<td>Not able to hypothesize</td>
<td>Able to hypothesize, but not clearly</td>
<td>Clearly hypothesizes</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Materials and apparatus</td>
<td>Not listed or incorrect</td>
<td>Partially correct</td>
<td>Correct</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Method</td>
<td>None</td>
<td>Confused, not in order or incorrect</td>
<td>Partially correct</td>
<td>Clearly and correctly stated</td>
<td></td>
</tr>
<tr>
<td>Results and observations (recorded either as a graph, table or observations)</td>
<td>No results recorded or incorrectly recorded</td>
<td>Partially correctly recorded</td>
<td>accurately recorded but not in the most appropriate or specified way</td>
<td>Correctly and accurately recorded in the most appropriate or specified way</td>
<td></td>
</tr>
<tr>
<td>Analysis or discussion</td>
<td>No understanding of the investigation</td>
<td>Some understanding of the investigation</td>
<td>Understands the investigation</td>
<td>Insightful understanding of the investigation</td>
<td></td>
</tr>
<tr>
<td>Evaluation</td>
<td>No attempt</td>
<td>Partially correct</td>
<td>Correct, but superficial</td>
<td>Critical evaluation with suggestions</td>
<td></td>
</tr>
<tr>
<td>Neatness of report</td>
<td>Untidy</td>
<td>Tidy</td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Logical presentation of report</td>
<td>Not logical</td>
<td>Some of report is logically presented</td>
<td>Report is logically presented</td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Total</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>/25</td>
</tr>
</tbody>
</table>

1.5. Assessment Tools
Assessment Rubric 3: Graph

Name:

Date:

Task:

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

Total: /15
Assessment Rubric 4: Table

Name: 
Date: 
Task: 

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

Total /12
Assessment Rubric 5: Scientific drawing

Name: 
Date: 
Task: 

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

Total /12
Assessment Rubric 6: Research assignment or Project

Name:

Date:

Task:

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Group work (if applicable)</td>
<td>Conflict between members or some did not participate</td>
<td>Some conflict and some members did not always participate</td>
<td>Worked efficiently as a group</td>
<td></td>
</tr>
<tr>
<td>Project layout</td>
<td>No clear or logical organisation</td>
<td>Some parts are clear and logical, while others are not</td>
<td>Clear and logical layout and organisation</td>
<td></td>
</tr>
<tr>
<td>Accuracy</td>
<td>Many errors in content</td>
<td>A few errors in content</td>
<td>Content is accurate</td>
<td></td>
</tr>
<tr>
<td>Resources used (material or media)</td>
<td>No resources used</td>
<td>Some or limited resources used</td>
<td>A range of resources used</td>
<td></td>
</tr>
<tr>
<td>Standard</td>
<td>Poor standard</td>
<td>Satisfactory</td>
<td>Of a high standard</td>
<td></td>
</tr>
<tr>
<td>Use of time</td>
<td>Did not work efficiently and ran out of time</td>
<td>Worked fairly efficiently</td>
<td>Worked efficiently and finished in time</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>1/12</td>
</tr>
</tbody>
</table>

1.5. Assessment Tools
Assessment Rubric 7: Model

Name:

Date:

Task:

<table>
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<tr>
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<th>0</th>
<th>1</th>
<th>2</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Scientifically accurate</td>
<td>Model inaccurate or incomplete</td>
<td>Mostly accurate, but with some parts missing or incorrect</td>
<td>Accurate, complete and correct.</td>
<td></td>
</tr>
<tr>
<td>Size and scale</td>
<td>Too big or too small, parts not in proportion to each other</td>
<td>Correct size, but some parts too big or too small</td>
<td>Correct size and proportional scale</td>
<td></td>
</tr>
<tr>
<td>Use of colour or contrast</td>
<td>Dull, with little use of contrast</td>
<td>Somewhat colourful</td>
<td>Creative and good use of colour and contrast</td>
<td></td>
</tr>
<tr>
<td>Use of materials</td>
<td>Inappropriate use or only expensive materials used</td>
<td>Satisfactory use of appropriate materials and recyclables where possible</td>
<td>Excellent use of materials and recyclables where appropriate</td>
<td></td>
</tr>
<tr>
<td>Use of a key or explanation</td>
<td>Not present</td>
<td>Present but incomplete or vague</td>
<td>Clear and accurate</td>
<td></td>
</tr>
<tr>
<td>Total</td>
<td></td>
<td></td>
<td></td>
<td>39</td>
</tr>
</tbody>
</table>

Chapter 1. Teacher’s Guide
Assessment Rubric 8: Poster

Name:

Date:

Task:

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

Total: /22
Assessment Rubric 9: Oral presentation

Name: 

Date: 

Task: 

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

Total /18
## Assessment Rubric 10: Group work

Name:

Date:

Task:

<table>
<thead>
<tr>
<th>Assessment criteria</th>
<th>0</th>
<th>1</th>
<th>2</th>
<th>3</th>
<th>Comments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Member participation</td>
<td>Very few members participated or one or two members did most of work</td>
<td>Only some members participated</td>
<td>In the beginning only some members participated but then full participation</td>
<td>Full participation throughout</td>
<td></td>
</tr>
<tr>
<td>Discipline within the group</td>
<td>Lack of discipline</td>
<td>Some members disciplined</td>
<td>Most members disciplined</td>
<td>All members disciplined</td>
<td></td>
</tr>
<tr>
<td>Group motivation</td>
<td>Unmotivated or lack focus</td>
<td>Some members motivated, but others lack focus</td>
<td>Most members motivated and focused</td>
<td>All members motivated and focused</td>
<td></td>
</tr>
<tr>
<td>Respect for each other</td>
<td>Show disrespect to each other</td>
<td>Some members showed disrespect</td>
<td>All members are respectful</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Conflict within the group</td>
<td>Considerable conflict and disagreements which were unresolved</td>
<td>Some conflict which was either resolved or unresolved</td>
<td>No conflict or any issues were resolved maturely</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Time management</td>
<td>Disorganised and unable to stick to time frames</td>
<td>Mostly able to work within the given time</td>
<td>Effective use of time to complete the task</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Total: 7/15

1.5. Assessment Tools
Recording

Recording is a process in which the educator documents the level of a learner’s performance in a specific assessment task. It shows learner progress towards the achievement of the knowledge and skills as prescribed in the Curriculum and Assessment Policy Statements. Records of learner performance should provide evidence of the learner’s conceptual progression within a grade and her / his readiness to progress or be promoted to the next grade. Records of learner performance should also be used to verify the progress made by educators and learners in the teaching and learning process.

Reporting

Reporting is a process of communicating learner performance to learners, parents, schools, and other stakeholders. Learner performance can be reported through report cards, parents’ meetings, school visitation days, parent-educator conferences, phone calls, letters, class or school newsletters, etc. Educators in all grades report in percentages against the subject.

The various achievement levels and their corresponding percentage bands are as shown in the table below.

**Note:** The seven point scale should have clear descriptions that give detailed information for each level. Educators will record actual marks against the task by using a record sheet, and report percentages against the subject on the learners’ report card.

Codes and Percentages for Reporting in Grades R - 12:

<table>
<thead>
<tr>
<th>Rating Code</th>
<th>Description of Competence</th>
<th>Percentage</th>
</tr>
</thead>
<tbody>
<tr>
<td>7</td>
<td>Outstanding Achievement</td>
<td>80% - 100%</td>
</tr>
<tr>
<td>6</td>
<td>Meritorious Achievement</td>
<td>70% - 79%</td>
</tr>
<tr>
<td>5</td>
<td>Substantial Achievement</td>
<td>60% - 69%</td>
</tr>
<tr>
<td>4</td>
<td>Adequate Achievement</td>
<td>50% - 59%</td>
</tr>
<tr>
<td>3</td>
<td>Moderate Achievement</td>
<td>40% - 49%</td>
</tr>
<tr>
<td>2</td>
<td>Elementary Achievement</td>
<td>30% - 39%</td>
</tr>
<tr>
<td>1</td>
<td>Not Achieved</td>
<td>0% - 29%</td>
</tr>
</tbody>
</table>

Schools are required to provide quarterly feedback to parents on the Programme of Assessment using a formal reporting tool such as a report card. The schedule and the report card should indicate the overall level of performance of a learner.
Introduction to Life Sciences

2.1 Life Sciences Orientation
2.2 The Scientific Method
2.3 Important principles and relationships in Life Sciences
2.4 Presenting data
2.5 Mathematical skills in Life Sciences
2.6 Lab safety procedures
2.1 Life Sciences Orientation

Time Allocation: 1 week (4 hours)

This chapter consists of the following sections:

1. Life Sciences Orientation
2. The Scientific Method
3. Important principles and relationships in Life Sciences
4. Presenting data
5. Mathematical skills in Life Sciences
6. Lab safety procedures

Introduction

The aim of this chapter is to provide learners with an overview of the skills that they will need to develop as a Life Scientist.

The following subsections can be found in the Introduction to Life Sciences:

- **What is Life Sciences?:** discuss many of the different Life Science fields and disciplines with learners.
- **Why study Life Sciences?:** learners should be told of the ways that they will improve by their study of Life Sciences. This is also an opportunity to explain the specific aims of the year.
- **An A to Z of possible careers in Life Sciences:** Learners should be told of the possible career options available to them as Life Scientists. This is also an opportunity to mention subject choice and entrance requirements to tertiary institutions.
2.2 The Scientific Method

Learners will learn how to gather evidence using the scientific method. The scientific method is a systematic way of testing a theory. It involves gathering and analysing information in order to come to an objective conclusion about the validity of a theory. The scientific method requires that we constantly re-examine our understanding, by testing new evidence with our current theories, and making changes to those theories if the evidence does not meet the test. The scientific method is a powerful tool learners will use throughout the Physical Sciences and Life Sciences.

2.3 Important principles and relationships in Life Sciences

Surface area and volume

NOTE:
The concept of surface area to volume ratio is difficult for some learners to grasp. The following explanation may help them to understand the concept better:

- Think of a piece of clay or Prestik. If we roll it into a ball, that ball has a certain volume (how much clay there is) and a certain surface area (how much of its surface is exposed to the air).
- Surface area is measured in square cm or cm², while volume is measured in cubic cm or cm³.
- This is important – if they are measured in different units, we cannot say ‘surface area is bigger than volume’. It’s like trying to decide whether 5 kg is smaller than R 20! It makes no sense.
- So our ball of clay has a surface area of say 50 cm² and a volume of say 150 cm³. This is a relatively large volume compared to a relatively small surface area – it is called a small surface to volume ratio.
- If the same ball of clay is now flattened into a log thin strip like a ruler, the volume is still the same (we have not removed or added any clay), but the surface area is much more. It now has a volume of 150 cm³ and a surface area of say 500 cm². This is called a large surface to volume ratio.
- Surface to volume ratio is critical in Life Science – an animal with a flat or very small body has a bigger surface to volume ratio than an animal with a rounder or bigger body. The first animal will be able to distribute nutrients and gases by means of diffusion, while the second animal will have to have a blood system.
NOTE:

- In plants, surface to volume ratio has a direct effect on how easily a plant dehydrates – leaves, for example, must have a large surface to volume ratio to absorb as much light as possible, so they have to have special structures like cuticles / hairs to prevent dehydration.

2.4 Presenting data

The communication of scientific discoveries is of paramount importance. Therefore, the presentation of data is one of the most important scientific skills that learners must master.

This section consists of the following sections:

1. Biological drawings and diagrams
2. Tables
3. Graphs

Activity: Identifying the key aspects of producing biological drawings

Instructions:

Make a list of what makes the above drawings good and bad.

Figure 2.1: Identify the features of the images that make each one good or bad.
Top drawing is good because:

- Cells are drawn neatly, with continuous lines, not sketched
- The nuclei are circular and not coloured in / shaded
- Label lines end on the part indicated
- Label lines are parallel to each other and all end in one vertical line

Lower drawing is bad because:

- Cell walls are roughly sketched
- The nuclei are shaded / coloured in
- Label line for ‘cell wall’ doesn’t touch any part of the drawing
- Label lines cross each other
- Lines do not end in one vertical line

Activity: Converting tables to graphs

Aim:

It is very important to be able to convert tables to graphs, and vice versa. Below are some exercises to practice this.

Questions:

1. Convert the data in the graphs below into Tables. Remember to identify which is the independent variable in the graphs and to place this in the first column of the Table.

Figure 2.2: The average height in boys and girls between the ages of 10 and 18 years.
(1) Table to show the average height of boys and girls at different ages:

<table>
<thead>
<tr>
<th>Age</th>
<th>Height (cm) Boys</th>
<th>Height (cm) Girls</th>
</tr>
</thead>
<tbody>
<tr>
<td>10</td>
<td>140</td>
<td>140</td>
</tr>
<tr>
<td>11</td>
<td>145</td>
<td>148</td>
</tr>
<tr>
<td>12</td>
<td>149</td>
<td>151</td>
</tr>
<tr>
<td>13</td>
<td>153</td>
<td>158</td>
</tr>
<tr>
<td>14</td>
<td>163</td>
<td>160</td>
</tr>
<tr>
<td>15</td>
<td>168</td>
<td>161</td>
</tr>
<tr>
<td>16</td>
<td>172</td>
<td>163</td>
</tr>
<tr>
<td>17</td>
<td>174</td>
<td>163</td>
</tr>
<tr>
<td>18</td>
<td>174</td>
<td>163</td>
</tr>
</tbody>
</table>

(2) Table to show the proportion of each blood group in a small population:

<table>
<thead>
<tr>
<th>Blood group</th>
<th>Proportion of learners (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>AB</td>
<td>5</td>
</tr>
<tr>
<td>A</td>
<td>40</td>
</tr>
<tr>
<td>B</td>
<td>10</td>
</tr>
<tr>
<td>O</td>
<td>45</td>
</tr>
</tbody>
</table>

2. Convert the data in the following tables into graphs. Look back at the features of each type of graph to decide which one you will use.
### Favourite take away restaurant in a class of learners

<table>
<thead>
<tr>
<th>Take aways restaurant</th>
<th>Learners (%)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Kauai</td>
<td>40</td>
</tr>
<tr>
<td>Anat Falafel</td>
<td>15</td>
</tr>
<tr>
<td>Nandos</td>
<td>25</td>
</tr>
<tr>
<td>Burger King</td>
<td>20</td>
</tr>
</tbody>
</table>

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2.5 Mathematical skills in Life Sciences

Mathematical skills are important in Life Sciences. Learners need to revise, practise and become familiar with the following mathematical skills.

- Scales
- Averages
- Percentages
- Conversions

2.6 Lab safety procedures

The Life Science Laboratory has rules that are enforced as a safety precaution.

These rules are:

- Take care when pouring liquids or powders from one container to another. When spillages occur you need to call the teacher immediately to assist in cleaning up the spillage.
- Take care when using acids. A good safety precaution is to have a solution of sodium bicarbonate in the vicinity to neutralise any spills as quickly as possible.
- Safety goggles and/ or gloves may need to be worn when doing experimental work, working with various chemicals, or heating substances, as spitting may occur.
- When lighting a Bunsen burner the correct procedure needs to be followed.
- Remember that when heating a substance in a test tube, the mouth of the test tube must face away from you and members in your group.
- Do not to overheat the solution when heating substances in a test tube.
• Ensure that you are dressed appropriately: hair should be tied back and loose clothing that could potentially knock over the equipment or catch alight if too near a flame should be avoided.

• Before doing any scientific experiment make sure that you know where the fire extinguishers are in your laboratory and there should also be a bucket of sand to extinguish fires.

• If scalpel blades, pins and knives are used, take care not to cut yourself. If you do cut yourself and draw blood call the teacher immediately.

• When working with chemicals and gases that are hazardous a fume cupboard should be used.
# The chemistry of life

## 3.1 Overview

## 3.2 Molecules for life

## 3.3 Inorganic compounds

## 3.4 Organic compounds

## 3.5 Vitamins

## 3.6 Recommended Dietary Allowance

## 3.7 Summary
3 The chemistry of life

3.1 Overview

Time Allocation: 2.5 weeks (10 hours)

This chapter consists of the following sections:

1. Overview
2. Molecules for life
3. Inorganic compounds
4. Organic compounds
5. Vitamins
6. Recommended Dietary Allowance
7. Summary
8. End of chapter exercises

Introduction

In this first chapter, learners will be introduced to the main ‘building blocks’ of life. This section should draw on their basic understanding from ‘Matter and Materials’ in Natural Sciences. Learners will study the molecular structure and biological functions of key molecules important to life. They will study the chemistry of proteins, carbohydrates, lipids, vitamins and nucleic acids and will learn the role of each nutrient class in plant and animal life. They will also learn how their diet allows them to obtain sufficient quantities of each of these nutrients. There are a variety of practicals and investigations in this section, which provide an opportunity for learners to practice applying the scientific method.

Key concepts

- Organic molecules always contain carbon (C), and usually also contain hydrogen (H) and oxygen (O). Some important organic molecules also contain nitrogen (N), phosphorous (P), sulfur (S), iron (Fe) and other elements.
- Water (H₂O) is an inorganic compound made up of two H and one O. Water helps with temperature regulation, form and support, transport and lubrication and is a medium for chemical reactions.
- Minerals are required as part of a healthy diet. A deficit in essential
minerals results in deficiency diseases in plants and animals.

- Fertilisers are a way that essential nutrients can be added to the soil to improve plant growth.

- Carbohydrates are made up of C, H and O. They can be in the form of monosaccharides (single sugars), disaccharides (double sugars) or polysaccharides (many sugars), and are an important energy source for plants and animals.

- Lipids are made up of C, H and O. Triglycerides are a type of lipid that contains glycerol and three fatty acid chains. Cholesterol, another type of lipid, can increase the risk of heart disease.

- Proteins are made up of C, H, O, N, and some have P, S and Fe. Proteins consist of a long chain of amino acids that fold into a very specific three-dimensional structure. Proteins are an important building block in plants and animals and play a role in the immune system and in cell communication.

- Enzymes are a type of protein that act as a biological catalyst to speed up reactions. They work by a “lock and key” mechanism and are affected by temperature and pH.

- Nucleic acids such as DNA and RNA are made of C, H, O, N and P. DNA contains the genetic information for heredity, and RNA has the instructions on how to make protein.

- Vitamins are important organic molecules that must be obtained in the diet. They often help enzymes to work properly, or act in growth or differentiation.

---

### 3.2 Molecules for life

ESG44

Revise the concept of the atom, elements, molecules and compounds.

A simulation on building a molecule

See video: 2CMH

### 3.3 Inorganic compounds

ESG45

The main focus of this section should be:

- **Water:** The functions of water in living organisms

- **Minerals:** The difference between macro-nutrients and micro-nutrients.
  The main functions of the essential minerals in animals and plants, and the deficiency diseases.

- **Fertilisers:** The need for fertilisers, the undesirable consequences of fertilisers (eutrophication) and organic fertilisers.
FACT
Watch one of the following videos for a demonstration of the iodine solution test for starch.
① See video: 2CMK
② See video: 2CMM
③ See video: 2CMN

3.4 Organic compounds

Learners will study carbohydrates, lipids, proteins and nucleic acids under the following headings:

- **molecular make-up**: the main elements that make up the class of compounds
- **structural composition**: how the monomers join up together to form polymers
- **biological role**: importance of these molecules to animals and plants
- **chemical test**: how to detect the presence of each class of compounds

There is also an explanation of enzymes in the section of proteins. This section of the chapter contains the most practical work, and therefore plenty of time should be allocated to covering this section.

### Carbohydrates

#### Investigation: Test for the presence of starch (Essential investigation-CAPS)

**Aim:**

To test food samples for the presence of starch.

**Apparatus:**

- piece of potato or bread
- lettuce leaf
- petri dish
- iodine solution
- dropper
- other food samples of your choosing
Method:

1. Place a piece of potato or bread, the lettuce leaf, and your other food samples in separate petri dishes.
2. Using the dropper add a few drops of iodine solution to the food item in each petri dish.

Figure 3.1: Experimental set-up: test for the presence of starch using iodine solution.

Observations:

Record your observations.

The potato or bread turns blue-black in the presence of iodine solution, but the lettuce leaf does not.

Questions:

Can this method be used to determine how much starch is present? Explain your answer.

Yes. The deeper the blue-black colour, the higher the starch content. If only a little starch is present, the resulting colour looks paler and more purple than black. If there is no starch at all, the only colours visible are the original colour of the material (e.g. green leaf) and the yellow-brown colour of the iodine solution.

Watch a video demonstration of the test for glucose.

See video: 2CMP
Investigation: Testing for the presence of reducing sugars (Essential investigation-CAPS)

Aim:

To test for presence of sugars using Benedict’s or Fehling’s test.

Apparatus:

- 4 heat resistant test tubes
- 1 beaker
- Bunsen burner or water bath with hot water (+50 °C)
- test tube rack (if using a water bath)
- glucose solution
- albumen solution or egg white
- starch solution
- water
- Benedict’s solution OR Fehling’s solution
- marking pen to mark the test tubes
- thermometer
- 10 ml syringe or measuring cylinder

Safety precautions:

- Follow the safety procedures (listed in Chapter 1) when lighting your Bunsen burner. Do not light it in a shelf or in an enclosed space. Remove all notebooks, papers and excess chemicals from the area. Tie back any long hair, dangling jewelry and loose clothing and never leave an open flame unattended while it is burning.
- When heating your test tubes in the heated water in the beakers ensure that the mouth of the test tubes point away from you and fellow learners.
- When handling the test tubes, especially when they are hot, use a test tube holder and wear goggles.

Method:

Prepare a water bath by filling a beaker to the halfway mark with water. Place the beaker on a tripod stand over a Bunsen flame as shown in Figure 3.2. This will serve as your water bath.

While you wait for the water to reach the desired temperature, carry out the following instructions:

TEACHERS NOTE: It is not essential that a water bath be used for this practical. Test tubes can be heated directly. It is however necessary to have a water bath if you do not have gas available and have to use a hot plate.
1. Label the test tubes 1–4.
2. Using the syringe or measuring cylinder, add the following to the test tubes:
   - test tube 1: 5 ml of 1% starch solution
   - test tube 2: 5 ml of 10% glucose solution
   - test tube 3: 5 ml 1% albumen solution
   - test tube 4: 5 ml water.
3. Add 5 ml Benedict’s solution to each tube.
4. Place the test tubes in the beaker of hot water on the tripod.
5. Use a thermometer to monitor the water temperature and adjust the flame to maintain the water temperature at approximately 50°C.
6. If using the water bath, place the test tubes into the test tube rack and place into the water bath with temperature set to 50°C.
7. After about 5 minutes, when a colour change has occurred in some of the test tubes, extinguish the flame, or remove the test tubes from the water bath.
8. Place the four tubes in a test tube rack and compare the colours.

Figure 3.2: Test for reducing sugars using Benedict’s test

Results:

Construct a table to record the results of this experiment. It is important to observe and record any changes that have taken place.
### Questions:

1. What colour changes (if any) did you observe after heating the samples with Benedict’s solution?
2. The three solutions tested are examples of the chemical substances found in cells: glucose, starch, protein (albumen). Which of the samples tested positive when the Benedict’s solution was added and the test tube was heated?
3. Other than the colour, what change took place in the consistency of the Benedict’s solution?
4. What can you conclude from the investigation?
5. Why was water included in test tube 4?

### Answers

1. The contents of test tube 2 goes yellow / orange, the others stay blue.
2. Only glucose.
3. It became a bit thicker / it coagulated.
4. Any other substance we test that also goes yellow / orange when heated with Benedicts solution, contains glucose or a reducing sugar.
5. It is a control, to show that the Benedicts solution reacts with another substance in the test tube, not with the water in which the glucose was dissolved.

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**Lipids**

**ESG4C**

**Investigation: Test for the presence of lipids (Essential investigation-CAPS)**

**Aim:**

To test for the presence of lipids.
FACT
Watch a video demonstrating the test for lipids.
See video: 2CMS

Apparatus:
- piece of paper or “fish-and-chips” paper bag
- food item e.g fries, piece of cooked meat, etc
- 10 ml of cooking oil (positive control)
- 10 ml water (negative control)

Method:

1. **Positive control**: add cooking oil to brown paper bag until it is soaked up. The part of the paper that soaks up oil should be translucent compared to the part that does not.

2. **Negative control**: wet the paper with water. The paper may become wet and soggy, but should not become translucent.

3. **Experimental samples**: stain the brown paper bag with the food item to be tested and hold it up to the light. If it is translucent, similar to the positive control, the food item contains lipid.

Observations:

Record your observations and note any key differences between the controls and the experimental samples.

The paper became translucent when the oily food was placed onto it, the same as the translucent spot on the paper containing cooking oil. The paper containing water was wet, but it dried out easily and was never translucent, so we can conclude that the food contained oils or lipids, not water.

Investigation: Alternative methods for testing for lipids

An alternative method to test for the presence of lipids in a sample, is to crush or dissolve the sample in ethanol. Fats and lipids dissolve in alcohol. Once your ethanol solution has been prepared, there are two ways of testing whether this sample contains lipids:

1. **Filter the ethanol solution through filter paper**: lipids that have dissolved in the ethanol will cause filter paper to go translucent. Once the alcohol evaporates away, a translucent spot will remain.

2. **Add the ethanol sample to water**: lipids cannot dissolve in water. Therefore, if the ethanol solution contains lipids, the lipids will precipitate out of solution when mixed with water, causing the solution to go milky.
**Proteins**

### Investigation: Test for the presence of proteins

**WARNING: Millon’s Reagent**

Millon’s Reagent is wildly poisonous. Its use in the classroom is not encouraged unless no alternatives are available, or the teacher is confident of its use.

**Aim:**

To use the Biuret test or Millon’s reagent to test for the presence of proteins.

**Apparatus:**

Instructions on how to prepare Biuret Reagent Solution

- Weigh 1.50 g of cupric sulfate pentahydrate with 6.0 g sodium potassium tartrate tetrahydrate.
- Dissolve in 500 ml of water.
- Add 300 ml of 10% NaOH.
- Make up to total volume of 1 liter. Store in a plastic bottle protected from light.

1. Bunsen burner and a beaker containing water
2. or water bath with hot water (50°C)
3. Dropper or plastic pipette
4. Test tubes:
   - two with albumin solution (positive control)
   - two with sugar water (negative control)
   - test tubes with samples to be tested for the presence of protein
   - test tube with Millon’s Reagent
   - test tube with solution for Biuret test

( **NOTE:** The Millon’s Reagent and Biuret’s solution in this experiment should be prepared for you by your teacher).

**Method:**

**Test for protein using Millon’s reagent**
WARNING! Millon’s reagent is highly toxic! Avoid breathing in its fumes.

1. Using the dropper or pipette, add a few drops of Millon’s Reagent to the test tube containing albumin.
2. Using the dropper or pipette, add a few drops of Millon’s Reagent to the test tube containing sugar water.
3. Using the dropper or pipette, add a few drops of Millon’s Reagent to the test tube containing samples of your food to be tested.
4. Heat the mixtures in boiling water for 5 minutes.
5. Observe any colour changes.

Test for protein using the Biuret test

1. Using the dropper or pipette, add a few drops of the Biuret solution to the test tube containing albumin.
2. Using the dropper or pipette, add a few drops of the Biuret solution to the test tube containing sugar water.
3. Using the dropper or pipette, add a few drops of the Biuret solution to the test tube containing samples of your food to be tested.
4. Observe any colour changes.

Figure 3.3: Biuret test: this is the expected colour change if protein is present

Observations:

Record your observations, noting any key differences between the positive control, negative control and experimental samples.
FACT
Learn about what enzymes are and how they work.
See video: 2CMW

Observations: Millon’s Reagent

The albumen goes a brick red colour and becomes solid. The reddish colour indicates a positive protein test. The sugar water does not become red – it stays clear, indicating no proteins present. Any food samples that go reddish-brown when heated with Millons reagent also contain proteins.

Observations: Biuret Test

The albumen goes violet, indicating that proteins are present. The sugar water stays the blue colour of the copper sulphate that was added - it does not go violet, indicating no proteins present. Any food samples that go violet when the Biuret chemicals are added contain protein.

View a video demonstration of the experiment to test for proteins:
See video: 2CMV

Enzymes

Investigation: Investigating how biological washing powders work

Aim:
To test how enzymes in biological washing powders work.

Apparatus:

- two soft boiled eggs (hard boiled eggs contain denatured proteins that do not cause stains)
- two beakers
- biological washing powder (with enzymes)
- non-biological washing powder (older type of washing powder)
- water
- two measuring spoons

Method:

1. Label 3 beakers ‘Bio’, ‘Non-Bio’ and ‘control’ which will contain biological washing powder, non-biological washing powder and water (negative control) respectively.
2. In the beaker labelled ‘Bio’ dissolve 5 g of biological washing powder in 30 ml water.
3. In the beaker labelled ‘Non-Bio’ dissolve 5 g of non-biological washing powder in 30 ml water.
4. Pour 30 ml of tap water into the control beaker.
5. Scoop out a small amount of egg yolk.
6. Place a teaspoon with the egg yolk in each of the beakers.
7. Leave the spoons in the beakers for 1 to 2 hours.
8. Observe your results.

Results:

1. Write down your observations.
2. Suggest a reason for your observations.
3. Write a conclusion for the investigation.

1. Results
   The egg yolk in the biological washing powder slowly dissolves off the spoon. The egg yolk in the non-biological washing powder partly lifts off the spoon, but does not break down and dissolve into the water. In the control beaker, there is no change – the egg yolk stays on the spoon.

2. Reasons
   The enzymes of the biological washing powder broke the egg yolk into smaller molecules that lift off the spoon and dissolve in the water. This did not happen in the non-biological powder or in the control.

3. Conclusion
   Biological washing powders are better than non-biological washing powder at removing organic stains from clothing.

Investigation: Investigating the effect of catalase from chicken liver on hydrogen peroxide

Aim:

To demonstrate the effect of catalase on hydrogen peroxide.

Apparatus:

- 10 ml measuring cylinders
- pipette
- 3% Hydrogen peroxide solution
Method:

Follow the instructions below:

- Cut two square pieces weighing 0.1 g from the fresh liver sample and place each in a separate 10 ml measuring cylinder.
- Use a clean measuring cylinder to measure 3 ml water. Pour into one of the fresh liver-containing cylinders. This is your negative control.
- Use a clean measuring cylinder to measure 3 ml hydrogen peroxide. Pour into the remaining fresh liver-containing cylinder. This is your positive control.
- Wait for four minutes and then measure and record the height of the resulting oxygen bubbles in each cylinder.

Questions:

1. Name the three variables that must remain stable throughout these experiments and explain why they must be kept stable.
2. What kind of reaction is taking place?
3. How could you make this experiment more accurate?
4. In addition to temperature, what other factors influence the rate of reaction?

Answers

1. Factors kept the same: [ANY 3 OF THE FOLLOWING]
   - Use the same amount of chicken liver in each measuring cylinder to control the amount of enzyme present.
   - Use 3 ml of water and 3 ml of hydrogen peroxide in the two different cylinders to keep the amount of liquid constant.
   - Give the 2 cylinders the same amount of time for the reaction to occur, so that the bubble columns can be compared reliably.
   - The contents of both measuring cylinders must be at the same temperature, so that temperature doesn’t interfere with the reaction being investigated.
2. This is a catabolic / breakdown reaction, since the hydrogen peroxide is broken down into oxygen (the bubbles) and water (the fluid left behind). The reaction is also exothermic, as the measuring cylinder got hot – heat was released during the reaction.

3. Improving accuracy:
   - Pour the liquid into both cylinders at exactly the same time.
   - Measure the amount of chicken liver more accurately.
   - It should be possible to calculate the volume of oxygen released by passing it through water and calculating the volume of oxygen more accurately by using the displacement principal. In the current method, some of the oxygen escaped into the air when the bubbles burst, so the height measurement is an approximation of the volume of oxygen released.

4. Other factors influencing the rate of reaction:
   - The amount of enzyme in the liver.
   - The amount of substrate available.
   - The pH of the medium.
   - The condition of the chicken liver – if not fresh, some of the enzymes may be inactive.
   - The temperature of the liver and liquid.

---

**Investigation: PART B**

**Aim:**

To demonstrate the effect of temperature on catalase activity.

**Method:**

- Add 3 ml of hydrogen peroxide to three separate 10 ml graduated measuring cylinders. Mark one cylinder “frozen chicken liver”; the second “boiled chicken liver” and the third “room temperature chicken liver”.
- Cut a 0.1 g square from each of the frozen and boiled and room temperature chicken livers. Add the liver pieces to the correspondingly labelled measuring cylinder with hydrogen peroxide in it.
- Leave the pieces of liver for four minutes and measure the height of bubbles produced.
Questions:

1. Give reasons for the differences observed across the three measuring cylinders.
2. Name the dependent and independent variables in this experiment.
3. How could you make this experiment more accurate?
4. What would you conclude from your observations?

Answers

1. The liver at room temperature reacts very quickly and produces a large amount of large, frothy white bubbles, because the enzymes are very active – they are close to their optimum temperature and easily break down the hydrogen peroxide into water and oxygen. The liver that was frozen reacts very slowly at first and forms very few bubbles, since the enzymes are inactive at such low temperatures – they lack activation energy. As the reaction releases heat, the enzyme speeds up a little later and forms bigger bubbles at a faster rate, but never as fast as the one at room temperature. The liver that was boiled does not show any reaction – no bubbles are formed, because the enzymes were denatured by boiling. Their shape was changed and they cannot catalyse the reaction at all.

2. • The dependent variable is the speed of the reaction, i.e. the amount of oxygen formed, which was measured as the height of the bubble column.
   • The independent variable is temperature – liver was at room temperature or frozen or boiled.

3. • Measure the amount of liver and the volume of the hydrogen peroxide more precisely and keep them exactly the same.
   • Ensure that all 3 measuring cylinders are identical – the same width.
   • Pour the hydrogen peroxide into the cylinders at exactly the same time.
   • Trap the amount of oxygen released and use the displacement principal to calculate the volume of gas more accurately.

4. Temperature has an effect on enzyme activity. Enzymes are most active at a temperature close to their optimum temperatures, but they denature and cannot function if the temperature is too high. At very low temperatures, enzymes cannot function effectively due to a lack of activation energy – they work very slowly.
3.5 Vitamins

This section should be linked to the digestive system and healthy diet that were covered in Grade 9 Natural Sciences. Vitamins are organic compounds required by organisms as vital nutrients in limited amounts. Vitamins are therefore essential to a balanced diet. The sources, functions and deficiency diseases of the main vitamins should be revised.

3.6 Recommended Dietary Allowance

In order to ensure that we consume adequate quantities of all the food types, nutritionists have compiled a list of guidelines known as the Recommended Dietary Allowance (RDA). The RDA defines the required intake of each nutrient type to meet the basic nutrient needs of almost all individuals in a gender group at a given life stage.

TEACHERS NOTE: Learners DO NOT need to learn the RDA tables by heart, but they must be able to use it and interpret it if they are given such a table in tests / exams.

Activity: Measuring your daily nutrient intake (Essential investigation-CAPS)

1. Keep a food diary for 3 days by writing down the food you eat. Make sure to note the time you eat, the type of food you eat, and how much of it you consume.
2. Pick one of the days you recorded (that is the most typical of your normal diet), and draw a pie chart with the energy component of each food item you consumed. Make sure your pie chart includes a key. (See the Introduction to Life Skills Chapter if you are unsure of how to do this.)
3. Draw another table with each food class (vitamins, proteins, carbohydrates, etc) listed. In one column, list the recommended dietary allowance and in the next column list the estimated amount of the food type you consume on a daily basis.
4. Which food types do you consume in excess? Which ones do you consume too little of? What are the consequences of each?

The table below lists the energy components of some common food items. Study it and answer the following questions:

1. Which food has the highest energy value? Why?
2. Name the key food items you would include in a balanced diet.
### Nutrient composition of some common foods

<table>
<thead>
<tr>
<th>Food type</th>
<th>Energy (kJ)</th>
<th>Protein (g)</th>
<th>Carbs (g)</th>
<th>Fat (g)</th>
<th>Sodium (mg)</th>
<th>Iron (mg)</th>
<th>Vitamin A (IU)</th>
<th>Vitamin C (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>rice, brown (250 ml)</td>
<td>969</td>
<td>5</td>
<td>48</td>
<td>2</td>
<td>10</td>
<td>0.9</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Muffin, blueberry (50 g)</td>
<td>824</td>
<td>4</td>
<td>34</td>
<td>5</td>
<td>317</td>
<td>1.1</td>
<td>24</td>
<td>1</td>
</tr>
<tr>
<td>Beansprouts (250 ml)</td>
<td>274</td>
<td>6</td>
<td>14</td>
<td>0</td>
<td>12</td>
<td>2.5</td>
<td>41</td>
<td>21</td>
</tr>
<tr>
<td>Carrots raw (1 medium)</td>
<td>145</td>
<td>1</td>
<td>8</td>
<td>1</td>
<td>35</td>
<td>0.4</td>
<td>22644</td>
<td>7</td>
</tr>
<tr>
<td>Apples, raw, with skin (7cm diameter)</td>
<td>341</td>
<td>0</td>
<td>21</td>
<td>2.6</td>
<td>0</td>
<td>0.2</td>
<td>73</td>
<td>8</td>
</tr>
<tr>
<td>Egg white, raw (1 egg)</td>
<td>69</td>
<td>3</td>
<td>0</td>
<td>0</td>
<td>54</td>
<td>0</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Lamb stew (250 ml)</td>
<td>914</td>
<td>33</td>
<td>0</td>
<td>9</td>
<td>69</td>
<td>2.7</td>
<td>0</td>
<td>0</td>
</tr>
<tr>
<td>Chicken roasted (1/2 breast)</td>
<td>218</td>
<td>30</td>
<td>0</td>
<td>10</td>
<td>69</td>
<td>0.6</td>
<td>107</td>
<td>0</td>
</tr>
</tbody>
</table>

### TEACHERS NOTE:

This answers to this activity will be learner-dependent.

Learners may use the Internet to look up food nutritional information, or simply use the information available on food packaging. It is important to note that this is a very complex, and personal activity for learners, and is likely to be challenging for a number of reasons:

- Learner’s from poor-income families may be embarrassed to do this activity and list their meals, especially if food is very scarce or basic.
- Learners may be embarrassed by how little, or how much they eat.
- This activity may be difficult for learners struggling with eating disorders, which are prevalent in this age-group, especially amongst teenage girls.
- Obtaining accurate information will be challenging. The energy content of the food type will be affected by the cooking method and will vary tremendously, e.g. mashed potato with butter added vs. boiled potato vs. fried chips vs. oven chips.
- It will be difficult for learners to establish their portion sizes accurately.
- Packaging often only lists the energy content and macronutrients (carbohydrates, protein and fat) in a meal, and very rarely lists vitamins and minerals.

In light of the potential difficulties that may occur during this activity, both social and pragmatic, it is up to the teacher to decide how best to modify and assess this activity.
3.7 Summary

- Cells are made up of organic and inorganic molecules which in turn are made up of atoms bonded together.
- Living organisms need to consume organic and inorganic compounds, which they break down for energy and use as building blocks for the components of life.
- Essential compounds are those that a living organism cannot build itself from other molecules, but must obtain from its environment.
- Plants may require a supply of inorganic nutrients through natural and non-natural fertilisers. An excess of non-natural fertilisers supplied to plants may result in eutrophication of rivers and lakes.
- Proteins, carbohydrates and fats are key organic molecules required for growth and survival of living organisms. All three are large molecules (polymers) made up of smaller molecules (monomers). We can test foods for the presence of these molecules.
- Each of these compounds has essential functions in living organisms, for example: fats (storage); proteins (growth); carbohydrates (energy); nucleic acids (store genetic information); vitamins (variety of functions in the body). An inadequate supply of these can result in diseases of malnutrition (e.g. kwashiorkor, marasmus, scurvy, rickets etc).
- The class of proteins known as enzymes is important in speeding up chemical reactions in living organisms. Enzymes work under specific pH and temperature conditions known as ‘optimal conditions’. They may become denatured or deactivated under unfavourable conditions.
- The Recommended Dietary Allowance is a measure of how much of the various organic and inorganic nutrients we require in our diet. The specific allowance is different across age groups and sexes. It is a useful guide to maintaining a balanced diet.

Exercise 3 – 1: End of chapter exercises

1. Which one of the following is not a biological role of water?
   a) prevents deficiency diseases  
   b) dissolves biochemical compounds  
   c) provides a medium in which chemical reactions take place  
   d) involved in the hydrolysis of foodstuffs  

   **Solution:**
   a
2. Which combination of the following substances is best to prevent rickets?
   a) magnesium, phosphorus and carrots
   b) phosphorus, calcium and fish liver oil
   c) iron, calcium and liver
   d) iodine, iron and oranges

   Solution:
   b

3. The diagram below is a schematic drawing, which means that the molecules represented may not resemble their actual chemical shape. Use the information provided in the diagram to answer the following questions:

   ![Diagram of carbohydrate metabolism]

   a) What is the polymer A that is found in an animal cell?
   b) What is the function of polymer A in the body?
   c) What could polymer B be?

   Solution:
   a) Glycogen.
   b) Glycogen is an energy storage molecule.
   c) Polymer B is starch.

4. The table below gives nutrients present in various dry seeds.

<table>
<thead>
<tr>
<th>Seed</th>
<th>Number of grams of nutrients in 100g of dry seed</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Fat</td>
</tr>
<tr>
<td>Green peas</td>
<td>1</td>
</tr>
<tr>
<td>Sunflower seeds</td>
<td>47</td>
</tr>
<tr>
<td>Maize</td>
<td>5</td>
</tr>
<tr>
<td>Peanuts</td>
<td>45</td>
</tr>
</tbody>
</table>
The following histogram shows the different amounts of nutrients found in one of the four seeds. The chart shows the nutrients found in:

- a) green peas
- b) sunflower seeds
- c) maize
- d) peanuts

**Solution:**

d
5. The graph below illustrates that enzymes:

- a) are pH-specific
- b) catalyses a specific substrate
- c) are denatured at high pH
- d) are sensitive to low pH

**Solution:**

a

6. The following diagrams show the enzyme lock-and key method of action. Label each of the letters.
Solution:

- **A**: substrate
- **B**: enzyme
- **C**: enzyme-substrate complex
- **D**: enzyme
- **E**: products

7. Explain briefly how you would test for glucose.

**Solution:**
Cut or crush the food or substance to be tested to expose a large surface area for the reaction. Add water to make a liquid medium. Add a few drops of Benedict’s solution (or Fehling’s solution) and heat it over a Bunsen burner or in a water bath. Watch to see whether colour changes occur.

8. Study the graph below. The graph shows total protein (in grams) present in a 100 grams of different food items. Use the graph to answer questions below.

![Graph showing protein content of different food items](image)

The numbers represent grams of protein per 100 grams

a) Name the two foods from which vegetarians would obtain the most protein.

**Solution:**
Almonds and haricot beans

b) Which foods contains only 2% protein?

**Solution:**
Runner beans and cabbage

c) Which food would be the best for a non-vegetarian person who is suffering from kwashiorkor and anaemia?

**Solution:**
Liver and beef

d) Name and explain the process which proteins undergo when heated excessively.
**Solution:**

Denaturing – the bonds holding the enzyme in the correct shape break down and the shape of the active site changes – the enzyme is no longer complementary to the substrate and can’t fit onto it, so it can’t catalyse the reaction.

9. Study the information in the following diagrams and the table below, for three different meals X, Y and Z.

<table>
<thead>
<tr>
<th>Meals</th>
<th>Energy (kJ)</th>
<th>Vitamin C (mg)</th>
<th>Calcium (mg)</th>
</tr>
</thead>
<tbody>
<tr>
<td>X</td>
<td>2900</td>
<td>25</td>
<td>70</td>
</tr>
<tr>
<td>Y</td>
<td>2100</td>
<td>47</td>
<td>265</td>
</tr>
<tr>
<td>Z</td>
<td>2600</td>
<td>40</td>
<td>170</td>
</tr>
</tbody>
</table>

a) Name three polysaccharide carbohydrates in meal X.

**Solution:**

Starch, cellulose, glycogen (in the meat patty).

b) Giving one reason for each answer, which meal will:

i. provide the greatest source of energy?

ii. be most suitable for the development of healthy bones and teeth?

iii. be least suitable for people who are prone to scurvy?

**Solution:**

i. Meal X, because it has the highest total amount of kilojoules (2900 kJ). According to the pie charts, the high energy content is due to its high lipid and carbohydrate content.

ii. Meal Y, due to the calcium in the milk (265 mg according to the table).
iii. Meal X, because it doesn’t have tomato, which is a source of Vitamin C - the other 2 meals have tomato. (It has the least amount of vitamin C (70g) according to the table).

c) Meal Z is relatively low in lipids (fat) yet high in energy content. Which of the food components in Z provides the energy?

Solution:
Brown bread and bitter beer

d) Which of the three meals can be regarded as the healthiest? Give three reasons for your answer.

Solution:
Meal Y.

• It is the lowest in kilojoules, and therefore is unlikely to lead to weight gain.
• It has an excellent ratio of carbohydrates: fat: protein.
• It has the highest concentration of calcium, due to the milk, rather than beer or Coke, as in the other 2 meals.
• It has lettuce, tomato and apple, which contain many vitamins, and result in it having the highest concentration of vitamin C.
• It also has a wholewheat roll, which takes longer to break down to sugar than white bread or coke in the other meals.
• The wholewheat roll and lettuce, tomato and apple contain cellulose, which acts as roughage.

Any other logical answer.

10. The following information (given in the table below) appeared on a box of breakfast cereal. Use this information in the table to assist you in answering the questions that follow.

<table>
<thead>
<tr>
<th>Nutrient</th>
<th>per 100 g of product</th>
<th>per serving (50 g)</th>
<th>Recommended daily allowance (RDA)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Vitamin C</td>
<td>35 mg</td>
<td>18 mg</td>
<td>35 mg</td>
</tr>
<tr>
<td>Vitamin B1</td>
<td>0,8 mg</td>
<td>0,4 mg</td>
<td>0,5 mg</td>
</tr>
<tr>
<td>Vitamin B2</td>
<td>0,3</td>
<td>0,15</td>
<td>0,6</td>
</tr>
<tr>
<td>Niacin (Vit B7)</td>
<td>4,0</td>
<td>2,0</td>
<td>8,0</td>
</tr>
<tr>
<td>Calcium</td>
<td>450 mg</td>
<td>225 mg</td>
<td>562,5 mg</td>
</tr>
<tr>
<td>Iron</td>
<td>8 mg</td>
<td>4 mg</td>
<td>16 mg</td>
</tr>
<tr>
<td>Energy</td>
<td>1 750 kj</td>
<td>875 kj</td>
<td>3 125 kj</td>
</tr>
</tbody>
</table>
a) How many servings does a person need to provide the RDA of energy?

**Solution:**
3.6 servings

\(\frac{3125}{875}\)

b) Which organic compounds are the most important energy providers?

**Solution:**

Lipids and carbohydrates

c) How much energy do the vitamins in the cereal provide?

**Solution:**
None – vitamins are not a source of energy.

d) What deficiency disease could result if a person does not obtain adequate amounts of vitamin B1?

**Solution:**
Beri Beri

e) Explain the role of iron in the diet.

**Solution:**

Iron is essential for the formation of haemoglobin in red blood cells.
It is also part of the structure of some proteins.

f) Consider the RDA of energy (3125 kJ). Do you think this amount is realistic for your requirements? Explain your answer.

**Solution:**

No. Young adults need more energy than 3125 kJ. According to the RDA, young adults need at least:

- Carbohydrates: \(230\text{ g} \times 17 \text{ kJ/g} = 3910 \text{ kJ}\)
- Protein: approximately \(50 \text{ g} \times 17 \text{ kJ/g} = 850 \text{ kJ}\)
- Fat: \(70 \text{ g} \times 38 \text{ kJ/g} = 2260 \text{ kJ}\)

**TOTAL:** 7020 kJ
11. The histograms below show the percentage of carbohydrates, fats, proteins and water in eight types of foods.

From the information provided in the histograms above, name two types of food that:

a) Contain more than 25% of a nutrient that is involved in the formation of an insulating layer
   **Solution:**
   Cheese and peanuts

b) Would best help to prevent kwashiorkor
   **Solution:**
   Cheese and chicken

c) Will form only monosaccharides and amino acids after digestion
   **Solution:**
   Potato and beans

d) Are not involved in the formation of cell membranes
   **Solution:**
   Apples and sugar

e) Contain more than 50% of a nutrient which is the primary source of energy
   **Solution:**
   Sugar and bread
12. The diagram shows the apparatus used in various organic food tests. Study it and answer the questions that follow:

a) Name the nutrients tested for in each of the experiments numbered A, B, C and D.

**Solution:**
- **A:** Fat/ lipids
- **B:** Glucose or reducing sugar
- **C:** Protein
- **D:** Starch

b) Identify the chemicals numbered 1, 2 and 3.

**Solution:**
- **1:** ethanol
- **2:** Copper sulfate
- **3:** NaOH (sodium hydroxide)

c) State the colour change for a positive reaction in each of the test tubes used in the experiments numbered B, C and D.

**Solution:**
- **B:** blue to brick red.
- **C:** blue to lilac through rose pink.
- **D:** brown/ orange to purple/ black.

d) Identify each of the compounds A, B and C. In each case give a reason for your answer.
Which compound (A, B or C)

i. serves as a main source of energy in cellular respiration

ii. is most likely to form part of an enzyme

Solution:

i. B

ii. C

13. The figure below shows the differences between the upper and lower basin of a water body.

a) What has caused the key differences between the upper and lower basin?

b) What could have been added to the water in the lower basin to cause it to look milky-green?

Solution:

a) The lower basin has undergone eutrophication.

b) Fertilizers may have been added to the lower basin, causing it to turn milky-green from eutrophication.

Check answers online with the exercise code below or click on 'show me the answer'.

1. 2CN2 2. 2CN3 3. 2CN4 4. 2CN5 5. 2CN6 6. 2CN7
7. 2CN8 8a. 2CN9 8b. 2CNB 8c. 2CNC 8d. 2CND 9a. 2CNF
9b. 2CNG 9c. 2CNH 9d. 2CNJ 10a. 2CNK 10b. 2CNM 10c. 2CNN
10d. 2CNP 10e. 2CNQ 10f. 2CRN 11a. 2CNS 11b. 2CNT 11c. 2CNV
11d. 2CNW 11e. 2CNX 12a. 2CNY 12b. 2CNZ 12c. 2CP2 12d. 2CP3

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CHAPTER 4

The basic units of life

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4.5 Summary 96
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4 The basic units of life

4.1 Overview

**Time Allocation:** 3 weeks (12 hours)

This chapter consists of the following sections:

1. Overview
2. Molecular make up of cells
3. Cell structure and function
4. Cell organelles
5. Summary
6. End of chapter exercises

**Introduction**

"In the year of 1657 I discovered very small living creatures in rain water." — Antonie van Leeuwenhoek, the Father of Microbiology, on discovering cells. Together with Robert Hooke’s discoveries, van Leeuwenhoek’s findings laid the foundations of microbiology.

**Key concepts**

- The invention of microscopes allowed us to see life at the microscopic level.
- Cell walls are present in plants, bacteria and fungi and provide a rigid support structure.
- Cell membranes are semi-permeable and have a fluid rather than a fixed structure. Substances move across them by diffusion, osmosis, facilitated transport and active transport.
- Cells contain organelles with structures adapted to perform specific functions within the cell.
- Cells differ in size, shape and structure in order to carry out specialised functions. Cells with similar structures and functions associate to form tissues.
- Plant and animal cells differ in many crucial ways.
This chapter will cover the following:

- Cells are considered to be the basic units of life.
- Cells are microscopic and we use microscopes to view them.
- Cells have different organelles, which perform specific functions in the cell.
- Cells differ in size, shape and structure and these are adapted to their specific functions within the tissue.

4.2 Molecular make up of cells

A brief overview of the history of microscopy needs to be taught. This should include the progression from the use of lenses, light microscopy and then electron microscopy. The development of microscopy over the years has enabled people to view cells and then with the introduction of the electron microscope the structures within cells. All this led to the cell theory.

The practical Life Science techniques are an important part of the Life Science assessment program. This section addresses some of these important skills. Learners are introduced to the various microscopes and should practice using a light microscope. The skills of drawing, labelling and annotating diagrams based on observations from microscope specimens and micrographs should also be practised. In all future microscope work, learners should calculate the magnification of cells and include a scale in their diagrams.

Worked example 1: Calculating overall magnification

**QUESTION**

Calculate the overall magnification of a compound light microscope with a magnification of 10 X due to the eyepiece and a magnification of a 100X due to the objective lens.

**SOLUTION**

Using the formula:

\[
\text{overall magnification} = \text{power of eyepiece} \times \text{power of objective}
\]

\[
= 10 \times 100
\]

\[
= 1000 \times \text{the original size}
\]
Worked example 2: Calculating size of object from its microscopic image

**QUESTION**

If the measured length of the magnified beetle larva image shown below was 2 centimetres (20 mm), the ocular magnification of the microscope is 5X and you are using an objective lens magnification of 10X, what is the actual length of the larva in millimetres?

![Figure 4.1: A beetle larva as seen under a light microscope.](image)

**SOLUTION**

**Step 1: Calculate the total magnification**

Use the same formula as above

overall magnification = power of eyepiece \( \times \) power of objective

\[ = 5 \times 10 \]

\[ = 50 \times \text{the original size} \]

**Step 2: Now calculate the size of the object**

If the image is 50 x larger than the object, what is the size of the object? Calculate this by simple proportion given in the formula below.

\[
\text{Size} = \frac{\text{size of image}}{\text{overall magnification}}
\]

\[ = \frac{20 \text{ mm}}{50} \]

\[ = 0.4 \text{ mm} \]
Worked example 3: Calculating actual size given of a structure given scale bar on an image

**QUESTION**

Calculate the actual length of AB from the image shown in the micrograph given with the scale bar given below.

**SOLUTION**

**Step 1: Measure the length AB shown in the diagram**

This should be approximately 20 mm

**Step 2: Work out the length AB**

Given that the measured length of the scale bar is approximately 5 mm, work out the length AB:

\[
\text{Size} = \frac{\text{length of AB on diagram}}{\text{measured length of scale bar}} \times \text{number on scale bar}
\]

\[
= \frac{20 \text{ mm}}{5 \text{ mm}} \times 500 \text{ nm}
\]

\[
= 2000 \text{ nm}
\]

\[
= 2 \mu \text{m}
\]
Activity: Investigation of cell size

Learners to be given photomicrographs to practice this exercise.

Activity: Drawing diagrams of scale

Learners to prepare slides to view under the microscope. Using the skills from the previous activity they are to do cell calculations.

4.3 Cell structure and function

This section introduces cell theory, the cell wall and the cell membrane.

Transport across membranes is also covered briefly. Learners will need to understand the movement of molecules by diffusion, osmosis and active transport.

Cells differ in size, shape and structure and therefore carry out specialised functions. Link this to tissues. The differences between plant and animal cells can be linked to Grade 9.

Group discussion:

1. In pairs, discuss the different organs in the human body and the way in which they function.
2. How do you think cells function?

TEACHER RESOURCES

Interactively explore the organelles of plant and animal cells in 3D

See simulation: 2CP5

An introduction to the cell, discussing various parts of the cell (21:03)

See video: 2CP6

NeoK12: Games on naming parts of plant and animal cells

See simulation: 2CP7

NeoK12: Videos on cells

See video: 2CP8
Learn the different parts of the cell by learning the cell song

- See video: 2CP9

Watch a video about the cell membrane.

- See video: 2CPB

A further description of the fluid mosaic model can be viewed at:

- See video: 2CPC

Watch diffusion taking place by clicking on the following link.

- See video: 2CPF

<table>
<thead>
<tr>
<th>Investigation: Observing diffusion</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Aim:</strong></td>
</tr>
<tr>
<td>To observe diffusion.</td>
</tr>
<tr>
<td><strong>Apparatus:</strong></td>
</tr>
<tr>
<td>- 1 x 500 ml beaker</td>
</tr>
<tr>
<td>- large funnel</td>
</tr>
<tr>
<td>- plastic straw</td>
</tr>
<tr>
<td>- potassium permanganate crystals</td>
</tr>
<tr>
<td><strong>Method:</strong></td>
</tr>
<tr>
<td>1. Fill a beaker with water and allow it to stand for a few minutes so that water movement stops.</td>
</tr>
<tr>
<td>2. Place a large funnel into the water so that it touches the bottom of the beaker. Drop a few small potassium permanganate crystals through the straw. Remove the funnel carefully and slowly.</td>
</tr>
<tr>
<td>3. Observe the size of the area that is coloured by the potassium permanganate at the beginning of the experiment, after 5 minutes and then after 20 minutes.</td>
</tr>
</tbody>
</table>
Questions:

1. What do you observe happening in the beaker?
2. What can you conclude based on your observations?
3. Explain how using hot water would affect the results of this experiment (remember that when you explain you need to give a reason for your answer).

Answers

1. The purple colour slowly spreads (diffuses) throughout the entire beaker of water, until the colour is evenly spread out.
2. The molecules of water and potassium permanganate must be constantly moving in order for the purple colour to diffuse throughout the water and spread out evenly.
3. Using hot water would speed up the spreading process/diffusion. The additional heat from the water gives the particles kinetic energy which enables them to move more quickly. The faster the particles move, the faster the colour spreads/diffuses throughout the beaker.

Watch osmosis taking place by clicking on the following link.

See video: 2CPG

Investigation: Predicting the direction of osmosis

Aim:

To predict the direction of osmosis.

Apparatus:

- 1 x 500 ml beaker
- 1 x large potato
- potato peeler/scalpel
- 2 x pins
- concentrated sucrose/sugar solution. To obtain this, add 100 g of sugar to 200 ml of water.
Method:

1. Peel off the skin of a large sized potato with a scalpel/potato peeler.
2. Cut its one end to make the base flat.
3. Make a hollow cavity in the potato almost to the bottom of the potato.
4. Add the concentrated sugar solution into the cavity of the potato, filling it about half way. Mark the level by inserting a pin at the level of the sugar solution (insert the pin at an angle into the cavity at the level) (Figure 4.3 A).
5. Carefully place the potato in the beaker containing water.
6. Observe what happens to the level of the sugar solution in the potato.
7. After 15 to 20 minutes, mark the level by inserting the second pin at the level of the sugar solution (insert as the first pin) (Figure 4.3 B).

Questions:

1. What do you observe happening to the level of the solution inside the potato?
2. What conclusion can you draw based on your observation?
3. What conditions were met in this experiment that makes this type of transport different to diffusion?
Answers

1. The level of the solution inside the potato increases.
2. Water moves out of the potato into the cavity in the middle. At the same time, water is drawn into the potato from the beaker. This means that the solution in the cavity is hypertonic and the water is hypotonic.
3. The semi-permeable membranes of the cells in the potato prevented the sugar molecules from moving. Only the water moves. In diffusion, all molecules are able to move. In osmosis, only water moves, and it moves across a semi-permeable membrane.

4.4 Cell organelles

This section deals with the ultra-structure of cells, including cell wall, cell membrane, nucleus, cytoplasm, and various organelles such as chloroplast, mitochondria, ER, vacuoles, Golgi bodies and centrosomes.

It is important to always relate structure and location of organelles to their function.

Powering the cell: mitochondria

See video: 2CPJ

This video shows the fascinating inner life of a cell:

See video: 2CPK

Investigation: Examining plant cells under the microscope

Aim:

To study the microscopic structures of plant cells.

Apparatus:

- onion
- blade
- slides and coverslips
- brushes
- compound microscope
• tissue paper
• forceps
• dropper
• iodine solution
• watchglass
• petri dish containing water

**Method:**

1. Peel off the outer most layer of an onion carefully, using a pair of forceps.
2. Place the peeled layer in a watchglass containing water. Make certain that the onion peel does not roll or fold.
3. Using a scalpel or a thin blade, cut a square piece of the onion peel (about 1 cm²).
4. Remove the thin transparent skin from the inside curve of a small piece of raw onion and place it on a drop of iodine solution on a clean slide.
5. Cover the peel with a coverslip ensuring that no bubbles are formed.
6. Using a piece of tissue paper wipe off any excess iodine solution remaining on the slide.
7. Observe the onion skin under low power of the microscope and then under high power.
8. Draw a neat diagram of 5-10 cells of the typical cells you can see.

![Figure 4.4: Onion cells stained with methylene blue.](image)

**Activity: Preparation of a wet mount**

Before the learners do this practical it may be necessary to recap the parts and functions of the microscope and the preparation of a wet mount.
**Instructions**

1. It is necessary to stain the onion to clearly show the parts of the onion under the microscope.
2. Learners will see a number of closely arranged, brick shaped cells.
3. Learners to draw 5-10 cells.
4. Learners should draw label lines to indicate the cell wall, cytoplasm, nucleus and vacuole.
5. The cells have a regular shape and each cell has a cell wall.

**Note:** As an extension activity learners can also do wet mount preparations of cheek cells. Methylene Blue can be used to stain the cheek cells.

**Investigation: Examining animal cells under the microscope**

**Aim:**
To study the microscopic structures of human cheek cells under a compound microscope.

**Apparatus:**
- clean ear bud
- clean slide
- methylene blue
- dropper
- water
- tissue paper
- forceps
- microscope

**Method:**
1. Place a drop of water on a clean glass slide.
2. Using a clean ear bud, wipe the inside of your cheek. The ear bud will collect a moist film.
3. Spread the moist film on a drop of water on a clean glass slide, creating a small smear on the slide.
4. Use a coverslip to cover the slide gently.
5. Place one or two drops of stain on the side of the cover slip.
6. Use a piece of tissue to remove the excess dye.
7. Observe the cheek cells under low power magnification and then under high power magnification.
Questions:

1. What are the shapes of epidermal cells of the onion peel and the human cheek cells?
2. Why is iodine used to stain the onion peel?
3. What is the difference between the arrangement of cells in onion cells and in human cheek cells?
4. Why is a cell considered the structural and functional unit of living things?

Figure 4.5: Cheek epithelial cells.

Answers

1. The onion cells have a regular shape – roughly rectangular. The cheek epidermal cells have an irregular shape.
2. The onion peel stores glucose as starch, and starch turns brown iodine solution purple. Using iodine solution as a stain because it will stain the starch purple, which makes the cells more easily visible.
3. In the onion, the cells are packed regularly, like bricks in a wall. The epidermal cells are packed irregularly – the packing depends on the shape of the cells in the region, which are irregular.
4. The cell is the smallest unit of life. It contains the DNA necessary to create an entire organism, and is the basic building block from which all tissues and organisms are made. Every cell performs the seven life processes, and so each cell individual cell is living.
Project: Cell organelles

You are required to compile a report on one of the organelles you have studied in class, or any other organelle you choose. Your report must include the following information:

- **Past**
  - The discovery of the organelle
  - All past understanding of the organelles structure and/or function that has now changed
  - The importance of the discovery of the organelle to cell science

- **Present**
  - The presently understood structure and function of the organelle
  - A 2-dimensional picture of the organelle showing all the relevant structures of the organelle
  - An electron-microscope picture of the organelle showing the structure of the organelle
  - An understanding of the importance of the organelle to human survival

- **Future**
  - What remains to be discovered or fully understood?
  - Any important role of the organelle could potentially play with the development of future technology (i.e. in industry or medicine).

- **Any other additional information or interesting facts you wish to include.**

### Presentation

- Learners are required to present results of their research in a booklet format.
- It must be neatly yet creatively set out.
- It should include a thorough and correctly structured bibliography.

Students should be marked according to the attached rubric.

<table>
<thead>
<tr>
<th>Assessing Knowledge</th>
<th>/5</th>
</tr>
</thead>
<tbody>
<tr>
<td>Discovery of the organelle identified</td>
<td></td>
</tr>
<tr>
<td>Story of the discovery of the organelle discussed and understood</td>
<td>/5</td>
</tr>
<tr>
<td>Future discoveries regarding the organelle discussed and understood</td>
<td>/5</td>
</tr>
</tbody>
</table>

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4.4. Cell organelles
Interpreting Knowledge

Information on the present structure and function of the organelle discussed and understood /5

2D picture of organelle provided and sufficiently detailed /5

3D picture of organelle provided and sufficiently detailed /5
Micrograph of organelle provided and sufficiently detailed /5

Additional information supplied /5

Understanding of content in everyday life

The importance of the discovery of the organelle to science provided and understood /5

The possible future role of the organelle provided, understood and relevant /5

Exploring science in the past

Past theories/understanding of the organelle that have changed discussed /5

Communicating information

Referencing technique correct /5
Presentation neat /5
Presentation creative /5
Total /70

Project: Diagrams of cells

Diagrams of the cell are very well understood but they often give us the wrong impression about how complicated cells really are. This assignment will help you understand the complexity of cells.

1. Learners are to find and submit a hard copy of 5 micrographs showing different cell organelles.

2. Of the five, learners must draw and label two so that they can demonstrate your drawing, labelling and interpretive skill.
FACT
Revise everything you have learnt about cells by watching this video. 
See video: 2CPM

Pay close attention to the following:

- The organelles should each comfortably occupy an A5 page.
- The organelles must each have a heading that includes the view, title and magnification.
- Drawings must follow the drawing skills you have learnt. One drawing must be the same size as the micrograph, the other must be exactly half the size.
- Your drawings must have a correct scale line.
- You must state the source of your micrographs according to the Harvard convention.
- Marks will be awarded for neatness: present your work as a uniform set.
- Select your hard copies well so they are of high quality and can be easily recognisable.
- Your images may be of the same organelle but only if the images show some significant variation.

**Project: Diagrams of cells**

Mark according to the following criteria:

1. Following instructions: size, quantity (5)
2. Images: choice, quality, headings, referenced (10)
3. Drawings: accuracy, realism, scale, labelling (10)
4. Effort: neatness, professionalism (5)

**4.5 Summary**

The discovery of cells:

- All living organisms are made of cells.
- Cells are very small therefore magnifying instruments such as lenses and microscopes are used to view them.
- By using a light microscope the simple features of cells can be studied. The light microscope uses a beam of light focused by various glass lenses.
- Electron microscopes have higher power of magnification than the ordinary light microscope, therefore allowing us to see very small structures inside the cells. These microscopes use a beam of electrons focused by electromagnets to magnify objects instead of light rays and lenses.
- Robert Hooke (1665) used a light microscope to examine non-living cork cells.
Antonie van Leeuwenhoek was the first person to observe living cells using a microscope.

The development of cell theory was from the study of microscopic cells.

Cell structure and function

- All cells have the same basic structure. They are all surrounded by a cell membrane and contain cytoplasm and organelles.
- Cells have different sizes, shapes and structures in order to carry out specialised functions.
- The cell membrane is made of phospholipids and proteins and controls substances which move in and out of the cell.
- The structure of the cell membrane is referred to as the Fluid Mosaic Model.
- The nucleus is made up of a nuclear membrane with nucleopores, chromatin material and the nucleolus inside the nucleoplasm.
- Mitochondria release chemical potential energy (ATP) for the cell during cellular respiration.
- Ribosomes are important for protein production.
- Cytoplasm is used for storage and circulation of various materials.
- Endoplasmic reticulum transports substances from one part of the cell to another.
- The Golgi body modifies, secretes, packages and distributes various organic molecules (proteins and lipids) around the cell.
- Vacuoles are used for storage. In plant cells these are large, whilst in animal cells, if present, are very small.
- Lysosomes are mainly found in animal cells.
- Centrioles are only found in animal cells.
- The cell wall is found only in plant cells and is made up of cellulose. The cell wall gives the plants shape, support and protection.
- Plastids are found only in plant cells. There are three types of plastids:
  - chloroplasts contain chlorophyll and their function is the production of food by photosynthesis
  - chromoplasts give colour to fruits and flowers
  - leucoplasts are white and are used mainly for starch storage
Exercise 4 – 1:

1. Examine the three images below. Use calculations to explain which organism would be the smallest when viewed with the naked eye. Show all the calculations you used to arrive at your answer.

   ![Images A, B, C]

   **Solution:**
   
   \[ A = \frac{4}{40} = 0.1 \text{ mm} \]
   \[ B = \frac{1.6}{100} = 0.016 \text{ mm} \]
   \[ C = \frac{0.4}{400} = 0.001 \text{ mm} \]

   So item C would be the smallest.

2. Below is a three-dimensional diagram of the cell. Provide the name and function of the following numbered structures:

   ![Diagram of a cell with labeled structures]
The following difficult-to-distinguish structures have been done for you:

- **4-vesicle**: spherical sacs that facilitate storage, metabolism and transport of molecules.
- **7-cell membrane**: selectively permeable to control the passage of substances into and out of the cell.
- **10-vacuole**: storage of sugars, minerals and pigments and help maintain water balance in the cell.
- **12-lysosome**: contain powerful digestive enzymes that digest damaged cell structures and food molecules.

**Solution:**

- **1-Nucleolus**: site of the transcription of RNA.
- **2-Nucleus**: controls metabolism of the cell and contains hereditary information.
- **3-Ribosome**: site of protein synthesis.
- **5-Rough endoplasmic reticulum**: many ribosomes therefore allowing for the production of many proteins.
- **6-Golgi body**: modify and package proteins and send them where they are needed in the cell.
- **8-Smooth endoplasmic reticulum**: the synthesis of lipids and the detoxification of drugs.
- **9-Mitochondrion**: the site of cellular respiration where energy is released from glucose molecules.
- **11-Cytoplasm**: jelly-like substance that contains all the organelles and which contains dissolved nutrients.
- **12-Centriole**: special structures that help cells to divide during mitosis.

3. Multiple answers are provided for each question. Write only the letter of the correct answer next to the corresponding number.

   a) Active transport is the movement of a substance from a:
      
      i. high concentration to a low concentration.
      ii. high water potential to a low water potential.
      iii. isotonic solution.
      iv. low concentration to a high concentration.

   **Solution:**
   
   iv

   b) Protoplasm consists of:

      i. nucleoplasm and nucleolus.
      ii. cytoplasm and nucleoplasm.
      iii. cytoplasm and organelles.
      iv. membranes and organelles.

   **Solution:**
   
   ii
c) This organelle is responsible for transporting substances around the cell:
   i. Ribosome
   ii. Golgi body
   iii. Nucleus
   iv. Endoplasmic reticulum

**Solution:**
   iv

d) The nucleus does **not** control:
   i. Hereditary transmission
   ii. Cellular respiration
   iii. Metabolism
   iv. Structure

**Solution:**
   ii

e) The energy that a molecule possesses while moving:
   i. Potential energy
   ii. Kinetic energy
   iii. Magnetic energy
   iv. Mechanical energy

**Solution:**
   ii

f) Which of the following is **not** a product of cellular respiration?
   i. CO₂
   ii. H₂O
   iii. O₂
   iv. ATP

**Solution:**
   iii

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

   a) Part of the cell that consists of about 90% water.

      **Solution:**
      cytoplasm

   b) Often referred to as the powerhouse of the cell.

      **Solution:**
      mitochondrion

   c) Pigment found in green plants.

      **Solution:**
      chlorophyll
d) The part of a plant cell that is composed of cellulose.

Solution:

Cell wall

e) The fluid inside the vacuole.

Solution:

Cell sap

f) The movement of a substance against a concentration gradient.

Solution:

Active transport

g) The structure that distributes substances made in the cell.

Solution:

Golgi body

5. Choose the correct option for each of the following questions. Write only the term next to the relevant question number.

a) What structure contains DNA and regulates most of the processes within the cell?
   i. Mitochondria
   ii. Chloroplast
   iii. Nucleus
   iv. Nucleolus

   Solution:
   iii

b) What is a cell membrane?
   i. Thin flexible barrier around the cell that regulates transport
   ii. Rigid cover that provides support for the cell
   iii. The place where light energy, water and carbon dioxide are used
   iv. Special organelle that converts solar energy to chemical energy

   Solution:
   i

c) Which two organelles contain their own DNA genome, separate from the nuclear genome?
   i. Lysosomes and transport vesicles
   ii. Endoplasmic reticulum and Golgi apparatus
   iii. Cilia and flagella
   iv. Mitochondria and chloroplast
   v. Ribosomes and vacuoles

   Solution:
   iv

6. Tabulate four differences between animal and plant cells.

Solution:
Any four of the following:

<table>
<thead>
<tr>
<th>Animal Cells</th>
<th>Plant Cells</th>
</tr>
</thead>
<tbody>
<tr>
<td>Do not contain plastids.</td>
<td>Almost all plant cells contain plastids such as chloroplasts, chromoplasts, and leucoplasts.</td>
</tr>
<tr>
<td>No cell wall.</td>
<td>Have a rigid cellulose cell wall in addition to the cell membrane. Do not contain centrioles.</td>
</tr>
<tr>
<td>Contain centrioles.</td>
<td>Contain plasmodesmata and pits.</td>
</tr>
<tr>
<td>Animals do not have plasmodesmata or pits.</td>
<td>Large central vacuole filled with cell sap in mature cells.</td>
</tr>
<tr>
<td>Few vacuoles (if any).</td>
<td></td>
</tr>
<tr>
<td>Nucleus is generally found at the centre of the cytoplasm.</td>
<td>Nucleus is found near the edge of the cell.</td>
</tr>
<tr>
<td>No intercellular spaces found between the cells.</td>
<td>Large intercellular air spaces found between some cells.</td>
</tr>
</tbody>
</table>

7. a) Name a structural adaptation of the mitochondria that makes it suited to its function:

   **Solution:**
   Mitochondria have many cristae (folds) that increase the surface area for reactions.

b) Name one structural adaptation of chloroplasts.

   **Solution:**
   Chloroplasts have many thylakoid discs, which contain chlorophyll, thus maximising the surface area for the absorption of light energy.
CHAPTER

Cell division

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5.2 The cell cycle 105
5.3 The role of mitosis 105
5.4 Cancer 105
5.5 Summary 111
5.6 End of chapter exercises 112
5 Cell division

5.1 Overview

Time Allocation: 2 weeks (8 hours)

This chapter consists of the following sections:

1. Overview
2. The cell cycle
3. The role of mitosis
4. Cancer
5. Summary
6. End of chapter exercises

Introduction

In this section we discuss how and why cells make copies of themselves, as well as what can go wrong when cell division is uncontrolled. Learners will be introduced to the mechanism by which cells replicate themselves through the process of cell division called mitosis. Mitosis is absolutely vital to the survival of all organisms, as without it unicellular organisms would not be able to reproduce and multicellular organisms would not be able to grow or heal after damage. However, uncontrolled mitosis can result in cancer, a potentially fatal condition. In this chapter we will review the stages of mitosis in plants and animal cells. We will then discuss how cancer is caused and some treatments that are available.

Key concepts

- The cell cycle is divided into two main stages: interphase and the mitotic phase.
- During interphase cells grow in size and replicate their DNA.
- Chromosomes are present in the nuclei of all cells and consist of two chromatids joined by a centromere.
- Mitosis is the process by which cells distribute their replicated DNA to two daughter cells.
- The mitotic phase consists of five stages: prophase, metaphase, anaphase, telophase and cytokinesis.
- Mitosis is the means of reproduction in unicellular organisms that undergo asexual reproduction.
Mitosis is required for growth and repair in multicellular organisms.
Cancer is a disease of uncontrolled mitosis.
Cancer is caused by carcinogens and is treated through surgery, radiation and chemotherapy.

5.2 The cell cycle

This section introduces the learner to the life cycle of a cell. Teachers should emphasise that mitosis and the cell cycle are not the same thing! Mitosis is simply one stage of the cell cycle. The process of mitosis (cell division) is explained. Learners need to know the names of the phases and they need to be able to draw simple descriptive diagrams showing the chromosome changes. A description of the differences in telophase between plant and animal cells is also required (plant cells lack centrioles). The difference between cytokinesis in animal and plant cells should also be addressed: plant cells invaginate and “pinch off” and plant cells grow a cell plate, which becomes the new cell wall.

5.3 The role of mitosis

Discuss the role of mitosis in growth, repair and reproduction in some simple organisms. Learners should be aware that there are two kinds of cell division, mitosis and meiosis, but only need to know mitosis in Grade 10. It is important that to remind learners that mitosis is the “copying” division, where the two daughter cells are exact copies of the mother cell. However, in meiosis, it is a reduction division where the daughter cells have half the number of chromosomes than the mother cell. No further detail is required.

5.4 Cancer

Cancers are caused by uncontrolled cell division and growth. Initially learners will need to be told what cancer is, and how cancer cells differ from normal cells. They will also need to understand how a tumour can be benign or malignant. The key characteristic of a malignant tumour is the ability to metastasise to other organs via the bloodstream or lymph.

A brief discussion of the causes of cancers with learners is necessary. Teachers should emphasise that learners can control some of the behaviours that cause cancer. Finally teachers should address the beliefs and attitudes of various communities and groups about cancer. This is an excellent opportunity to hold a class discussion, and we encourage teachers to invite questions and stories from learners and not to focus on only some of the common misconceptions outlined in this book.
The various treatments of cancer including traditional, other non-conventional treatments also need to be discussed. The advancement of medical biotechnology e.g. radiotherapy, chemotherapy needs to be introduced to the learners, but no detail is required.

**Websites to visit**


Watch some videos to learn more about how normal cells turn cancerous.

Very simply explained visual depiction of cancer.

See video: [2CQG](http://www.khanacademy.org)

Animation - Overview of cancer.

See video: [2CQH](http://www.khanacademy.org)

Cancer: An introduction to what cancer is and how it is the by-product of broken DNA replication.

See video: [2CQJ](http://www.khanacademy.org)

Cancer: An introduction to what cancer is and how it is the by-product of broken DNA replication (pt 2).

See video: [2CQK](http://www.khanacademy.org)
Activity: Cancer and smoking

Aim:
Investigating the relationship of smoking and cancer.

Instructions:
Look at the graph and answer the questions that follow:

Questions:

1. In what year was the first incidence of lung cancer seen in male smokers?
2. How many years was this after the introduction of cigarettes?
3. In which year did the average number of cigarettes smoked per year reach a peak?
4. Approximate how many years it takes most male smokers to develop cancer? Clue: Compare the number of years seen between the two line graphs for 1000, 2000, 3000 and 4000 cigarettes per year. Add the years together and divide by 4 to get the average time (in years) taken for smokers to develop cancer.
5. What can you say about the shape of the two graphs? Do they look similar or different? What does this mean?
6. What was the death rate from lung cancer in 1950? Express your answer as a percentage and show your working.
7. Suggest a reason why the number of cigarettes smoked shows a decrease after 1945.
**Answers**

1. Approximately 1918-1919 (1)

2. Approximately 18 years - 19 years (1)

3. Around 1945 (accept one year either way) (1)

4. The average is about 20 years. (4)

5. They are very similar in shape (where the smoking graph shows an increase in the average number of cigarettes smoked per year, the incidence of lung cancer increased), but are approximately 20 years apart. The fact that the two lines converge (get closer together) near the top, indicates that the more cigarettes one smokes, the less time it takes for lung cancer to develop. (3)

6. 125 deaths per 100 000 people = \( \frac{125}{100 000} \times 100 = 0.125 \)

7. Fewer people were smoking after the Second World War – it became widely known that smoking damages one’s health, so they stopped / gave up. The ones who were still smoking may also have decided to cut down / reduce the number they smoke. (2)

**Activity: Research on cancer**

**Aim**

To research and present information on one of the human cancers

**Resources required:**

1. Science journals such as "New Scientist", "Scientific American" and any other journals you can find.

2. Use the Internet widely, including the websites below:
   - Howard Hughes Medical Institute: contains links for educators and learners on a variety of approaches to determining causes and potential cures for cancer: [http://www.hhmi.org/](http://www.hhmi.org/)
   - Whitehead Institute for cancer research. This is one of the world’s leading cancer research labs where you can find interactive videos, links to other resources and information about a variety of cancers: [http://wi.mit.edu/](http://wi.mit.edu/)
Instructions

Using the resources available, you are required to research ONE of the cancers affecting humans. In particular you are required to:

- Write a report under the following main headings:
  - Discuss the major causes of the cancer: discuss cancer with respect to its genetic and/or environmental causes and how the cancer spreads within a particular individual.
  - Describe the common beliefs and attitudes concerning the particular cancer you have chosen to research: present the popular (common) attitudes people have about cancer, its treatment and how cancer is caused in the first place.
  - Describe the major forms of treatment available: what are the major treatments available. Provide an analysis of these under the sub-headings "Modern biotechnological methods" and "Traditional methods".
  - Describe the prevalence of the cancer type: prevalence refers to how common a cancer is in a particular location. Provide statistics in the form of histograms and pie charts of how prevalent the cancer is in different age groups, races and genders.

- At the end of your report, provide a complete list of references of websites, articles and other sources of information used in compiling the report.

- Include any pictures, diagrams and information that you think may be relevant to your report.

Research on Cancer

This can be an extremely complex research task, or one that is relatively easily managed, depending on how the teacher approaches the task. It is recommended that the following guidelines be used:

1. All staff members who teach classes in Grade 10 should get together and decide on how detailed they want the research tasks to be. All learners in the grade should get the same guidelines.

2. Decide on what the maximum mark will be and how much this task will contribute towards the term mark of learners. The guideline rubric for marking has a maximum of 25.

3. It is suggested that teachers do not require HUGE amounts of detail, since learners are in Grade 10 and the aim should be to have them expand their knowledge while also having fun with the subject matter. This should not take up all their free time for the term.

4. THE FOLLOWING BROAD GUIDELINES MAY BE USED IF TEACHERS PREFER
a) **Major causes:** Describe two to four causes. It is recommended that learners list these in order of importance. Each cause should be approximately one short paragraph of about 4 lines. More marks will be allocated to four, rather than two causes.

b) **Common beliefs / attitudes:** Find and briefly describe three commonly held beliefs about the causes, treatment, progression and origins of cancer. These do not have to be accurate, but they do have to be substantiated. Learners are required to indicate sources for where these beliefs / attitudes were found. It is also expected that learners indicate whether these are in fact accurate or incorrect.

c) **Treatment:** Briefly describe two forms of treatment for the specific type of cancer that was researched. It is not expected that learners name specific drugs or give dosages of radiation or drugs.

d) **Prevalence:** Sources must be acknowledged when quoting statistics. Teachers are to check that learners give stats for the SPECIFIC type of cancer they researched, not for cancers in general. Teachers should guard against plagiarism in copying pie charts and other graphs directly off the Internet – learners should be asked to give their sources if doing so is deemed acceptable by the staff, or they may be required to hand in only HAND DRAWN graphs and other charts. It is suggested that learners be told SPECIFICALLY what graphs to hand in, e.g. you MUST have at least one graph to support your research, but you may not submit more than three.

5. Teachers should draw up a rubric for marking the research task. The following table provided below is merely a suggestion – it may be used or altered as the staff at the school feel. They just need to print one rubric per task and put ticks in the relevant blocks:

<table>
<thead>
<tr>
<th>Section</th>
<th>5 Excellent. Clear, detailed, neat</th>
<th>4 Good. Well-researched, less detail</th>
<th>3 Average. Tried, but made errors</th>
<th>2 Not so good. Some gaps in knowledge</th>
<th>1 Very weak. Very few facts</th>
<th>0 Not done / no proof given</th>
</tr>
</thead>
<tbody>
<tr>
<td>Causes</td>
<td></td>
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<td>Beliefs</td>
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<td>Treatment</td>
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<td>Prevalence</td>
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<tr>
<td>Pictures/Graphs</td>
<td></td>
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<tr>
<td>Total</td>
<td></td>
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</tr>
</tbody>
</table>

Table 5.1: Marking rubric for Cancer Research Project
5.5 Summary

**Mitosis and the cell cycle**

- During interphase the DNA replicates.
- The process of mitosis occurs in four stages: prophase, metaphase; anaphase and telophase.
- Cytokinesis differs in plant and animal cells. In animal cells the cytoplasm invaginates and divides the cell in two, and in a plant cell the cell is divided in two by the cell plate which forms the cell wall.
- Mitosis ensures growth of tissues and organisms.
- Damaged and worn out tissues are repaired and replaced by new cells through mitosis.
- Single-celled (unicellular) organisms like amoeba often reproduce asexually by mitosis.

**Cancer**

- Cancer is caused by DNA mutations.
- Abnormal and uncontrolled cell division results in tumour formation.
- Tumours affect the functioning of the tissue or organ.
- Cancer cells can enter the bloodstream or lymph and spread to distant parts of the body and form new tumours (metastasise).
- Cancers are caused by substances called carcinogens.
- Carcinogens such as certain chemicals, radiation, viruses and genetics can be the cause of certain cancers.
- Cancers can be treated by various methods including surgery, radiation, chemotherapy and traditional medicines.
Exercise 5 – 1:

1. Multiple answers are provided for each of the questions below. You are required to choose the most appropriate answer for each question. Write down the number only.

   a) During which stage does DNA replication occur?
      i. prophase
      ii. anaphase
      iii. metaphase
      iv. none of the above

      Solution: iv

   b) Which of the following statements is correct?
      i. The chromosomes shorten and thicken during prophase.
      ii. The nucleolus reappears following telophase.
      iii. Interphase is characterised by little cellular activity, as the cell is resting to prepare for the next mitotic event.
      iv. All of the above.

      Solution: i

   c) Which of the following is not true?
      i. Only plant cells grow a cell plate.
      ii. Animal and plant cells both contain centrioles.
      iii. Metaphase is when the chromosomes line up on the equator of the cell.
      iv. All of the above.

      Solution: ii

   d) There are two copies of DNA in the cell during:
      i. G\textsubscript{1} phase
      ii. telophase
      iii. G\textsubscript{2} phase
      iv. all of the above

      Solution: iii
2. Study the onion root-tip slides below and identify the stage of mitosis (most stages are represented more than once).

<table>
<thead>
<tr>
<th>i</th>
<th>ii</th>
<th>iii</th>
</tr>
</thead>
<tbody>
<tr>
<td>iv</td>
<td>v</td>
<td>vi</td>
</tr>
</tbody>
</table>

**Solution:**

a) i) prophase  
b) ii) anaphase  
c) iii) metaphase  
d) iv) interphase  
e) v) anaphase  
f) vi) metaphase

3. What is the difference between a benign and a malignant tumour?

**Solution:**

A malignant tumour has the ability to invade and spread to other parts of the body (metastasise), while a benign tumour cannot spread.

4. Name five preventative measures or behaviours that will decrease your chances of developing cancer.

**Solution:**

a) Avoid smoking.  
b) Do not consume excessive alcohol.  
c) Eat a healthy diet.  
d) Partake in regular physical activity.  
e) Protect yourself from the sun.  
f) Attend regular preventative screenings at your doctor.
5. Cancer in South Africa. Look at the following table showing the percentage of deaths by cancer type in South Africa in 2000.

<table>
<thead>
<tr>
<th>Cause of death</th>
<th>Percentage in all people</th>
<th>Percentage in men</th>
<th>Percentage in women</th>
</tr>
</thead>
<tbody>
<tr>
<td>Tracheal/ Bronchial/ Lung cancer</td>
<td>16.5</td>
<td>21.9</td>
<td>10.9</td>
</tr>
<tr>
<td>Oesophageal cancer</td>
<td>13.4</td>
<td>16.7</td>
<td>9.9</td>
</tr>
<tr>
<td>Cervical cancer</td>
<td>8.4</td>
<td>0</td>
<td>17.2</td>
</tr>
<tr>
<td>Breast cancer</td>
<td>7.7</td>
<td>0.2</td>
<td>15.6</td>
</tr>
<tr>
<td>Liver cancer</td>
<td>6.4</td>
<td>7.8</td>
<td>4.9</td>
</tr>
<tr>
<td>Colorectal Cancer</td>
<td>6.2</td>
<td>5.4</td>
<td>6.9</td>
</tr>
<tr>
<td>Prostate cancer</td>
<td>6.1</td>
<td>11.8</td>
<td>0</td>
</tr>
<tr>
<td>Stomach cancer</td>
<td>5.6</td>
<td>6.5</td>
<td>4.7</td>
</tr>
<tr>
<td>Pancreatic cancer</td>
<td>3.7</td>
<td>3.7</td>
<td>3.7</td>
</tr>
<tr>
<td>Leukaemia</td>
<td>3.5</td>
<td>3.8</td>
<td>3.2</td>
</tr>
</tbody>
</table>

a) What medical procedures should women take to detect breast cancer early?

**Solution:**
Mammograms, self-examination for lumps, x-rays and ultrasound scans.

b) Draw a bar graph to show the percentage deaths for each type of cancer for men and women.

**Solution:**
Learner-dependent answer. Must show males and females next to each other for each type of cancer, with a space between each cancer type. Graph must have a heading, axis should be labelled correctly: x-axis= cancer type, y-axis= percentage. There should be a key which identifies which bar represents males and which bar represents females.

c) Which type of cancer is the most common in:
   i. men
   ii. women

**Solution:**
   i. tracheal/ bronchial/ lung cancer
   ii. cervical cancer

Check answers online with the exercise code below or click on ‘show me the answer’.
1a. 2CQP 1b. 2CQQ 1c. 2CQR 1d. 2CQS 2. 2CQT 3. 2CQV 4. 2CQW 5a. 2CQX 5b. 2CQY 5c. 2CQZ

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Plant and animal tissues

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6 Plant and animal tissues

6.1 Overview

Time Allocation: 3.5 weeks (14 hours)

This chapter consists of the following sections:

1. Overview
2. Tissues
3. Plant tissues
4. Animal tissues
5. Applications of indigenous knowledge and biotechnology
6. The leaf as an organ
7. Summary
8. End of chapter exercises

Introduction


This section introduces the concept of tissues to learners, building upon their previous knowledge of cells. Learners need to be able to recognise a range of key tissue-types found in plants and animals. The structure, location and function of each of the tissues will be described, and learners need to understand how structure and function are related.

This unit lends itself to microscope work. There are many opportunities for learners to view the various plant and tissues under the microscope either by using already prepared slides or making their own slides (for plant tissue).

The relationship between structure and function is important to understanding this chapter and is important to the study of Life Sciences in general. This chapter requires you to build on the concepts you understood in the section on cell structure.
Key concepts

- Tissues are group of similar cells that are structurally adapted to perform a particular function.
- Cells are adapted for specific functions through a process of cell differentiation.
- Examples of plant tissues include: xylem, phloem, parenchyma, collenchyma, sclerenchyma, epidermis and meristematic tissue.
- Examples of animal tissues are: epithelial tissue, connective tissue, muscle tissue and nerve tissue.
- Various plant tissues are important ingredients in traditional medicine.
- Biotechnology is a modern science that involves manipulating the properties of tissues and cells.
- Many tissues group together to form an organ, which has a very specific role in an organism.
- The leaf is an example of a plant organ that is made up of a number of tissues that collectively enable the process of photosynthesis.

Previous chapters have discussed the molecular and cellular levels of organisation of living organisms. In this chapter we will examine how similar cells associate together to form tissues.

atom → molecule → cell → tissue → organ → system → organism → ecosystem

6.2 Tissues

What is a tissue?

Learners are introduced to the concept of a tissue as a group of similar cells adapted for a particular function. Encourage learners to try and list or identify some tissue types. Throughout the chapter, emphasise the relationship between basic structure of the tissue and its function.

Tissues simulation:

See simulation: 2CR2
Plant tissue is divided into four different types:

- **Meristematic tissue** which is responsible for the making of new cells by mitosis.
- **Epidermal tissue** which is the outer layer of cells that cover and protect the plant.
- **Ground tissue** which has air spaces, and manufactures and stores nutrients.
- **Conducting tissue** which is responsible for the transport of water and nutrients throughout the plant.

**Key Outcomes:**

- Be able to identify the four different groups of plant tissue
- Understand the structure and function of the different plant tissues and the importance of their location within the plant.
- Be able to draw and label plant tissues.
- Be able to prepare slides of the various plant tissues.
- Understand the importance of meristematic tissue in biotechnology and in our indigenous knowledge systems.

Learners need to be able to examine and identify some plant tissues using microscopes, bio viewers, photomicrographs and posters. Learners need to be able to draw the cells that make up the various plant tissues, showing the specialised structures.

**TEACHER RESOURCES:**

Types of plant tissues: http://users.rcn.com/jkimball.ma.ultranet/BiologyPages/P/PlantTissues.html

Plant tissues picture: http://www.britannica.com/EBchecked/media/388/Cell-types-and-tissues

Learn more about plant tissues:

- See video: 2CR3
Activity: Practical investigation of leaf epidermis

Aim:

To observe epidermal cells and stomata.

Materials:

- leaves of *Agapanthus*, Wandering Jew (*Tradescantia*) or similar plants that have epidermis that strips off easily
- microscopes
- microscope slides and cover slips
- dissecting needles
- scissors

Instructions:

1. Rip a piece of leaf lengthwise and check for ‘thinner bits’ near the edges, which will be epidermal tissue. (Ensure that you have lower epidermis because this is where the guard cells are found).
2. Use the scissors to cut off a small section of epidermis and mount it in water on a microscope slide. Cover with a cover slip.
3. Focus the slide on low power and search for a section of the sample that does not have air bubbles over the stomata.
4. Enlarge the part of the specimen you chose and focus on high power.
5. Adjust lighting if necessary and draw one stoma and its guard cells. Label all parts.

NOTES TO TEACHERS

- Learners to use microscope and slide preparation skills.
- *Tradescantia*, a common SA plant with purple leaves, works particularly well for this practical since the epidermis rips off easily.
- Learners should be encouraged to rip the leaves quickly in order to get epidermal tissue.
- They must search the entire specimen on low power, in order to get the best part to magnify. There is little value in just enlarging the first part of the leaf they focus on – there will be many stomata that have air bubbles with thick black outlines over them. Learners must search carefully and enlarge the best stoma they can find.
- Learners must be encouraged to draw the guard cells as they see them, even if they are lying at an angle.
Figure 6.1: *Tradescantia*, a common SA plant with purple leaves.

Questions:

1. Describe the shape of the guard cells and normal epidermal cells.
2. Which epidermal cells have chloroplasts?
3. Describe the wall thickness around the guard cells and account for any visible differences.

Answers

1. Guard cells are bean shaped and normal epidermal cells are irregular, square-shaped or elongated (depending on leaf used.
2. Only the guard cells.
3. Guard cells have thick inner walls and thinner outer walls, as this helps them to open the pores for gaseous exchange.

Activity: Observing parenchyma cells.

Aim:

To observe the structure of fresh parenchyma cells.
Materials:

- banana
- petri dishes or watch glasses
- dissection needles
- iodine solution
- microscopes, microscope slides and cover slips

Instructions:

1. Use the dissecting needle to lift off a small piece of the soft banana tissue.
2. Put the sample onto a petri dish or watch glass and mash it slightly using the dissecting needle (and a pencil if you want).
3. Lift a small sample of the tissue onto a microscope slide on which you already have placed a drop of iodine solution. Put the cover slip on.
4. Observe the cells under low power and find a section where the cells are lying separate, not all over each other.
5. Enlarge this section and focus carefully to see if you can find nuclei in some of the cells (they will be bigger than the purple plastids and transparent).
6. Draw 2 or 3 cells and label.

Questions:

1. Describe the shape of the cells and their wall thickness.
2. What are the plastids called which appear purple and what is their function?

NOTES TO TEACHERS

- Learners to use microscope and slide preparation skills.
- The cells will be large and have very thin walls. Many cells have leukoplasts storing starch.
- Encourage learners to use the diaphragm on the microscope to prevent their cells being over-exposed to light – this can make the cells difficult to see.

Answers

1. Cells are rounded or oval and have very thin walls.
2. The plastids are leukoplasts and they store starch.
Learn more about permanent simple tissues.

See video: 2CR4

### Activity: Observing sclerenchyma in pears

**Aim:**

To observe sclerenchyma stone cells (sclereids) in pears.

**Materials:**

- soft, ripe pear
- microscopes, microscope slides and cover slips
- iodine solution
- dissecting needles or forceps

**Instructions:**

1. Use the forceps or needle to lift a small piece of soft pear tissue onto your microscope slide.
2. Add a drop of iodine solution.
3. Mash the tissue slightly to separate the cells.
4. Cover with a cover slip and observe under low power. You should focus on the groups of dark “stones” that appear amongst the rounded parenchyma cells of the pear. Try to find one or two stone cells or sclereids that are separate from the rest.
5. Enlarge a good specimen (or focus on the edge of a group where one cells sticks out) and adjust the lighting.
6. Look carefully while you focus up and down to see the long, narrow PITS running through the extremely thick walls of these cells.
7. These "stone cells" are called sclereids. They are a modified form of sclerenchyma found in pears, guavas and the shells of nuts for extra support.
8. Also observe the large round cells around the sclereids.

**Questions:**

1. Do you see cytoplasm inside the stone cells? Are they living or dead cells?
2. What tissue type do the large round cells around the sclereids belong to?
NOTES TO TEACHERS

1. Learners to use microscope and slide preparation skills.
2. Learners need a very small amount of pear tissue for this practical – the riper the pear, the better. This practical works best in pears that are actually over-ripe and extremely soft.
3. Once again, encourage learners to scan the entire slide for the best parts before enlarging. They need to find a very small group of sclereids (they will appear as “little groups of black stones” amongst the large, thin-walled parenchyma cells of the pear).
4. Learners must expect that it will be very difficult to focus them – the sclereids lie in a heap at slightly different levels, so it will not be possible to focus on all of them at the same time.
5. The cells and pits are best seen if one FOCUSES UP AND DOWN slightly on high magnification using the fine focus adjustment – warn them not to touch the coarse focus adjustment!
6. It will be necessary to adjust the diaphragm to prevent over-illumination of the material.

Answers

1. No, they are dead cells.
2. Parenchyma.

Activity: To investigate sclerenchyma fibres

Aim:
To see sclerenchyma fibres in tissue paper.

Materials:

- cheap toilet paper (single ply)
- iodine solution or water
- microscopes and slides

Instructions:

1. Tear a tiny piece of toilet paper off the sample and mount it in water or iodine solution.
2. Place on a cover slip and examine under the microscope on low power.
3. Focus on the torn edge of the paper and observe the long sclerenchyma fibres.
4. Observe on high power.
NOTES TO TEACHERS

1. It’s important that learners focus on the torn EDGE of the paper, not the centre.

Questions:

1. Describe the shape of these cells.
2. Are they living or dead cells?
3. Suggest their function.

Answers

1. Cells are very long and pointed.
2. Dead cells.
3. They provide strength and support and help transport water.

Activity: Observing the patterned secondary walls in the xylem of fresh plant tissue

Aim:
To observe the patterned secondary walls in the xylem of fresh plant tissue.

Materials:

• celery stalk, rhubarb stalks or pumpkin stems (macerated - chop them across and boil them in water for 3 minutes, then add an equal amount of glycerine. Cool before using. It can be stored for a few months in the refrigerator.)
• microscopes and slides
• dissecting needles
• petri dishes or watch glasses
• eosin solution
Instructions:

1. Lift a small piece of celery / any other tissue chosen from the dish and transfer it to a watch glass or petri dish.
2. Use the dissecting needle and a pencil to tease the tissue apart (separate the thread-like, thicker cells away from each other). Try to get the long cells away from each other, otherwise bundles will be too thick to allow you to see individual cells. Ignore the thin walled parenchyma cells around them.
3. Transfer the plant tissue to a microscope slide and add eosin solution. Separate a bit more if necessary.
4. Examine under low power, focusing on the bundles of xylem vessels. Look for long bundles of fairly wide cells with thickening in the form of rings or spirals. Do not confuse xylem vessels with the more common and much narrower sclerenchyma fibres - fibres have walls all the same thickness, have no spirals or rings and they are pointed at the end. If necessary, make a second slide if you did not find xylem.
5. Move a good part to the centre and enlarge. Examine the secondary walls of these cells.

NOTES TO TEACHERS

1. Learners to use microscope and slide preparation skills.
2. Learners must ensure that they transfer some of the “stringy tissue” that been prepared, not just the soft tissue (which is parenchyma).
3. They will need to spend a bit of time teasing the cells apart with dissecting needles; otherwise the cells are very clumped together and difficult to see properly. They need to separate the ‘stringy’ bits from the normal soft tissue and mount only the stingy stuff onto the microscope slide.
4. These cells can be successfully mounted in iodine solution if eosin is not available.
5. Remind learners to adjust the diaphragm and look specifically for spirals / rings in very long, tubular cells. There will be many long, pointed sclerenchyma cells with the xylem.
6. It is frustrating if no such cells can be found – it may be necessary to make a second slide and try again.

Questions:

1. Describe the shape of xylem vessels.
2. What secondary walls patterns do you see?
3. Suggest the function of such secondary walls.
Answers

1. Long, tubular cells with open ends.
2. Hopefully spirals and rings, maybe a reticulate/netted vessel as well.
3. To provide flexibility, support and allow the stem to stretch as it grows. They also resist the suction of transpiration pull and prevent the vessels collapsing during water transport.

6.4 Animal tissues

Animal cells with the same structure and function are grouped together to form tissues. There are four types of animal tissues: epithelial tissue, connective tissue, muscle tissue and nervous tissue.

Key Outcomes:

- Understand the differentiation of animal tissues and the relationship between structure and function of the various tissues.
- Know the location of the various tissues within the animal body.
- Learn the skill of drawing the various animal tissues.
- Be able to prepare slides of selected animal tissues.
- Know the importance of stem cell research in biotechnology and genetic engineering.

Learners need to be able to identify the four basic animal tissues and relate structure to function. Learners will be required to examine and identify some animal tissues using microscopes, bio viewers, micrographs or posters. They are required to be able to draw the various cells that make up these tissues in order to show their specialised structures.

TEACHER RESOURCES:


Watch a video about the different tissue types in animals

See video: 2CR5
In this section the following needs to be discussed with the learners to ensure an understanding of Life Science and the related technology.

- Traditional Technology which includes the role of traditional healers using herbal plants and traditions passed down to members in the community over generations.
- The advances in Medical Biotechnology and the importance of vaccines and antibiotics. Technology advance in blood transfusion to prevent complications during transfusions.
- The cloning of plant and animal tissues and stem cell research. The moral, ethical and legal issues around cloning needs to be discussed with learners.

TEACHER RESOURCES:

Takes students on a step-by-step process showing them how to genetically engineer a plant and bacterium


Australian government resource for educators and learners on various aspects of biotechnology.


All the latest articles on developments in biotechnology written in accessible language.

- [http://www.scientificamerican.com/biotechnology](http://www.scientificamerican.com/biotechnology)

Discusses latest issues in biotechnology and their political, economic and cultural implications.

- [http://seedmagazine.com/content/tag/biotechnology/](http://seedmagazine.com/content/tag/biotechnology/)
Learners are reminded of the fact that an organ is a collection of tissues that are joined together to perform a common function. A group of organs work together to form an organ system. Organs exist in all higher biological organisms, they are not restricted to animals, but can also be identified in plants. For example, the leaf is an organ in a plant, as is the root, stem, flowers and fruits. In this section the leaf is used as an example of an organ.

The leaf structure will be discussed using a cross-section of a dicotyledonous leaf. Structure needs to be related to functions, such as transport, gaseous exchange and photosynthesis. Link this section with the plant tissues already taught, the cell organelles and the movement of molecules across membranes into, through and out of the leaf.

Activity: Examining leaf structure under a microscope

Aim:
To identify different tissues found in plant leaf.

Questions:

Study the image shown and answer the questions given below.

1. Compare Figures A and B. Which of the numbered structures shown in B can you identify from Figure A?
2. Which of the numbered structures shown in B are absent in A?
3. The image given in Figure A is of a Spiderworts leaf. They grow in a part of Canada where the sun shines in the morning and it is cloudy in the afternoon. How would this affect the structure of the leaf?
afternoon. Describe what changes you would expect to see to the structures in the plant leaf during the day. How would these changes compare to a plant that grows during hot, sunny days and cold, dry nights?

6.7 Summary

- Cells which are similar in structure group together to form tissues performing a particular function. Tissues form organs which combine to allow organisms to exist.
- Plant and animal cells have structures related to their functions.
- Plant tissues are broadly divided into Dividing or Meristematic and Permanent tissues.
- Meristematic cells are small, have high amounts of cytoplasm and a large nucleus to assist in their role in cell division.
- Permanent tissues are further divided into simple permanent (which have only one type of cell) and complex permanent (which have different types of cell coming together to perform a particular function). The simple permanent tissues include (with their function in brackets): Epidermis (protection), Parenchyma (storage), Collenchyma (support) and Sclerenchyma tissues (strength and structural support). Complex tissues are made up of the xylem and phloem.
- Xylem tissue is important in the transport of water and mineral salts. Phloem tissue is structured to allow the transport of organic compounds required for the plant (typically in the form of sucrose). Together the parenchyma, collenchyma and sclerenchyma are referred to as ground tissue. The xylem and phloem make up the vascular tissue.
- Animal tissues are made up of epithelial, connective, muscle and nerve tissue.
- Epithelium is made up of flat squamous cells, cuboidal cells or columnar cells in single or multiple layers. Epithelial cells are involves in secretion of enzymes, protective substances such as mucus and they provide a supportive function.
- Muscle tissue is made up of cardiac muscle, skeletal muscle and smooth muscle. Cardiac and skeletal muscle are striated. Smooth muscle and cardiac muscle are involuntary muscles whereas skeletal muscle is under voluntary control.
- Connective tissues are composed of areolar and fibrous connective tissues, cartilage, bone and blood. They provide strength and support, reduce friction and act as shock absorbers.
- Blood is made up of red blood cells (transport oxygen), white blood cells (responsible for immune response) and platelets (important in blood clotting).
• Nerve tissue is responsible for receiving stimuli from the environment (sensory neurons), processing it (interneurons) and sending impulses to muscles or glands (motor neurons) so that we can respond to the stimuli.
• Traditional healers and traditional medicine is an application of indigenous knowledge of plant and animal tissues.
• Modern Biotechnology is focused on a variety of applications of technology.
• Vaccines and antibiotics enhance the body’s immunity. Vaccines rely on T-memory-cell derived immunity to fight subsequent infections.
• Immunity relies on the natural mechanisms (skin, mucus etc) as well as cellular mechanisms (T-cells and B-cells) fighting viral and bacterial infections.
• Blood transfusion is a way of replacing lost blood. It requires accurate blood type matching.
• Cloning of plant tissues requires either a piece of the plant tissue through vegetative propagation or chemical treatment to produce calluses in tissue culture propagation.
• Cloning of animal tissues occurs through the process of reproductive cloning. It can result in the replacement of a whole organism or, through therapeutic cloning the creation of stem cells.
• There are broad legal and ethical questions regarding cloning of organisms as well as the use of stem cells. These differ from country to country.

The leaf as an organ

• Plant leaf is an example of an organ, as it consists of a group of tissues that form part of a structural unit performing a common function.
• Plant leaves are adapted to absorb light in order for photosynthesis to occur as well as to manufacture sugars for transport to the rest of the plant.
• The major processes for which leaves are therefore adapted are photosynthesis, transpiration and gaseous exchange. Leaves transport oxygen, carbon dioxide, water and sucrose.
• Water is lost from the plant through transpiration out of stomata in the leaf. The movement of carbon dioxide and oxygen is through diffusion in and out of the leaf stomata.
• Sugar manufactured in the leaf is transported through the phloem vessel.
• Stomata open and close in response to a variety of environmental stimuli.
1. Answer the following questions based on the drawings below.

![Diagram with labeled parts 1, 2, 3, and 4.](image)

a) Provide labels for 1, 2, 3 and 4.

**Solution:**
- 1-chondroblasts
- 2-lacuna
- 3-chondrin
- 4-nucleus of squamous epithelium cell

b) Which tissue, A or B, is found in the rib cage?

**Solution:**
Tissue A

c) Which tissue, A or B, is found in the lining of blood vessels?

**Solution:**
Tissue B

2. Tissues come together to form a/an

a) organ
b) organ system
c) body system
d) organelle

**Solution:**

a

3. What kind of tissue can parenchyma tissue be described as being?

a) simple tissue
b) complex tissue
c) xylem
d) phloem

**Solution:**

a
4. Which of the following is not a simple tissue?
   a) xylem
   b) parenchyma
   c) collenchyma
   d) sclerenchyma

   **Solution:**
   a

5. What is the key difference between meristematic and permanent tissue?
   a) the ability to conduct photosynthesis
   b) the ability to divide
   c) the ability to move
   d) the complexity to perform a function

   **Solution:**
   b

6. Which type of tissue has lignified walls?
   a) Parenchyma
   b) Collenchyma
   c) Sclerenchyma
   d) Cambium

   **Solution:**
   c


   **Solution:**
   Multicellular organisms are made up of millions of cells. Specialised cells that perform a specific task group together to form tissues. Thus different tissues perform different functions.
   In humans, for example, muscle cells contract and relax to produce movement. Nerve cells are specialised to carry messages, blood flows to transport oxygen, food, hormones etc. In plants, vascular tissues conduct water from one part of the plant to the other. Thus multi-cellular organisms exhibit division of labour.

8. Why do plants have more dead tissues compared to animals?

   **Solution:**
   Plants need the hard, dead cells to remain upright – they don’t have skeletons, and each cell must support itself or receive direct support from tissues around it, in order for the plant to remain upright. Most plant tissues are dead, since dead cells can provide mechanical strength as easily as live ones and therefore need less maintenance. Also, plants are stationary and hence require less energy. Animals require energy for movement. Animals are supported by hard (often bony) skeletons and do not need dead cells to support them.
9. List the characteristics of meristematic tissues.

**Solution:**

They are actively dividing cells and divide throughout their life; cells are compactly arranged with no intercellular spaces; lack vacuoles; cells have dense cytoplasm and thin cell walls; have prominent nuclei.

10. Which tissues are responsible for secondary growth in plants?

**Solution:**

Vascular cambium and cork cambium (also called secondary meristems) are responsible for secondary growth. They increase the thickness (girth) of the plant body.

11. What are the key features which allow you to tell that a tissue type is collenchyma?

**Solution:**

Living cells that are elongated and generally contain chloroplasts; cell walls are irregularly thickened at corners due to deposition of cellulose or pectin; oval, circular or polygonal in shape; few intercellular spaces.

12. Thando was shown two slides of plant tissues: parenchyma and sclerenchyma. Which of the features given below would be crucial in identifying sclerenchyma and why?

a) location of nucleus  
b) size of cells  
c) thickness of cell walls  
d) position of vacuoles

**Solution:**

C, the thickness of the walls. The walls of the sclerenchyma are thickened due to lignin which thickens the walls. Sclerenchyma cells are dead and will not have vacuoles or nuclei.

13. Why do meristematic cells lack vacuoles?

**Solution:**

Vacuoles are responsible for storing food and certain types of waste product. Meristematic cells being young and actively dividing do not participate in food manufacture and in storage functions. They do not generate waste. Therefore they do not require vacuoles. Meristematic cells are always young cells that have not had time to form vacuoles. They divide constantly so the cells are ‘embryonic’ – vacuoles are characteristic of mature plant cells.

14. Considering the plant leaf as an organ, describe the main tissues that come together to form the organ. What is the role of each tissue type? Why are they all important in the functioning of the organ?

**Solution:**

- **Epidermis** forms the protective outer layer that has the waxy cuticle to prevent dehydration. It may form trichomes to reflect heat, repel herbivores and trap water vapour. The epidermis has stomata
mainly in the lower epidermis to allow gaseous exchange without the leaf getting dehydrated. The cells are transparent to allow sunlight through to the photosynthesising cells.

- **Palisade mesophyll** consists of vertically elongated cells that all receive individual sunlight. These cells also have many chloroplasts, as they are below the upper epidermis and receive most sunlight. All mesophyll cells have large vacuoles to support the leaf by turgor pressure.

- **Spongy mesophyll** consists of loosely packed chlorenchyma cells with fewer chloroplasts, but large intercellular spaces to allow diffusion of gases throughout the leaf. All mesophyll cells have thin, moist walls to allow faster diffusion of gases and water. The air chambers in these mesophyll cells link directly to the stomata.

- **Veins** contain xylem to bring water into the photosynthesising tissues, as well as phloem to remove the sugars like glucose. Veins are well supported by a bundle sheath of sclerenchyma or collenchyma.

Check answers online with the exercise code below or click on ‘show me the answer’.

1a. 2CRC 1b. 2CRD 1c. 2CRF 2. 2CRG 3. 2CRH 4. 2CRJ
5. 2CRK 6. 2CRM 7. 2CRN 8. 2CRP 9. 2CRQ 10. 2CRR
11. 2CRS 12. 2CRT 13. 2CRV 14. 2CRW

[www.everythingscience.co.za](m.everythingscience.co.za)
Support and transport systems in plants

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7.1 Overview

**Time Allocation:** 3 weeks (12 hours)

This chapter consists of the following sections:

1. Overview
2. Anatomy of dicotyledonous plants
3. Transpiration
4. Uptake of water and minerals in the roots
5. Summary
6. End of chapter Exercises

**Introduction**

The previous chapter discussed the structure of plant and animal tissue. This chapter focuses on the plant tissues that transport food and water around the plant. Learners have previously been taught that plant leaves use sunlight, carbon dioxide and water to make sugars (food) during photosynthesis. The next concept is understanding how the phloem and xylem tissue transport food and water within the plant. Which cells are responsible for moving food throughout the plant? How are the tissues adapted for their functions in transporting either water or food? What do these cells look like under the microscope?

Learners will further explore the relationship between structure and function by studying how different types of leaves are structurally adapted to minimise water loss. In addition, this chapter will explain how stomata are able to respond to environmental conditions in order to regulate the rate of water loss from the leaf during transpiration.

**Key concepts**

- The plant is made up of the root and stem where tissues with dividing (meristematic) cells are contained.
- Secondary growth of trees is measurable by observing the annual rings within tree trunks and can be used to infer climate change.
- Transpiration, the loss of water vapour from plant leaves, is influenced by factors such as temperature, light intensity, wind and humidity.
Wilting is a process that results from loss of water through transpiration and guttation is a process that results from high root pressure.

Water and minerals are taken up into the xylem tissue present in roots and transported to leaves in the plant.

Manufactured food (sugar) is translocated, via phloem tissue, from sites of manufacture (in the leaves) to other parts of the plant where sugars are used or stored.

The following website provides information on plant structure and support and may be used as a resource for this chapter:

http://www.emc.maricopa.edu/faculty/farabee/biobk/biobookplantanat.html

### 7.2 Anatomy of dicotyledonous plants

This section describes the structure of dicotyledonous roots and stems, followed by a description of the structure of the cells in the different tissues. Learners can use microscopes or photomicrographs to observe and draw cross sections of the root and stem. Slides can be made from celery or pumpkin stalks to view xylem tissue and secondary thickening patterns. This section can also be linked to mitotic cell division when describing the secondary growth. Link the annual rings in a tree trunk to environmental studies (climate change) which will be taught later. Annual rings are also used to assess the age of a tree.

<table>
<thead>
<tr>
<th>Investigation: Examining the structure of the root and stem</th>
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</table>

**Aim:**

To examine the structure of the root and stem.

**Apparatus:**

- light microscope
- scalpel or knife
- celery stalk (stem)
- carrot (root)
- glass slide
- iodine solution (Stain) or water
- cover slip
- dissecting needle or tweezers
- paper and pencil
• blotting paper or paper towel or tissue
• for variation you can also try using other vegetables

Method:
Prepare a temporary mount using the irrigation method:

1. Cut a very thin slice (cross section) from the middle of the celery stem and the carrot root. Although you will not be able to see microscopic details of the carrot tissue under a microscope, the differentiation by colour will be evident.
2. Place this section on a glass slide, in the centre.
3. Add a drop of iodine solution on top of the sample to stain it. This makes it more visible under the microscope. Water can be used if iodine is not available.
4. Place the coverslip next to the droplet, as shown in the diagram, then lower it slowly onto the glass slide. This will prevent bubbles forming under the coverslip. You can use a dissecting needle to lower the the coverslip into position. The drop will spread outward and suspend the sample between the slide and the coverslip.

5. Call your teacher.
6. Switch on the microscope making sure the lowest objective is in position (the 4x objective).
7. Place your slide on the stage.
8. Focus the image under the 4x objective (lowest objective) and view the structure of the celery stem. Switch to the 10x objective to look a little more closely. To see details of the structure of plant tissue, use the 40x objective. Carefully observe all of the parts and different tissues.
9. Once you are able to see specific tissue types, call your teacher.
10. Make a biological drawing of your specimen as viewed under the microscope. Take note of the magnification and draw a scale bar. Label your diagram according to the tissues you have learnt about.

7.2. Anatomy of dicotyledonous plants
NOTES FOR THE TEACHER:

It is essential that teachers use a very young carrot for this – the smaller / narrower the carrot, the greater the chance that learners will be able to cut a very thin section completely across it. If the carrot is thick, it may be better to attempt to cut a thin section from HALF the carrot, rather than make it so thick that light will not shine through it. Thick sections will not allow one to see any detail at all. It is essential to use a very sharp blade / knife.

The age or size of the celery does not matter. These stems are fairly easy to cut thin, but they should still be as thin as the learner can make them. Note in particular the very obvious vascular bundles (darker, thick-walled ‘dots’ in the stem).

Alternatively, this practical can be conducted using various vegetables. Educators can get learners to discuss various vegetable which have roots, stems and leaves.

This practical requires the use of Iodine, therefore it is important to establish if any learners are allergic to iodine. If the learners are not sure, any learner that is allergic to shell fish should not be allowed to do the experiment as they may have an allergic reaction to the iodine.

Learners will be preparing slides in this practical. This should not be a new skill for the learners, but it is still important to conduct a demonstration for the students before they do the practical.

It is recommended that the drop of water or iodine solution be placed onto the slide BEFORE the specimen. Learners should be encouraged to remember the phrase “Always Fluid First” – this prevents dehydration of the specimen.

Since these are large specimens, learners may not need the 40x objective. Their specimens are also likely to be a bit thick and little detail may be observable, but the colour difference between the root cortex and vascular tissue should be visible, as well as the obvious vascular bundles of the stem compared to the background parenchyma tissue.

It is not necessary to formally assess the drawings learners make. It is good practise for them to make drawings off materials they have prepared themselves, and provides practise in doing biological diagrams correctly. They should have a heading that includes the magnification and should include a scale bar.

The following link gives information about making a wet mount microscope slide and shows an instructional video:

Investigation: Observing annual tree rings to assess age and climatic conditions

Aim:

Background

Every year a tree forms a new layer of xylem around the trunk. This forms tree rings, which are visible as circles in a cross section of a tree that has been cut down. Each tree ring, or wood layer, consists of two colours of wood; light wood that grows in spring and summer and dark wood that grows in autumn and winter. Tree rings can be counted to give you a rough estimate of the age of a tree. Occasionally a tree will form many rings in one year or miss forming rings in a year. The width of the tree rings is greater in years where good growing conditions occur. In years with droughts or low temperatures, the trees will produce narrower rings. Therefore, by looking at the tree rings you can get an idea of the weather affecting a tree in a particular year. Scientists can use this information to help determine the weather patterns of the past as well as events such as forest fires, earthquakes, and volcanic eruptions. The study of past events using the growth rings of trees is known as dendrochronology (dendros = tree, chronos = time).

Method:

1. Examine a section of a tree trunk/stem provided by your teacher and count the tree rings, starting with the innermost ring. Measure the width of each ring using a ruler, or make a note of whether a ring is narrow or wide. Make a note of any scars caused by events such as fires or pests.
2. Draw a bar graph showing the width of your tree rings for every year of the tree’s life.
3. How old is this tree? What can you say about the climatic conditions throughout the life of this tree?

NOTES FOR THE TEACHER:

- In this investigation teachers are to source a tree trunk. It is recommended that teachers obtain a tree trunk with clear annual rings and then have it cut professionally / using an electric saw, so that several sections are obtained for use in the classroom. It may be interesting to find different species of trees or trees from different areas, so that the type of annual rings in different areas and species can be directly compared. However, if a tree trunk cannot be sourced, learners can be given a picture of a tree trunk showing the annual rings.
- Note that trees from eastern coastal areas may not form clear annual rings at all, since the climate is reasonably warm and wet all year, whereas trees from areas with very cold, dry winters like the Free State will have annual rings that are clearly visible.
It is important that the learners read the introductory paragraph as this will assist them in answering the questions.

The bar graph is merely a suggestion, not a requirement. Teachers can decide for themselves whether they have time for this.

The age and climatic history of the trees can be successfully done orally, if teachers prefer this. A class discussion can be very fruitful, without any written work being done.

An alternative means of assessment is to divide the class into groups and provide each group with a different sample.

### 7.3 Transpiration

This section explains how various environmental factors can change the rate of transpiration, and also examines how the structure of the leaves has adapted to minimise this water loss.

Learners will need to understand the factors that affect the transpiration rate such as temperature, light intensity, wind and humidity. Simple experiments can be conducted to demonstrate these factors.

**TEACHER RESOURCES:**

This interactive website explains transpiration pull.


Of particular use to learners is an interactive animation that lets them determine the effect of different environmental factors on transpiration rate.

**Investigation: Determining the effect of environmental conditions on transpiration rate using a potometer**

**Aim:**

To determine the effect of environmental conditions on transpiration rate using a simple potometer.

**Apparatus:**

- drinking straw or clear plastic tubing
- soft green leafy shoot
- Vaseline
Method:

A potometer measures the rate of transpiration by measuring the movement of water into a plant. The following experiment uses a simple hand made potometer. The class will be divided into four groups. Each group will investigate a different factor and then all the results can be shared at the end of the investigation.

Perform the following steps under water:

1. Cut the stem of the leafy shoot (at an angle to increase the surface area) **under water**. The reason we cut it under water is to prevent air bubbles entering the xylem vessel. You must use a very sharp knife or new scalpel and cut at an angle in order to increase surface area for water uptake in the xylem. Florists who cut plants before immersing them in water follow the same procedure for this reason.
2. Test to make sure the stem of the leafy twig will fit snugly into the top of the straw.
3. Remove the leafy shoot from the straw and set aside, keeping the stem submerged, and the leaves above water.
4. Fill the straw with water. Place your finger over one end of the straw to stop the water from running out.
5. Put the leafy shoot into the open end and seal it with play dough/putti/Prestick while removing it from water **keeping your finger on the straw**.

Perform the following steps above water:

6. Seal with Vaseline. Make sure it is air tight and water tight. If not, all the water will run out when you take your finger off the straw.
7. Mark the water level on the straw.
8. Place your potometer under one of the following conditions for one hour:
   a) as is, in a warm, sunny place (no wind)
   b) as is, in a warm, windy place
   c) with a plastic bag tied around the leaf, in a warm, sunny place
   d) a shady place.
9. Every 10 minutes use a marking pen to mark the change in water level on the straw. Continue taking measurements for 1 hour.
10. Measure the distance the water moves during each time interval.
The four groups should have leafy twigs of the same type of plant and about the same size, so that results in different environmental conditions can be reliably compared at the end. They should choose twigs with stems likely to fit tightly into a drinking straw and the stems should be strong enough not to be crushed when forced into the straws.

**ALTERNATIVE METHOD:**

Alternatively, if available, learners can use narrow clear plastic tubing filled with water that can be cut open / slit at one end to insert the twig. Plastic tubing is easier to seal with tape than drinking straws and it can be taped in place horizontally along a desk or table once an air bubble has been introduced at the open end. One learner will have to hold the plant off the desk. The tube is then placed into water and a ruler is taped in place next to it to track the movement of the bubble over time. They won’t be able to reset it, but that’s fine – take 3 or 4 measurements of how far the bubble moves in 2 minutes and get an average for each environmental condition. This is faster than doing it for an hour in each condition.

Learners can create the various environmental conditions in the laboratory.

- The conditions in the laboratory can serve as the “control” environment.
- Learners can use a fan to mimic ‘windy’ conditions.
- Learners can use an electric heater to mimic ‘hot’ conditions.
- Learners can place the apparatus under a bell jar or under a plastic bag to mimic ‘humid’ conditions.

**Precautionary Measures:**

- The stem must be cut under water as this will prevent air obstructions in the xylem tissue
- The system must be airtight (use Vaseline to ensure this)
- Use the same stem during the whole experiment to get the same readings
- If using a potometer, and the bubble gets too close to the plant, one can open the stopcock (tap), to allow extra water into the tube and push the bubble back to the start. This resets the potometer for further readings. Be careful not to push the bubble too far, otherwise it may escape completely and one has to wait with the tube out of the beaker, until a new air bubble has been sucked into the tube.
- It is important that learners WAIT TEN MINUTES after setting it up for the plant’s transpiration rate to stabilise before taking measurements.
Results:

Each of the four groups that investigated different environmental conditions should contribute their results for the final analysis.

1. Draw a table and record the class’ results.
2. Plot a bar graph to compare the total distances the water moved in the different straws in 1 hour under the four different environmental conditions.
3. At the end of the experiments, all students must plot the following line graphs:
   a) the effect of temperature on the rate of transpiration
   b) the effect of light intensity on the rate of transpiration
   c) the effect of relative humidity on the rate of transpiration
   d) the effect of wind on the rate of transpiration

Observations:

Record your observation from the table, bar graph and line graphs.

Observations and Results:

Teachers should be able to guide the class in drawing up tables to compare the transpiration rate in the four conditions, but the following table is suggested as a guideline:

<table>
<thead>
<tr>
<th>Conditions</th>
<th>Cumulative distance water has moved (mm):</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>0</td>
</tr>
<tr>
<td>Sunny, no wind</td>
<td></td>
</tr>
<tr>
<td>Sunny, with wind</td>
<td></td>
</tr>
<tr>
<td>Sunny, plastic bag around plant</td>
<td></td>
</tr>
<tr>
<td>Shade, no wind</td>
<td></td>
</tr>
</tbody>
</table>

Table 7.1: The effect of different environmental conditions on the rate of transpiration

Learners should find the following transpiration rates:

- Fastest transpiration rate in the sun with wind
- Second fastest in the sun, but no wind
- Third fastest in the shade with no wind
- Slowest transpiration rate in the plant that had the bag around it.

Bar graphs should have headings similar to the table heading. Environmental conditions will go onto the horizontal axis and rate of transpiration on the vertical axis. Since measurements were taken every 10 minutes for an hour, the total cumulative transpiration at the end of the 60 minute period will be the transpiration rate per hour.

**Conclusions:**

1. What can you conclude from this investigation?
2. Give two ways in which you can improve your experimental results.

**Conclusions:**

- Different environmental conditions have an effect on transpiration rate in plants.
- Warm conditions, wind and bright sunlight speed up transpiration rate.
- Cool conditions, no wind and humidity slow down transpiration rate.

**Improving the accuracy of findings:** Accept any 2 of the following:

- Do not take measurements directly after changing the conditions.
- Use the same plant and take it to different places to keep the leaf surface area constant.
- If using different plants, they must be of the same species and the same size.
- Do not get water on the leaves, as this will block stomata and reduce transpiration rate.
- Use a woody stem, to stop the xylem being crushed when it is inserted into the tube / straw.
- Cut the stem under water to stop air bubbles entering the xylem.
- Take several readings in each condition and average the findings.

**Questions:**

1. Why is it important to cut the stem at an angle under the water?
2. Which part of the stem does the straw represent?
3. Which four factors are you investigating?
4. Under which condition is the highest rate of transpiration?
5. Name one possible error that could have occurred in your investigation.
6. What are the potential limitations of this investigation?
**Answers:**

1. To prevent air from getting into the xylem. Cut at an angle so there is a large surface area through which the water can enter the plant. It is important to remember that cutting straight across the stem may crush and block the xylem.

2. The xylem of the stem.

3. Humidity, wind, light and moisture.

4. Learners should find the sunny area with wind to have the highest rate of transpiration. However, learners are to assess their own experiments and base answer on results.

5. Accept any error:
   - We didn’t measure for exactly the same amount of time every time
   - The plants were not exactly the same size
   - The tube was too wide and the bubble hardly moved
   - The tube wasn’t sealed, so the bubble didn’t move at all and the water ran out
   - Wind speed varied in our area
   - We had wind on our plant and couldn’t stop it – supposed to be no wind there
   - ANY other error that may have occurred during this investigation.

6. The following are some examples of answers that learners may provide:
   - We can’t be sure that we were accurate, because we couldn’t keep the wind speed the same.
   - We had wind when we didn’t want any.
   - We were comparing the transpiration rates of completely different plants so different numbers of leaves on the twigs could have caused differences in their transpiration rates
   - Since we were using different plants it was not only the environmental conditions that differed, but the plants themselves.

**ADDITIONAL RESOURCES**

More information about potometer experiments can be found on the following websites:


In addition, the following website has a ‘virtual laboratory’ that allows you to perform the above experiment online:

http://www.mhhe.com/biosci/genbio/virtual_labs_2K8/pages/PlantTranspiration.html

Perform the experiment and complete the laboratory exercise given on the website.

The following activity can be done as a DEMONSTRATION and is optional. It is not easy to collect water in bags and then remove the bag without losing the water.

### Investigation: Determining the effect of light intensity on transpiration

**Aim:**

To determine the effect of light intensity on transpiration.

**Apparatus:**

- plants
- plastic bag
- piece of string
- graduated measuring cylinder

**Method:**

1. Use at least three plants of the same species and as close to the same size as possible (think of why this might be important).
2. Ensure that all three plants are exposed to the same amount of light.
3. Use clear plastic bags to completely cover all the leaves of each plant.
4. Tie the bottom of the plastic around the main stem of the plant, allowing the water lost from the plant to collect inside the bag. Try not to crush the leaves of the plant with the bag.
5. Place the bags on the plants early in the morning. Leave the bags on all day and check for signs of water drops inside. If there are water drops, shake the bag so that the water drops to the bottom of the bag.
6. At the end of the day, carefully remove the bags to ensure that you do not lose any water. It will help if you tilt the plant slightly while removing the bags.
7. Collect the water inside a measuring cylinder and measure how much water the plant has lost.
8. Tie a new plastic bag around the plant and leave overnight. The following morning, collect and measure the water that was released by the plant overnight.

Results:

1. Record the amount of water lost during the day and during the night.
2. Using the three plants, figure out the average water loss for each time period.
3. Plot a bar graph comparing the average amount of water loss in the day and night.

Observations:

Write down anything you observed about the plants, the plastic bags and the rate of water loss from the plant.

Conclusions:

What can you conclude regarding the rate of transpiration at different light intensities? Was there higher or lower water loss when you left the plant overnight compared to when you monitored it throughout the day?

Conclusions:

The plant loses more water during the day, because it’s hotter and the light intensity is higher than at night.

Questions:

1. How can you improve this experiment to determine the effects of different light intensities on transpiration?
2. In this experiment what are the key variables we are controlling for? Have we properly controlled for these?

7.4 Wilting and guttation

This section explains to the learners how excessive loss of water can cause plants to wilt and lose some of their structural support.

During transpiration the learners learnt how the leaves are constantly losing water vapour to the environment. However, what happens when there is not enough water in the soil to replace the water that was lost? Similarly, what
happens when there is too much water? In this unit we discuss wilting, and why plants wilt and get floppy in hot weather or after a long drought. We will also look at ways that plants can rid themselves of extra water when there is too much water in the environment and the plant has to cope with high root pressure and a low transpiration rate.

FACT
Learn how water is transported from the soil to the leaves of a plant.
See video: 2CRY

FACT
Learn how transpiration helps with the transport of water to the leaves.
See video: 2CRZ

7.5 Uptake of water and minerals in the roots

In this section learners need to know how water enters from the soil into the specialised cells of the root.

Learners need to relate this section to:

- the movement of water down a water potential gradient (osmosis and diffusion)
- the structure of the dicotyledonous root and stem
- the different cells in the specialised tissues of the plant root and stem

TEACHER RESOURCES:

This website shows a diagram of how water moves up through the plant.

http://www.neok12.com/Plants.htm
This video shows plant transport and provides some interactive quiz games.

Transport of Water and Minerals to Leaves

In this section the transport of water and minerals to the leaves is discussed.

Plants must transport water from the roots to the leaves where it is needed for the process of photosynthesis. Nutrients produced in the leaves by photosynthesis are transported to all the parts of the plant. The phloem carries nutrients up and down the plant. The xylem only carries water up the plant.

To understand this section you need to remind learners need to link this to previous units learnt in the Chapter.

- the internal structure of a dicotyledonous leaf and stem and the structure of the cells that make up the specialised tissues.
- the movement of water from the soil into the root
- transpiration and the loss of water vapour from the stomata
Investigation: Examining water uptake by the stem

Aim:

To examine water uptake by the stem.

Apparatus:

- water
- food colouring dye (available at supermarket)
- white flower on a stem, e.g. Impatiens, carnation or chrysanthemum
- scissors
- two jars, cups or measuring cylinders
- plastic tray
- sticky tape

Method:

1. Fill one jar with plain water, and one with water containing several drops of food colouring dye.
2. Take the flower and carefully cut the stem lengthwise, either part way up the stem or right up to the base of the flower (try both, the results will be different!)
3. Put one half of the stem into the jar containing plain water and one half of the stem into the jar containing food colouring dye. To make it easier to insert the stalks without breaking them, it helps to wedge paper underneath the jars so that you can tilt them towards each other. Tape the jars or cylinders down onto a tray so that they do not fall over.
4. Observe the flowers after a few hours and the next day, and note where the dye ends up in the flower head. You can leave the flowers up to a week but be sure to make sure that they have enough water.

Variation: Instead of using one cylinder with water and one with food dye, use two different colour food dyes (e.g. blue and red). At first the flower will show two separate colours, but as time goes by the whole flower will show both dyes. This is because water can move sideways between xylem vessels through openings along their length. The ability of water to move laterally between vessels is useful for when air becomes trapped in a vessel, causing a blockage. If you cut the stem right up to the base of the flower, this will limit movement between the xylem vessels.

Variation: Try using celery stalks with leaves. Cut open the celery stalk (cross-section) and you will see darker-coloured little holes/ spots. These are the vessels.
Results:

Record your observations and results

Results

In this investigation learners are to write down their observations. The learners should observe that the flowers show the red or blue colour of the food colouring in their petals, especially in the veins. The celery stalk should have dark red / blue spots, where the xylem in the vascular bundles has been stained by the dye in the food colouring.

Conclusions:

What did you conclude from this experiment?

Conclusions

The class can then discuss their observations and conclusions, particularly if learners used different plants. Learners should conclude that the water in plants is transported by xylem in the veins. Xylem vessels branch throughout the flower petals, starting off as fairly large bundles of xylem vessels at the base of the petal and becoming finer bundles as it gets to the edges of the petals.

TEACHERS RESOURCE

An example of this experiment with photographs can be found at: http://www.practicalbiology.org/areas/intermediate/cells-to-systems/transport-in-plants/investigating-transport-systems-in-a-flowering-plant,70,EXP.html

Movement of manufactured food

This section deals with how sugars are transported from the leaves to the rest of the plant via specialised phloem cells.

Revise the concept of photosynthesis and that plants use carbon dioxide and water to manufacture glucose and oxygen is the waste product. Sunlight and enzymes are necessary for photosynthesis to occur. Once the food is manufactured in the leaves it needs to be distributed to the entire plant so that the glucose can be used by each cell for respiration (manufacture energy).

Learners to understand that the glucose is manufactured mainly in the palisade cells and then passes into the phloem. Transport of food material from leaves to other parts of the plant is called translocation. This food may be stored in roots, stems or fruit.
• **Anatomy of dicotyledonous plants**: Structures discussed in the previous chapter (collenchyma, sclerenchyma, xylem and phloem) are important in carrying out the transport functions.

• **Root anatomy and function**: The root is important in absorption, anchorage and storage of food. It is made up of the epidermis, cortex, endodermis and stele (consisting of xylem, phloem and pericycle).

• **Stem anatomy and function**: Stems contain an epidermis, cortex and vascular cylinder (consisting of pericycle, xylem, phloem, cambium and pith). Stems are important for growth, support, storage and transport of water, mineral salts and manufactured sugars.

• **Secondary growth**: Secondary growth is the thickening of the stem or root as new layers of xylem and phloem are formed by mitosis. It is carried out by cambium and results in stems and roots becoming thicker as the plant ages / matures. Secondary thickening results in the annual rings found in trees that can be used to work out the age of a tree.

• **Transpiration**: Transpiration is the loss of water from the stomata of plants. It creates a 'suction' or transpirational pull that is important for the movement of water through the plant. Transpiration is affected by environmental conditions e.g. wind, temperature, humidity and light intensity. The rate of transpiration is measured using a potometer. In order to prevent excessive transpiration, plants have developed adaptations such as thickened cuticle, position of stomata, hairs on leaves, reduction of leaf size, leaf spines, leaf arrangements and rolling of leaves.

• **Translocation**: Translocation is the transport of food material (sugars), synthesised in the leaves, to other parts of the plant via phloem. This mode of transport is multi-directional, but requires energy as it occurs by active transport against a concentration gradient. Phloem vessels consist of sieve-tube elements and companion cells which are connected by plasmodesmata. Companion cells act as the regulators and energy stores of the phloem.

• **Wilting and guttation** are processes of water loss in the plant. Wilting entails excessive loss of water through plasmolysis resulting in excessive cell death, at times resulting in death of the entire plant. Guttation is the release of water via the hydathodes due to high humidity.
Exercise 7 – 1: End of chapter exercises

1. The water loss in two plants was recorded over a 12 hour period. Study the information below and then answer the questions that follow. The results for the two plants were recorded in the following table.

<table>
<thead>
<tr>
<th>Time of Day</th>
<th>06:00</th>
<th>08:00</th>
<th>10:00</th>
<th>12:00</th>
<th>14:00</th>
<th>16:00</th>
<th>18:00</th>
</tr>
</thead>
<tbody>
<tr>
<td>Water loss in Plant A (cm³)</td>
<td>0,0</td>
<td>0,4</td>
<td>1,6</td>
<td>6,0</td>
<td>9,0</td>
<td>8,0</td>
<td>7,6</td>
</tr>
<tr>
<td>Water loss in Plant B (cm³)</td>
<td>0,2</td>
<td>0,7</td>
<td>4,0</td>
<td>14,0</td>
<td>19,0</td>
<td>18,2</td>
<td>17,7</td>
</tr>
</tbody>
</table>

a) What is the correct biological term for water loss in a plant?

Solution:
Transpiration

b) From which plant was the greatest amount of water loss recorded?

Solution:
Plant B

c) Assuming the plants were kept in identical conditions; suggest two possible ways that the plant that lost less water may have differed structurally from the plant that lost more water.

Solution:
Any two of the following: It could have smaller or fewer leaves / trichomes or hairs on the leaves / leaves in a rosette arrangement / sunken stomata / fewer stomata per leaf / thicker cuticle / curled up leaves.

d) Which time of day was the greatest water loss recorded for both Plants A and B. Why do you think this is so?

Solution:
14h00 (2pm). It is the hottest part of the day. The sun shines brightly, causing stomata to open wider and the high air temperature causes water vapour to diffuse rapidly out of stomata.

e) At 18h00 the rate of water loss was lower. Why did this occur?

Solution:
The sun went down, so light intensity became lower, closing the stomata. The air temperature was also lower, reducing the diffusion rate of water vapour, so both plants lost less water.

f) What is the apparatus that was used in the laboratory to measure the rate of water loss in plants A and B.

Solution:
Potometer

2. What do you understand by guttation and how does the process of guttation occur?

Solution:
Guttation is the loss of liquid water from the hydathodes on the leaves of some plants. It occurs early in the morning when air is cool, soil is wet and humidity is high, so transpiration rate is low. Guttation is independent of transpiration and results from root pressure.
3. Tabulate the differences between guttation and transpiration.

**Solution:**

<table>
<thead>
<tr>
<th>Guttation</th>
<th>Transpiration</th>
</tr>
</thead>
<tbody>
<tr>
<td>occurs early morning and at night</td>
<td>occurs during the day when it is hot and light</td>
</tr>
<tr>
<td>takes place through hydathodes</td>
<td>takes place through the stomata</td>
</tr>
<tr>
<td>Water is lost in liquid form</td>
<td>Water is lost as vapour</td>
</tr>
<tr>
<td>caused by root pressure</td>
<td>caused by high water potential</td>
</tr>
<tr>
<td>Water droplets are found on the margin of the leaf</td>
<td>Water vapour transpiration takes place mostly in the lower surface of the leaf where stomata are located</td>
</tr>
</tbody>
</table>

4. Briefly discuss the movement of water through the dicotyledonous root.

**Solution:**

Water enters the root hair cells from soil water. It passes through the thin cell walls of root hair cells into the vacuoles and then passes by osmosis through parenchyma cells of the cortex or via intercellular spaces towards the endodermis. Casparian strips in endodermal cells force water into the xylem but passage cells allow water to pass right through them. Water passes through the pericycle and into the xylem, from where it is transported upwards due to transpiration pull, capillarity and root pressure.

5. Give a short explanation for the following:

- Capillarity
- Dicotyledon
- Transpiration
- Water potential gradient

**Solution:**

- **Capillarity** is the tendency of water molecules to cling to each other (cohesion) and cling to the sides of xylem vessels (adhesion). These two forces together cause capillarity – the make a water column in xylem continuous, so it ‘creeps up’ the xylem and is easily moved up by transpiration pull.

- **Dicotyledons** are plants in one class of the Angiosperms / flowering plants. They have seeds with 2 cotyledon or seed lobes, net veins, petioles, flower parts in multiples of 4 or 5, tap root systems and vascular bundles in a ring in the stem.

- **Transpiration** is the loss of water vapour from the aerial parts of plants. It occurs mainly through stomata on the leaves. It is fastest during the hottest times of the day and is increased in low humidity and when the wind blows.
• **Water potential gradient** is the difference in the water potential of two liquids. Water potential is the potential of water to move from one area to another due to differences in pressure, solutes dissolved in the water and other factors. The water potential gradient between two solutions has a direct effect on the rate of osmosis – the bigger the gradient, the faster osmosis occurs in the direction of the gradient, i.e. always from a high to low water potential.

6. On a hot day in the middle of a drought, what can you expect the leaves of a plant to look like? Draw a diagram to describe your answer.

**Solution:**
Learners should draw wilted leaves.

7. List the environmental conditions that would result in the highest rate of transpiration.

**Solution:**
- Dry air / low humidity
- high air temperature
- high wind speed
- bright light

8. Name four defining characteristics of a monocotyledonous plant.

**Solution:**
Any four of the following:
- Leaves with parallel veins
- Leaves with leaf sheaths, not petioles
- Fibrous root system
- Flower parts in multiples of 3
- Seeds with one cotyledon
- Vascular bundles scattered in the stem, not in a circle

9. In a short paragraph, explain how secondary thickening in a stem comes about.

**Solution:**
The parenchyma cells in medullary rays become meristematic and form cambium between the vascular bundles, which joins up with vascular cambium to form a complete cambium ring. This divides by mitosis to form secondary xylem to the inside and secondary phloem to the outside of the stem. Secondary xylem is formed faster than secondary phloem and its rate of formation is affected by temperature and rainfall. In spring and summer, large xylem cells with thinner walls are formed in a broad band – this is called spring wood. In autumn and winter, a narrow band of smaller, thick-walled xylem cells are formed – this is called autumn wood. One layer of spring wood and the layer of autumn wood next to it are called an annual ring – it indicates the growth in thickness of the stem in one year. Just under the hypodermis, a parenchyma layer also becomes meristematic and forms the cork cambium, which forms cork cells to the
outside and parenchyma / cortex cells to the inside. Lenticels usually develop in the cork layer to assist gaseous exchange in older stems.

10. Name and briefly discuss the adaptation of leaves to minimise transpiration.
   **Solution:**
   Leaves can have the following adaptations to reduce transpiration rate:
   - Small or narrow leaves to reduce the surface area over which water vapour is lost
   - Leaves in a rosette arrangement to shade lower leaves and trap water vapour
   - Curled up leaves to trap water vapour inside the leaf cavity
   - Thick cuticles to prevent evaporation of water
   - Sunken stomata to trap water vapour in pits near the leaf
   - Very few stomata or stomata only on the lower surface to reduce water loss
   - Trichomes to make leaves reflective and trap water vapour

11. Name the two main ways that water can travel through the parenchyma of the root.
   **Solution:**
   Along the cell walls or in the intercellular spaces or from vacuole to vacuole.

12. Explain the difference between cohesion and adhesion.
   **Solution:**
   Cohesion is the force that holds water molecules together whereas adhesion is the force that allows water molecules to cling to other substances, e.g. to the walls of xylem vessels.

13. During transpiration, the movement of water through the xylem is largely due to:
    a) mitosis
    b) capillary action
    c) osmosis
    d) all of the above
   **Solution:**
   b

14. Stomata:
    a) are found in plant roots
    b) permit the intake of carbon dioxide
    c) prevent the intake of oxygen
    d) all of the above
   **Solution:**
   b
15. Water can be lost by a plant through which process(es)?

   a) guttation  
   b) transpiration  
   c) condensation  
   d) a and b  

**Solution:**  
d

16. What environmental condition(s) always lead to an increase in transpiration rate in each plant tested?

   a) heat  
   b) wind  
   c) light  
   d) all of the above  

**Solution:**  
d

17. Wind appears to increase the rate of transpiration in a plant. This is most likely due to the fact that:

   a) humidity increased  
   b) evaporation increased  
   c) stomata were forced to close  
   d) all of the above  

**Solution:**  
b

18. Describe how light intensity is responsible for an increase or decrease in the transpiration rate.

**Solution:**  
Light intensity increases rate of photosynthesis. This increases the rate of glucose production and storage in guard cells. This leads to movement of water into the guard cells as a result of a lower water potential with respect to outside the guard cells. The increase in turgor pressure of the guard cells results in the opening up of the stomata which results in increased transpiration.

19. Study the two graphs on the following page which show water loss from a plant over a period of time, and answer the following question:
Which graph could show water loss under increasing external humidity? Give reasons for your answer.

**Solution:**

*Graph 2.* As the humidity increases over time, the transpiration rate slows down. When the humidity is low water is lost more rapidly because there is a steep water potential gradient between water vapour inside the stomata and the outside atmosphere. As humidity increases, the water potential gradient across the inside and outside the leaf become more equal, and so the rate of transpiration decreases. At high humidity, the water loss is reduced to zero.

20. Describe how each of the following adaptations results in a decrease in the transpiration rate:

   a) Spiny leaves  
   **Solution:**
   Lower surface area over which water is lost.

   b) Rolled leaves  
   **Solution:**
   Have sunken stomata which creates an artificial ‘humidity’ layer outside the plant thereby preventing water loss.

   c) Waxy cuticle  
   **Solution:**
   The thick waxy cuticle layer is hydrophobic, thus making it more difficult for water to pass through, therefore decreasing water loss by transpiration.

21. Complete the following sentences:

   a) Translocation refers to the ...
   **Solution:**
   Translocation refers to the movement of manufactured sugars from the leaves to the rest of the plant through the phloem.

   b) Xylem tissue in plants is responsible for the transport of ...
   **Solution:**
   Xylem tissue in plants is responsible for the transport of water and mineral salts.
c) The roots absorb water through the ...  

**Solution:**  
*The roots absorb water through the root hairs.*

22. Draw a table showing how the structure of root hairs is adapted for their function.  

**Solution:**

<table>
<thead>
<tr>
<th>Structure</th>
<th>Function</th>
</tr>
</thead>
<tbody>
<tr>
<td>Thin and long root hairs</td>
<td>Increase surface area over which absorption of water and mineral salts can occur</td>
</tr>
<tr>
<td>Thin cell wall</td>
<td>Makes osmosis faster</td>
</tr>
<tr>
<td>No cuticle</td>
<td>Cuticle would hinder water absorption</td>
</tr>
<tr>
<td>Large vacuole</td>
<td>Allows for storage of water and mineral salts</td>
</tr>
<tr>
<td>Mineral salts in vacuole</td>
<td>Creates a concentration gradient to encourage osmosis</td>
</tr>
<tr>
<td>Several root hairs</td>
<td>Increased surface area</td>
</tr>
</tbody>
</table>

Table 7.2: Table showing relationship between structural adaptations of root hairs and their function

Check answers online with the exercise code below or click on 'show me the answer'.  

1a. 2CS2 1b. 2CS3 1c. 2CS4 1d. 2CS5 1e. 2CS6 1f. 2CS7  
2. 2CS8 3. 2CS9 4. 2CSB 5. 2CSC 6. 2CSD 7. 2CSF  
8. 2CSG 9. 2CSH 10. 2CSJ 11. 2CSK 12. 2CSM 13. 2CSN  
14. 2CSP 15. 2CSQ 16. 2CSR 17. 2CSS 18. 2CST 19. 2CSV  
20a. 2CSW 20b. 2CSX 20c. 2CSY 21a. 2CSZ 21b. 2CT2 21c. 2CT3  
22. 2CT4  

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Support systems in animals

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<td>8.8 Summary</td>
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</table>
8 Support systems in animals

8.1 Overview

**Time Allocation:** 3 weeks (12 hours)

This chapter consists of the following sections:

1. Overview
2. Skeletons
3. Human skeleton
4. Musculoskeletal tissues
5. Human locomotion
6. Muscle structure and function
7. Diseases
8. Summary
9. End of the chapter exercises

**Introduction**

This chapter begins by introducing the different basic skeletal types in animals. The link between skeletal structure and function is explored by examining advantages and disadvantages of each skeleton type; and by linking the different skeletal types to various evolutionary adaptations that took place over time. In Grade 12 learners will come to know how the human skeletal structure evolved.

The majority of the chapter focuses on the musculoskeletal systems of humans. There is a large focus on understanding the anatomy of the human skeleton in some detail. Learners will be introduced to the main features and functions of the human skeleton.

This is followed by a broad overview of the other components of the musculoskeletal system, such as cartilage, joints, tendons, ligaments and muscles. The structure of muscles, and their organisation into antagonistic pairs, will be covered using the biceps-triceps antagonistic pair as an illustrative example. The chapter ends with an overview of some common diseases affecting the musculoskeletal system.

By focusing on specific structures of the human skeleton, we once more emphasise a common theme of our study of Life Sciences: that structure is related to function.
Key concepts

- Some of the main types of skeleton found in living things are the hydrostatic skeleton, endoskeleton and exoskeleton. Each of these skeletal types have advantages and disadvantages.
- Skeletal structures are adapted for the transition from an aquatic to a terrestrial existence where greater support was required.
- The human skeleton consists of the axial skeleton and the appendicular skeleton.
- The main functions of the skeleton are to allow for movement, provide protection, provide support, store minerals, produce blood cells and allow for hearing.
- It is important to understand the relationship between structure and function of bones, cartilage, tendons and ligaments.
- Joints connect pieces of skeleton and allow independent movement of neighbouring pieces. Joints are of three types: fixed, partly movable and freely movable (synovial joints). Synovial joints are of either ball-and-socket, hinge, pivot, or gliding structure.
- Skeletal muscle is attached to the skeleton through tendons and ligaments. The structure of voluntary skeletal muscle is made up mainly of myofibrils which allow for muscle contraction. This contraction is used to move part of the skeleton.
- Diseases affecting the skeleton include rickets in children, and osteoporosis and arthritis in adults.

8.2 Skeletons

Learners do need to know detail from this section on the evolution of skeletons. Rather, it is important that they grasp how form has adapted to function over time. This section should be used to reinforce the learner’s previous understanding of evolution, covered in earlier grades, and should lay a foundation for the later chapter on the ‘History of Life on Earth’.

8.3 Human skeleton

The different bones of the human skeleton are described in this section. There is a lot of new terminology and it may help learners to use models or demonstrate the locations and names of bones in their own bodies.
TEACHER RESOURCES:

Axial skeleton animation


Activity: Draw and label a longitudinal section of a long bone

In this activity you need to draw and label the parts of a long bone.

Instructions:

Make sure that you follow all the guidelines for biological drawings:

1. Give your diagram a caption or heading
2. Your diagram must take up at least half a page
3. Your drawing should be in pencil
4. Label lines should be drawn with a ruler
5. Label lines should not cross

Draw and label a longitudinal section of a long bone

Learners should accurately draw a long bone, resembling that in Figure ??

Make sure learners follow all the criteria for a biological drawing. Marks should be deducted for shading or colouring.

Investigation: Optional Investigation: Investigating organic and inorganic components of bones

Aim:

Experiment A: Remove the inorganic component of bone in order to investigate the organic component

Experiment B: Remove the organic component of bone in order to observe the properties of the inorganic component

8.3. Human skeleton
WARNING!

Bunsen burner and methylated spirits: Wear safety goggles and no loose fitting clothes. Do not wear synthetic clothes that easily catch fire (cotton and wool clothes are preferable).

Hydrochloric acid: Wear closed shoes, safety goggles, a lab coat and gloves.

Apparatus:

Experiment A

- 2 small chicken bones
- 2 test tubes
- dilute hydrochloric acid/white vinegar

Experiment B

- towel
- 1 small chicken bone
- pipe clay triangle or wire gauze on a tripod stand
- bunsen burner or Methylated spirits burner

Method:

Experiment A

1. Label 2 test tubes with your initials and A and B. Put a bone in each test tube.
2. Cover Bone A with water and Bone B with dilute hydrochloric acid. Leave for a few days. The acid will dissolve out the mineral component of the bone leaving behind the organic part.
3. Take out Bone A and dry it.
4. Use tweezers to take Bone B out of the acid. Rinse it under the tap and dry it.
5. Compare the two bones and write down how they appear and whether they are soft or hard, flexible or brittle.

Experiment A: observations

The bone that was in the hydrochloric was much softer and more flexible than the bone in water. This is because the acid reacts with the calcium phosphate in the bone and removes the calcium from the bone tissue. It is the calcium salts in the bone tissue make the bones strong and hard. Calcium salts precipitate out of the bone and this precipitate can be seen in the bottom of the test tube.
NOTE: If you leave the chicken bone in the hydrochloric acid too long you will also remove the collagen.

Experiment B

1. Place the chicken bone (Bone C) on a pipe triangle or wire gauze on a tripod stand.
2. Roast the bone strongly for 10 minutes. Roasting will burn off the organic component of bone (mainly the protein collagen) leaving behind the mineral part.
3. Allow the bone to cool down completely before you touch it.
4. Describe the appearance of Bone C stating whether it is soft or hard, flexible or brittle.

Observations:

Note down your observations in your lab notebook.

Experiment B: observations

The chicken bone has now become bone ash. It is extremely brittle.

NOTE: This bone ash can contain calcium oxide which is an alkali so it is important to avoid inhaling any dust or powder from the bone.

Conclusions:

What can you conclude about the different organic and inorganic components of bones?

Conclusions

The inorganic component of bone (calcium) helps make bone hard and rigid. The organic component of bone (collagen) helps give bone its flexibility and strength, so that it is not too brittle and does not snap, crumble or break.

Questions:

1. What are the main inorganic components of bone?
2. What changes have occurred in Bone A?
3. What properties have been removed from bone B with the loss of its inorganic components?
4. Which deficiency disease can have similar effects on bones in children?
5. What is the role of Bone B in this experiment?
6. What protein makes up the main organic component of bone?
7. What changes took place in Bone C during the roasting process?
8. What properties have been removed from Bone C with the loss of its organic component?

**Answers**

1. Calcium and phosphate (calcium phosphate).
2. None. Bone A was kept in water.
3. Calcium has been removed from the bone tissue, and the bone has become flexible and soft.
4. Rickets.
5. Bone B was the experiment as it was covered with the hydrochloric acid and an observation needed to be made.
6. Collagen, which is an elastic protein which improves fracture resistance.
7. The organic components were burnt away and the bone turned to ash.
8. The bone ash contains calcium oxide and the collagen has been destroyed, therefore the bone is no longer flexible and becomes brittle.

### 8.4 Musculoskeletal tissues

The tissues which provide structure to the body and enable movement are part of the **musculoskeletal** system. The tissues in the this system include the bones, cartilage, joint, tendons, ligaments and muscles. In this section learners will examine each of these types of tissues, so that in the next section on locomotion, they can understand how these structures work together to bring about movement.

**Activity: Movement at joints**

Joints occur where two bones meet. Different types of joints allow for different types of movements. In this activity you will need to identify the different joint types, identify where they are located in the body and describe their motion.

**Instructions:**

For each of the following joints, you need to:

- give an example of their location in the body
- describe their motion
1. Fibrous joints
2. Ball and socket joints
3. Gliding joints
4. Hinge joints
5. Pivot joints

**Answers**

1. Fibrous joints:
   - sutures of the skull
   - no movement

2. Ball and socket joints:
   - hip and leg, shoulder and arm
   - Allows movement in all directions, such as swinging and rotation.

3. Gliding joints:
   - wrist and ankle, metacarpals, metatarsals
   - Small movement in one direction as bones slide past each other—e.g. sideways or up and down.

4. Hinge joints:
   - elbow, knees, fingers, toes
   - Allows movement in one direction only: e.g. up and down. Work like the hinge of a door.

5. Pivot joints:
   - atlas and axis of vertebral column, radius and ulna of arm
   - Allows a rotating movement as one bone pivots around another.

The mechanics of the antagonism within the biceps and triceps.

See video: 2CT5

**Activity: Dissection of animal tissue**

**Aim:**

The aim of this dissection is for you to revise the theory behind tissues and apply your knowledge to actual tissues.

The purpose of this dissection is to revise the theory behind tissues and apply it to actual tissues.
Instructions:

You will be working in pairs. Instructions for this activity will be bulleted and written in italics. Questions for you to answer are numbered.

At the end of the practical you should:

1. Know and be able to use dissecting instruments correctly, especially insertion and removal of blades.
2. Be able to recognise and use ether responsibly
4. Use a scale: zero (calibrate) and record mass
5. Perform simple mathematical calculations: percentage
6. Be able to read a vernier calliper.
7. Clean and dry thoroughly and appropriately.

Materials:

- 1 piece filter paper
- scissors
- forceps
- threader
- pointer
- scalpel
- blade
- dissecting tray
- petri dish
- chicken wing
- 1 ml Ether
- cloths
- roller towel

Method:

1. Skin

- Before you begin, look at the external appearance of the chicken wing.
- Weigh the entire wing and record its mass in the table on the last page.
- Insert the scalpel blade onto the handle.
- Lie the wing upside down on the dissecting board.
- Cut with scissors from the severed end towards the wingtip along the midline of the wing.
- Remove as much of the skin as you can by freeing it from the underlying tissue with a blunt instrument or pulling with your fingers.
Carefully observe the tissue that you are breaking.

1. Is skin a tissue or an organ?
2. Why is there a ‘web’ of skin between the joints?
3. What are the ‘bumps’ on the skin?
4. How easily does the skin come off between the joints?
5. Where is the skin most firmly attached?
6. Record the mass of the skin in a table as shown on the last page.

1. **Skin**

   1. Skin is an organ.
   2. To increase the surface area for the attachment of feathers and to help hold them together.
   3. The bumps are feather follicles.
   4. Easily – it is loosely attached on the muscle between the joints.
   5. At the joints.
   6. OPTIONAL – learners can record mass if scales are available.

2. **Connective tissue**

   The skin is held to the underlying pink tissue by a type of connective tissue.

   1. Name this particular type of connective tissue.
   2. Give two adjectives that accurately describe it.

2. **Connective tissue**

   1. Areolar connective tissue.
   2. Soft, flexible, thin, elastic, transparent.

3. **Fatty tissue**

   - Look at the underside of the skin you have removed. You should see clumps of yellow material. This is fat, or adipose tissue. It is also a type of connective tissue.
   - Take a small amount of this fatty tissue and squash it gently in a small beaker with some ether.
   - Pour some of this solution onto a piece of filter paper.
   - Dry the filter paper by waving it in the air.
   - This oily stain is known as a translucent stain.
   - From now on collect all the fatty material as you find — you will need it later (place in a separate beaker)

8.4. Musculoskeletal tissues
1. What do you think the function of connective tissue is here?
2. What do you notice? There is an oily stain on the paper after the ether has evaporated.

3. **Fatty tissue**

   1. To store reserve food in the form of lipids and to insulate the body against heat loss.
   2. There is an oily stain on the paper after the ether has evaporated, indicating that this substance is fat.

4. **Muscle**

   Muscle is the pinky-orange tissue you can see under the skin. The muscles were most likely severed when the chicken was dismembered in the butchery. Muscles are all arranged in ‘antagonistic pairs’ where the action of one muscle does the opposite to its partner.

   • **Hold the wing in your left hand.**
   • **Grip the end of one of the muscles with forceps. Pull it.**
   • **Describe what happens and name the type of action it caused.**
   • **Let go and pull various other muscles.**
   • **Can you get one to cause the opposite movement?**
   • **Carefully dissect out a single muscle in FULL. Remove it from the wing completely.**

   1. What type of tissue lies between the muscles?
   2. Draw the wing muscle.
   3. You need to follow the convention of drawing diagrams by:
      a) providing a heading or title
      b) adding labels (tendon, muscle, epimysium, fat tissue)
      c) labelling on the right hand side of the diagram
      d) providing a scale bar

4. **Muscle**

   **NOTE TO TEACHERS:** It is difficult to remove the entire muscle without damaging the tendons, where the muscle attaches to the bone. Very few learners will do this successfully. Most of them will cut through the muscle above the tendon.

   1. When the upper muscle is pulled, the wing flexes / bends at the elbow. When the lower muscle is pulled, the wing straightens.
2. DIAGRAM: Adding a scale bar is optional. The epimysium is the membrane around the entire muscle – this is also an optional label, as this was not in the notes.

5. Blood vessels

The smallest vessels you will be able to see are small arteries (arterioles) and small veins (venules). Capillaries are the very smallest blood vessels — so narrow in fact that erythrocytes can only fit through in single file. It is ONLY between these vessels and the surrounding tissues where diffusion of substances occurs. Capillaries will not be visible to the naked eye.

- As you work, look out for blood vessels.
- The darker vessels are venules; the redder ones are arterioles.
- In the cut end of thicker vessels you may be able to see the lumen and vessel wall.
- If you find one, work the blunt end of the threader into it and down the vessel and see where it leads.

1. Name two substances that will diffuse into the tissues and out of the tissues in this wing.

5. Blood vessels

NOTE TO TEACHERS: It is not always possible to see the difference between arteries and veins. Learners should look for any narrow dark red / blackish tubes.

1. Oxygen and food will diffuse from the blood to the wing tissues. CO2 and other wastes will diffuse from the tissues to the blood.

6. Nerves

Nerves are bundles of neurons enclosed in a membrane rather like a piece of electrical flex. They tend to be deep in the tissues for protection.

- Keep a look out for nerves.
- Nerves are hard to see but when soaked in ethanol they become white (If possible check with your teacher if he or she can do this for you).

6. Nerves

NOTE TO TEACHERS: Learners sometimes find very narrow, whitish threads, which are the nerves. They are generally right against the bone and are often destroyed when learners remove the muscle.
7. Tendons

Muscles are attached to bones by means of tendons. Tendons are made of a type of connective tissue that contains lots of white fibres made of collagen. It is this collagen that gives the connective tissue its properties.

- Your task now is to remove all the muscles neatly from the bones.
- As you do so, try and pull one or two off the bone using your fingers or forceps; remove the rest using scissors or the scalpel.
- Look carefully at how the tendon joins the muscle.
- If necessary dissect into the muscle tissue.
- Collect ALL the muscles you remove.
- You should now have a pile of fat and a pile of muscle.
- Weigh and record the mass of subcutaneous fat and muscle in the table where you recorded the mass of the wing.

1. How firmly are the muscles attached to bones?
2. Approximately how many muscles did you remove?
3. Describe how the tendon and muscle join.
4. Write down four adjectives to describe collagen from what you can observe.

7. Tendons

1. Muscles are VERY firmly attached to bone by tendons. It is not possible to just pull them off using fingers or forceps. They have to be cut off.
2. Learner dependent answer. Most groups manage to remove one or two at least.
3. Tendons are attached directly to the bone and gradually become muscle – the two are intermeshed at the start.
4. White, strong, inelastic, flexible, firm, fibrous, occurs in bundles.

8. Bone

- You should now be left with some bones joined together with skin, muscles and ‘proper’ connective tissue removed.
- Use the miniature hacksaw to cut a bone in half.

1. Describe what you see after sawing the bone in half.
2. Use the vernier calliper to measure the thickness of the bone wall.
3. The bones of most birds are hollow. Why are hollow bones an advantage for a bird?
8. Bone

1. If learners do not have miniature hacksaws available, the bone can be broken by hand. Learners should be able to see red bone marrow and a marrow cavity inside.

2. Use the vernier callipers if they are available for measurements.

3. Being hollow makes bones lighter, so it’s easier for the bird to fly. BUT chickens can’t fly, so their bones are not hollow, they contain bone marrow.

9. Ligaments

Ligaments look similar to tendons and have a very similar histology with lots of collagen fibres. Ligaments join bone to bone, and also form protective capsular ligaments around synovial joints by for instance, keeping in the lubricating synovial fluid.

- Cut through and carefully remove the capsular ligament of a large joint using your scissors.

1. Can you see internal ligaments?
2. Write down three observable characteristics of the ligament you cut.

10. Cartilage

- Look at the end of a bone and find the cartilage (it is pearly white in colour).
- Try to remove it from the bone. Then try to scratch it first with your nail and, then with something very hard and sharp.

1. Describe what you observe.
2. What type of cartilage is this?
3. What do you think the function of cartilage is?
4. What common, man-made material is closest in its properties to cartilage?
10. Cartilage

1. It cannot be removed easily by just scratching it. The cartilage is very firmly joined to the end of the bones and forms a smooth, glassy surface on the bone.
2. Hyaline cartilage, but it can also be called articular cartilage.
3. The cartilage makes the end of the bone smooth, to reduce friction when the bones are moved by muscles.
4. It is similar to plastic.

Questions:

Data (show all working)

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Mass, correct to 1 decimal place (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire wing</td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td></td>
</tr>
<tr>
<td>Muscle</td>
<td></td>
</tr>
<tr>
<td>Subcutaneous Fat</td>
<td></td>
</tr>
</tbody>
</table>

1. Muscle is eaten for its protein. Muscle is made of protein. What percentage of this wing is muscle?
2. What total percentage of this wing was made up of fat?
3. Calculate the total fat-to-muscle ratio as a percentage.
4. Look at the price per kilo for these wings. Assuming the wings have the same mass, and there are 6 per pack, how much does one wing cost?
5. You are paying the above price only to really eat the muscle (protein), what is the actual price per kilo you are paying for the meat (protein) in this case?

Cleaning:

Tidy and clean the work station thoroughly after each session. Wash instruments in hot soapy water with a sponge/scourer, rinse in the cold sink (NOT under running water) and dry with a cloth. Replace apparatus in the correct containers. Scalpel blades are to be removed, cleaned, dabbed dry with roller-towel and returned to their envelopes.

Answers

DATA (SHOW ALL WORKING)

Learners may not have tables of mass measurements if scales were not available.
1. Teachers will have to check the percentage calculations if mass measurements were done. It is calculated as mass of muscle divided by mass of entire wing x 100.

2. Mass of fat divided by mass of wing x 100.

3. Fat mass divided by muscle mass x 100.

4. All learners can do these calculations, even if mass was not recorded. Price divided by 6 = cost per wing

5. The price would be 100/(percentage protein) x cost per kilogram = price per kg of protein

<table>
<thead>
<tr>
<th>Tissue</th>
<th>Mass, correct to 1 decimal place (g)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Entire wing</td>
<td></td>
</tr>
<tr>
<td>Skin</td>
<td></td>
</tr>
<tr>
<td>Muscle</td>
<td></td>
</tr>
<tr>
<td>Subcutaneous Fat</td>
<td>(4 + 1 + 1)</td>
</tr>
</tbody>
</table>

Mark Scheme: Chicken wing

<table>
<thead>
<tr>
<th>Self-Assessment: Assess yourself after chatting through each point with your partner</th>
<th>Most (0)</th>
<th>Most no</th>
<th>Yes</th>
<th>Very much so</th>
</tr>
</thead>
<tbody>
<tr>
<td>I followed the instructions carefully and read everything</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We asked questions where we needed to</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We did not ask irrelevant questions</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can now recognise all the tissues mentioned</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can confidently describe the tissues we saw</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We worked well together</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>We stayed focused on the work</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Our apparatus was clean and dry after our practical</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I can confidently insert and remove scalpel blades</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>I used the apparatus well and successfully</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Our wing was neatly dissected</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Total (out of 33, convert to 15)</td>
<td>/33</td>
<td>/15</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
8.5 Human locomotion

Locomotion refers to the ability to move. Specifically, it refers to the way in which organisms travel from one place to another. Examples of types of locomotion include running, swimming, jumping or flying. Human locomotion is achieved by the use of our limbs. In this section we discuss the major organs and structures that bring about movement in humans. Encourage learners to think about and describe the way that different components of the musculoskeletal system function when they make movements such as straightening or bending their knee, bending over at the waist, reaching for something above their head etc.

8.6 Muscle structure and function

Previously, learners were introduced to the three types of muscle tissue: skeletal, smooth and cardiac. In this chapter, they will look at striated or skeletal muscle. Skeletal muscle is voluntary muscle which means it can be controlled by will. They are the muscles that enable one to run, skip, walk etc. Muscle contraction is also introduced.

TEACHER RESOURCES

Watch a video about the anatomy of a muscle cell:

See video: 2CT8

Learn more about myosin and actin:

See video: 2CT9

Learn about the role of sarcoplasmic reticulum in muscle cell:

See video: 2CTB

Summary of the workings of the muscle:

See video: 2CTC

See video: 2CTD
8.7 Diseases

As a result of wear-and-tear over time and due to lack of proper nutrition, individuals can develop bone problems. Common bone problems include rickets, osteoporosis and arthritis.

Visualise osteoarthritis

See video: 2CTF

TEACHER RESOURCES:


8.8 Summary

- There are 3 types of skeletons:
  1. Hydrostatic skeleton
  2. Endoskeleton
  3. Exoskeleton

- When animals moved from water to land, there was a need for the development of strong limbs and a skeleton to provide support to the bodies, which had previously been provided by water.

- Humans have an endoskeleton consisting of:
  1. Axial skeleton (cranial, facial bones, foramen magnum, palate and jaws, vertebral column, rib cage and breastbone/sternum)
  2. Appendicular skeleton (pectoral girdle with arms and pelvic girdle with legs)

- Functions of the human skeleton are:
  1. Movement
  2. Protection
  3. Support
  4. Storage of minerals
  5. Hearing

- The tissues associated with the human skeleton are bone, cartilage, tendons and ligaments.

- Joints
  A joint is formed when two or more bones come into contact.
There are three types of joints:
1. Immovable joints
2. Partly movable joints
3. Synovial joints (Hinge joints, ball and socket joints, pivot joints, gliding joints)

- Human locomotion requires the use and coordination of bones, joints, ligaments, tendons and antagonistic muscles.

- Muscles
There are three types of muscle tissue:
1. Smooth/involuntary
2. Skeletal/voluntary
3. Cardiac muscle

Myofibrils are responsible for muscle contraction.

- There are many diseases that affect the skeleton, such as rickets, osteoporosis and arthritis.

Exercise 8 – 1: End of chapter exercises

1. Draw a table showing the three types of skeletons and provide one advantage and one disadvantage of each.

Solution:
Learners need only provide one example of an advantage and one example of a disadvantage for each skeleton type.

<table>
<thead>
<tr>
<th>Advantage</th>
<th>Disadvantage</th>
</tr>
</thead>
<tbody>
<tr>
<td>Hydrostatic Skeleton</td>
<td></td>
</tr>
<tr>
<td>- Allows animal to be very flexible; moves easily; not restricted in terms of possible movements.</td>
<td>- There is very little protection for the internal organs.</td>
</tr>
<tr>
<td>- Give support without adding much weight.</td>
<td>- Lacks a structure and does not have surfaces for the attachment of muscles or limbs.</td>
</tr>
<tr>
<td>- Allows rapid diffusion of gases through the body wall, so a transport system is often unnecessary, e.g. jellyfish.</td>
<td>- Not very strong easily damaged or lost if the enclosed cavity around it is pierced.</td>
</tr>
<tr>
<td>- Cushions the internal organs of the animal from shock.</td>
<td>- Generally not suitable to terrestrial animals and offers no protection against dehydration.</td>
</tr>
<tr>
<td>- These organisms are suited for life in moist aquatic environments.</td>
<td>- Limits the size of the animal – large animals would not be feasible, as they would collapse under their own body weight.</td>
</tr>
<tr>
<td>Advantage</td>
<td>Disadvantage</td>
</tr>
<tr>
<td>-----------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td><strong>Exoskeleton</strong></td>
<td></td>
</tr>
<tr>
<td>- Very strong and provides</td>
<td>- Heavy, so it prevents the animal getting very large. (small animals are easy prey)</td>
</tr>
<tr>
<td>good protection against physical damage.</td>
<td>- Necessitates moulting, making the animal very vulnerable.</td>
</tr>
<tr>
<td>- Can be present in great variety of colours</td>
<td>- Movement is only possible at thinner joints, but these are more vulnerable than thick areas.</td>
</tr>
<tr>
<td>to provide protection via camouflage.</td>
<td>- The final body size is limited because as the body increases the surface area to volume ration decreases.</td>
</tr>
<tr>
<td>- Offer good protection against dehydration.</td>
<td></td>
</tr>
<tr>
<td>- The exoskeleton forms the point of attachment</td>
<td></td>
</tr>
<tr>
<td>of internal muscles needed for movement.</td>
<td></td>
</tr>
<tr>
<td>- The exoskeleton provides structural shape</td>
<td></td>
</tr>
<tr>
<td>and support for the organism.</td>
<td></td>
</tr>
<tr>
<td>- Exoskeletons of insects have a low density</td>
<td></td>
</tr>
<tr>
<td>there these skeletons are lightweight</td>
<td></td>
</tr>
<tr>
<td>allowing for flight.</td>
<td></td>
</tr>
<tr>
<td><strong>Endoskeleton</strong></td>
<td></td>
</tr>
<tr>
<td>- Provides shape and structural support.</td>
<td>- Broken bones take a long time to heal and are painful.</td>
</tr>
<tr>
<td>- Bone is very hard, so provides excellent</td>
<td>- Bones inside the body offer no protection to some soft tissues, e.g. intestine.</td>
</tr>
<tr>
<td>protection of vital organs e.g. brain,</td>
<td>- The skeleton consists of living tissue so it is susceptible to infections and diseases.</td>
</tr>
<tr>
<td>heart, lungs.</td>
<td></td>
</tr>
<tr>
<td>- Bones vary in size to support the animal’s</td>
<td></td>
</tr>
<tr>
<td>mass.</td>
<td></td>
</tr>
<tr>
<td>- Allows animal to become bigger – large</td>
<td></td>
</tr>
<tr>
<td>animals have fewer predators.</td>
<td></td>
</tr>
<tr>
<td>- Consist of living tissue, so it is able to</td>
<td></td>
</tr>
<tr>
<td>grow within the animal.</td>
<td></td>
</tr>
<tr>
<td>- Endoskeleton is jointed which allows for</td>
<td></td>
</tr>
<tr>
<td>flexible movement and support.</td>
<td></td>
</tr>
<tr>
<td>- Animals have successfully adapted to</td>
<td></td>
</tr>
<tr>
<td>locomotion in their living environments.</td>
<td></td>
</tr>
</tbody>
</table>

2. State where the Haversian canal is located and state its function.

**Solution:**

Haversian canal is in the centre of an Haversian system in compact bone. It contains a nerve to carry impulses, blood vessels to transport gases, food and wastes and a lymph duct to drain tissue fluid.
3. State four functions of bone tissue.

**Solution:**
Any four of the following:

- To serve as a firm support framework for the whole body.
- To protect such delicate structures as the brain and spinal cord.
- To serve as levers, working with attached muscles to produce movement.
- To serve as a storehouse for calcium salts, which may be reabsorbed into the blood if there is not enough calcium in the diet.
- To produce blood cells in the red marrow.

4. Tabulate two differences between tendons and ligaments.

**Solution:**
Any two of the following differences:

<table>
<thead>
<tr>
<th>Tendons</th>
<th>Ligaments</th>
</tr>
</thead>
<tbody>
<tr>
<td>Attach muscles to bones</td>
<td>Attach bones to other bones</td>
</tr>
<tr>
<td>Contain more white collagen fibres and very few yellow elastic fibres</td>
<td>Contain white collagen fibres and a network of yellow elastic fibres</td>
</tr>
<tr>
<td>Very inelastic in order to efficiently convert muscle contraction into movement of the skeleton</td>
<td>Have some elasticity to enable bending at joints</td>
</tr>
<tr>
<td>Fibre in tendons are all along the long axis for strength</td>
<td>The fibres in ligaments are woven together, not arranged longitudinally</td>
</tr>
</tbody>
</table>

5. Supply the biological term for each of these bones:

a) thigh bone
b) knee cap
c) shin bone
d) ankle bones
e) heel bone
f) upper arm bone
g) wrist bones
h) breast bone

**Solution:**

a) femur
b) patella
c) tibia
d) talus
e) calcaneum
f) humerus
g) carpals  
h) sternum

6. State four functions of the human skeleton.  

**Solution:**  
Any four of the following:

- **Protection** - protects vital organs, e.g. brain, heart, lungs  
- **Movement** - provides point of attachment for muscles, and resistance for muscle contraction (levers for locomotion)  
- **Support and structure** - gives shape to the body, e.g. facial features; supports body parts and keeps us upright  
- **Storage of minerals** - bones store minerals such as calcium and phosphate ions  
- **Red blood cells production** - long bones and flat bones contain red bone marrow to produce red blood cells  
- **Hearing** - bones in the middle ear, called the hammer, anvil and stirrup, amplify sound waves and assist in the hearing process

7. State the number of:

   a) bones in the human vertebral column  
   b) pairs of true ribs  
   c) lumbar vertebrae  

**Solution:**  
   a) 33  
   b) 7  
   c) 5

8. Study the following diagrams showing the main bones of the pectoral girdle and the human arm (forelimb) and answer the questions that follow:

**Different Types of Bones**

A B C D E F G H
a) Identify bone X.

b) Parts of some of these bones meet at certain joints. By using the letters (A–H) only, state which parts of the bones form the shoulder joint.

c) Name the type of synovial joint that is located at the following parts of the body:
   i. At the elbow
   ii. Where the lower limb joins the pelvis
   iii. In the wrist

Solution:
   a) Scapula
   b) Bone end B joins to part F
   c) i. hinge joint
      ii. ball and socket joint
      iii. gliding joint

9. The diagram below shows the legs of an athlete while he is waiting for a race to start. The letters A to F show some of the muscles as well as joints that will be used during the race.

   a) When the Starter’s gun is fired, the athlete’s right leg will straighten, pushing the athlete upwards and forwards. Which of the letters (A to F) indicate muscles that will:
      i. Relax
      ii. Contract

   b) The leg shown in the diagram has different types of joints. Which of the following letters (A to F) indicates:
      i. A hinge joint
      ii. A ball and socket joint
Solution:

a) i. B
   ii. B, C and E

b) i. D
   ii. A

10. During the race the above athlete suffered injury to his right ankle that resulted in torn ligaments. As a consequence, he was not allowed to participate in competitions for six weeks, and was only paid one third of his monthly income during this time.

- What are ligaments?
- Do you think that athletes who are unable to take part in competitions due to injury should be entitled to their full income? Give a reason for your answer.
- After six weeks the athlete found out that the knee injury was permanent. He had surgery to fit in an artificial knee, which could perform better than his original knee. Suggest why he should NOT be allowed to participate in the competitions he took part in previously.

Solution:

- Ligaments are made of connective tissue, and join bone to bone.
- Yes
  The injury may not be the athlete’s fault- it is unintentional. An athlete not being able to compete due to injury is just like being paid sick leave.
- No
  Not taking part in the competition may make their team lose. Reducing pay prevents athletes from willingly pulling out of the competitions under the pretext of injury.
  Any other logical answer.
- He will have an unfair advantage over other competitors with normal knees.

11. Skeleton and Movement – True or False? If it is false provide a reason for why you think the statement is false.

a) The skeleton’s role is to provide support, protection and capacity for movement.

b) The skeleton is divided into the axial and appendicular skeleton.

c) The axial skeleton consists of the pectoral and pelvic girdles and their attached limbs.

d) Carpals are found in the ankles and tarsals in the wrists.

e) The biceps muscle raises the arm while the triceps lowers it in an antagonistic pair.

f) Synovial liquid lubricates joints and keeps them friction free.
g) Bone joints in the cranium are examples of fibrous joints.
h) The neck contains 7 lumbar vertebrae.
i) Tendons join muscles to bone and are elastic while ligaments join bone to bone and are non-elastic.
j) Bone is composed of flexible minerals such as Calcium and Phosphate with rigid fibres of Collagen.
k) Osteocyte is another word for bone cell.

Solution:

a) True  
b) True  
c) False (should be appendicular skeleton)  
d) False (other way round carpals are in the wrist, tarsals in the ankle)  
e) False (the biceps and triceps respectively raise and lower the LOWER arm or forearm, not whole arm)  
f) True (not entirely ‘friction-free’, but close)  
g) True  
h) False (neck has cervical vertebrae)  
i) False (joining functions are correct, but tendons are inelastic and ligaments are more elastic)  
j) False (Ca and P are inflexible minerals and collagen is a flexible protein)  
k) True (but bone cells can also be called osteoblasts)

12. Compare the biceps and triceps muscles with respect to:

a) Point of origin
b) Point of insertion
c) Function

Solution:

a) Biceps and triceps both originate at the shoulder. Biceps has two tendons attached to the shoulder (two at origin), triceps has three attached to the shoulder (three at origin)
b) Biceps muscle inserts on the radius and ulna, while the triceps inserts on the ulna only.
c) The biceps contract to bend the arm at the elbow, the triceps contracts to straighten the arm at the elbow.

Check answers online with the exercise code below or click on ‘show me the answer’.
1. 2CTG 2. 2CTH 3. 2CTJ 4. 2CTK 5. 2CTM 6. 2CTN 7. 2CTP 8. 2CTQ 9. 2CTR 10. 2CTS 11. 2CTT 12. 2CTV

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Transport systems in animals

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9.3 Lymphatic circulatory system 195
9.4 Cardiovascular diseases 195
9.5 Treatment of heart diseases 196
9.6 Summary 196
9 Transport systems in animals

9.1 Overview

Time Allocation: 3 weeks (12 hours)

This chapter consists of the following sections:

1. Overview
2. Circulatory systems in animals
3. Lymphatic circulatory system
4. Cardiovascular diseases
5. Summary
6. End of chapter exercises

Introduction

In this chapter, learners will be introduced to the circulatory system in humans. The chapter starts with an introduction of different types of circulatory systems found in animals.

Learners will then spend some time studying the pulmonary and systemic circulatory systems; the internal and external structure of the heart; the cardiac cycle and the different types of blood vessels. A brief overview of the lymphatic circulatory system follows. The chapter concludes with an overview of some diseases that affect the cardiovascular system, as well as their treatments.

There are two important practicals in this chapter. In the first practical investigation, learners will need to dissect an animal heart in order to examine the structure of the heart. In the second investigation, learners will evaluate the effect of exercise on heart-rate. This activity should be conducted in the form of a scientific experiment, with an hypothesis, method, analysis of results and conclusion.

All living organisms require oxygen and nutrients, and a method of removing carbon dioxide and waste products. However, the circulatory system is not limited to the delivery of nutrients, gas exchange, and waste removal. Hormones, too, rely on the circulatory system to reach target organs, and the immune system depends on the transport of white blood cells and antibodies.
Key concepts

- There are open and closed circulatory systems. In an open circulatory system blood enters a cavity, in a closed circulatory system blood remains in vessels.
- A double closed circulation system consists of the pulmonary and systemic circulatory systems.
- The direction of blood flow is significant. In the systemic circulatory system oxygenated blood is transported to the body and deoxygenated returns to the heart. In the pulmonary circulatory system, deoxygenated blood is sent to the lungs, and oxygenated blood is returned to the heart.
- Specialised cells (sinoatrial node) send signals to the atrioventricular node to cause the atria and ventricles to contract and control the cardiac cycle and heart rate.
- The structure of blood vessels such as arteries, veins and capillaries are suited to their function.
- The lymphatic system transports lymph around the body and returns fluid to the blood circulatory system.
- The lymphatic system also plays an important role in immunity.
- Conditions and diseases of the heart and circulatory system include high and low blood pressure, heart attacks and strokes. Treatments include stents, valve replacements, bypass surgery, pacemakers, and heart transplants.

TEACHERS RESOURCE:

The following website has interactive activities that summarise different material covered in this chapter. The different activities are best done when the relevant material is covered:

http://www.kett6.net/adulteducation/heartanimations.html

9.2 Circulatory systems in animals

Transport systems are crucial to survival. Unicellular organisms rely on simple diffusion for transport of nutrients and removal of waste. Multicellular organisms have developed more complex circulatory systems. Discuss open and closed circulatory systems and single and double circulatory systems.

A simulation that shows how the human circulatory system is divided into two circuits: the systemic and the pulmonary circulatory systems: http://www.biologyinmotion.com/cardio/index.html
**FACT**

This video shows the passage of blood through the heart and around the body.

See video: 2CTW

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**TEACHERS RESOURCE:**

Circulation animation: [http://www.bbc.co.uk/schools/gcsebitesize/pe/appliedanatomy/0_anatomy_circulatorysys_rev1.shtml](http://www.bbc.co.uk/schools/gcsebitesize/pe/appliedanatomy/0_anatomy_circulatorysys_rev1.shtml)

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### Investigation: Dissecting a mammalian heart

**Aim:**

To dissect a mammalian heart (sheep or ox heart).

**Apparatus:**

- your teacher will give each group a heart to dissect
- a scalpel handle with a blade or a sharp non-serrated knife
- a sharp pair of scissors
- a pair of forceps
- gloves
- paper towel
- pictures of the external and internal views of the heart

**Method:**

1. Work in groups of four.
2. Place the heart on the dissecting board with the atria at the top and the ventricles facing downwards.
3. Carefully examine the external view of the heart. Try identify the vertical and horizontal groves on the heart. This is the position of the internal walls between the chambers of the heart.
4. Examine and note the difference in the walls of the ventricles and atria. Also note the difference in appearance between the walls of the ventricles and atria.
5. With the scalpel or sharp knife carefully cut the heart open across the left atrium.
6. Compare the thickness and the size of the right ventricle and atrium.
7. Identify the valves and examine the tendinous cords which are attached to the valves.
8. Identify the semi-lunar valves at the bottom of the pulmonary artery.
9. Now cut through the left side of the heart in the same way as you did the right side of the heart.
10. Carefully cut through the septum of the heart so that you have two halves.
Questions:

1. What is the smooth outer layer of the heart called?
2. Did you notice any fat around the heart?
3. Did you notice a difference between the atria and ventricles externally?
4. Name the blood vessels visible on the outside of the heart.
5. Compare the thickness of the walls of the atria and ventricles. Explain why they are different.
6. Explain the difference between the left and right ventricular walls.

Answers

1. Pericardium
2. Yes - fat should be present in some places, especially in the grooves.
3. Yes – the atria are much smaller than the ventricles, they have thinner muscle walls and are at the top of the heart, whereas ventricles are at the bottom.
4. Coronary arteries and veins
5. Atria have thin, flexible walls and ventricles have much thicker, stronger walls. This is because atria only have to pump blood down to the ventricles (short distance), so they do not have to be as strong as ventricles, that pump blood much further (to the lungs or the entire body).
6. The wall of the left ventricle is much thicker than that of the right ventricle, since it needs to exert greater force / be stronger. The left ventricle pumps blood to the entire body, which requires much more force than simply pumping blood from the right ventricle to the lungs, which are also in the thoracic cavity.

TEACHERS RESOURCE:

View Cardiac Magnetic Resonance imaging of a beating heart. Large magnets are used to create images of the heart inside the body, without the need for surgery.

- View from the front (upside down):
  [Four_chamber_cardiovascular_magnetic_resonance_imaging.gif](http://upload.wikimedia.org/wikipedia/commons/7/73/Four_chamber_cardiovascular_magnetic_resonance_imaging.gif)
- View from the top:
  [Beating_Heart_axial.gif](http://commons.wikimedia.org/wiki/File:Beating_Heart_axial.gif)
- View from the side:
  [Cardiac_mri_ani_sagittal_bionerd.gif](http://commons.wikimedia.org/wiki/File:Cardiac_mri_ani_sagittal_bionerd.gif)
Watch this simple simulation of how electrical activity spreads over the heart.

**TEACHERS RESOURCE:**

Simple simulation of how electrical activity spreads over the heart.

* See simulation: 2CTX

**TEACHERS RESOURCE:**

Before conducting the following activity, it may be useful to read the following resource on measuring pulse rate: http://www.nlm.nih.gov/medlineplus/ency/article/003399.htm

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**Investigation: Investigating heart rates before, during and after strenuous exercise**

**Aim:**

To investigate your heart rate before, during and after strenuous exercise

**Apparatus:**

- stopwatch
- pen and paper for recording

**Method:**

1. Work in pairs on the field and ensure you have a stop watch.
2. One partner performs the experiment and the other records the results. Partners then swap roles.
3. Take the resting pulse rate before exercising.
4. One partner runs quickly around the field twice.
5. Immediately after the run take his/her pulse.
6. Continue to take his pulse every minute for 5 minutes.
7. Record the results and plot a graph using the data pertaining to you.

**Results:**

Record your results here:
## Results:

Learners should have a resting pulse that is significantly lower than the pulse rate after running around. Check that if they have taken their pulse for 30 seconds x 2, all readings should be EVEN numbers. In the minutes after running, pulse should gradually return to resting pulse rate. Most teenagers should have a resting pulse around 60 – 84 beats per minute.

### Graph to show changes in pulse rate before, during and after exercise

- Graph should have Time (minutes) on horizontal axis and Pulse rate (beats per min) on the vertical axis.
- Both axes must go up in equal intervals along the entire length.
- Resting pulse is shown as a dotted line parallel to the horizontal axis.
- Graph should start ON resting pulse and go up, then gradually back down to resting pulse rate.

### Conclusions:

Write your conclusion.

**Conclusion:**

Pulse rate increases when exercise is done, then gradually returns to resting pulse after the exercise. (Learners may notice that individuals who are fit return to resting pulse FASTER than unfit individuals.)

### Questions:

1. Write a hypothesis for this investigation.
2. Write down the independent variable.
3. Write down the dependent variable.
4. Name ONE factor that must be kept constant during this investigation.
5. Write down TWO ways in which the accuracy of this investigation can be improved.

6. What conclusions can be made about your cardiovascular fitness?

7. Explain why the heart rate increases during exercise.

**Answers**

1. Pulse rate during exercise will be higher than resting pulse rate.

   Accept ANY hypothesis, as long as it is:
   - geared towards the aim of the investigation
   - written as a statement, not a question
   - written in the FUTURE tense
   - a clear expectation of what will be found – it does not have to be correct

2. There are TWO independent variables. The main one is Resting, Doing Exercise and Recovering (or Type of Activity), but time can also be seen as a secondary independent variable.

3. The dependent variable is Pulse Rate.

4. There are several variables that need to be controlled:
   - The same learner needs to be used when taking the pulse before and after exercise.
   - Both learners in a group must do the same exercise (run around field twice).
   - Pulse must be taken before and immediately after exercise.
   - Pulse must be taken exactly at one minute intervals during recovery.
   - Always take pulse as 30 seconds x 2 or over a full minute.

5. Several things may be done:
   - Repeat the investigation again two or more times with one learner and obtain an average. Use large groups of individuals in a certain age group and average their results.
   - Keep measuring pulse rate until it returns to resting rate – this may take longer than 5 min in some learners.
   - Use a heart rate monitor for greater accuracy with pulse rates.
   - Control more variables in order to get similar groups of people – all the same age, same gender, same fitness level, same mass approximately etc.

6. The conclusions MUST be based on the results obtained and will probably also indicate relative fitness levels – fit individuals tend to recover faster after exercise. It must also be linked to the original hypothesis and state whether this hypothesis is accepted or rejected. Learners must be encouraged to evaluate the hypothesis and should be told that it is perfectly acceptable for the hypothesis to have been incorrect – they must NOT go back to it and change it.
7. Heart rate increases due to the higher rate of cell respiration that is required to provide the necessary energy during running. The cells demand MORE oxygen and release MORE carbon dioxide than normal, so breathing and heart rate both speed up to deliver the greater amount of O₂ and remove the greater amount of CO₂ formed.

TEACHERS RESOURCE:

Interactive diagram illustrating arterial and venous structure:


9.3 Lymphatic circulatory system

The lymphatic system is part of the circulatory system, comprising a network of inter-connected tubes known as lymphatic vessels that carry a clear fluid called lymph towards the heart. The lymphatic organs play an important part in the immune system. The lymphatic system transports the white blood cells which are important in the immune response against pathogens.

TEACHERS RESOURCE:

Use this resource to learn more about the lymph system and to select short informative videos to show to the class.


Watch this video on lymph.

See video: 2CTY

9.4 Cardiovascular diseases

Cardiovascular diseases affect the heart or blood vessels (arteries, veins and capillaries). In this section learners will study the causes of heart attacks and strokes as well as how these may be treated. Learners will also study the causes of high and low blood pressure and how these have an effect on our well-being. Learners will finally discuss the types of treatments that are available such as stents, valve replacements, bypass surgery, pacemakers and heart transplants.
Heart diseases and heart attacks

See video: 2CTZ

Thrombo-emboli and thromboembolisms

See video: 2CV2

Stenosis, ischemia and heart failure

See video: 2CV3

Stroke

See video: 2CV4

9.5 Treatment of heart diseases

Treatments of heart disease http://www.pharmadynamics.co.za/

Watch a video of the placement of a stent into a coronary artery

See video: 2CV5

How Bypass surgery is done

See video: 2CV6

9.6 Summary

- Nutrients and oxygen are required by cells for cellular respiration. These are transported by blood to the various cells.
- Carbon dioxide and other waste products need to be transported from the cells to the exterior. This is also transported via blood.
- There are open and closed circulatory systems. In an open circulatory system blood enters a cavity, in a closed circulatory system blood remains in vessels.
- A double closed circulation system consists of the pulmonary and systemic circulatory systems.
- Blood is pumped through the heart under high pressure to the various parts of the body.
- The right side of the heart receives deoxygenated blood from the body via veins and sends it to the lungs to be oxygenated.
- The left side of the heart receives oxygenated blood from the lungs and
sends it via arteries to all parts of the body.
- Specialised cells (sinoatrial node) send signals to the atroventricular node to cause the atria and ventricles to contact and control the cardiac cycle and heart rate.
- The lymphatic system is composed of lymph vessels, lymph nodes, and organs.
- Lymph vessels assist the circulatory system and all the cells of the body by removing wastes, germs and excess water from the tissue fluid.
- There are many diseases that affect the heart and circulatory system and many treatments are available.

**Exercise 9 – 1: End of chapter exercises**

1. The following diagrams show the heart during the cardiac cycle. The arrows represent the flow of blood. Study the diagrams and answer the questions that follow:

   a) Identify the structures labelled A and B respectively.
   b) Name and explain what happens in each of the phases of the cardiac cycle represented in:
      i. Diagram I
      ii. Diagram II
      iii. Diagram III

   **Solution:**

   a) A: semi-lunar valve; B: Bicuspid or mitral valve
   b) i. Diagram I: **General diastole:** Blood enters the atria from the venae cava (right atrium) and from the pulmonary veins (left atrium). The entire heart is relaxed.
      ii. Diagram II: **Atrial systole:** Both atria contract and blood is pumped from the atria through the bi-/tricuspid valves to the ventricles. The bi-/tricuspid valves open easily downward to allow blood through.
iii. Diagram III: **Ventricular systole:** Both ventricles contract and pump blood upwards into the pulmonary artery (right ventricle) and aorta (left ventricle). The bi-/tricuspid valves close (because of chordae tendinae preventing them from opening backwards, so blood does not return to the atria. The semilunar valves open at the base of the major arteries to allow blood into them.

2. Loss of a lot of blood, vomiting and diarrhoea often causes a decrease in blood volume. As a result, blood cannot move normally around the body, as blood vessels are not completely full. The tissues do not get enough blood, leading to possible death of cells and hence damage to organs.

   a) Explain why severe vomiting and diarrhoea would cause a decrease in the blood volume.
   
   b) What is the relationship between blood volume and blood pressure?

**Solution:**

   a) Both vomiting and diarrhoea involve loss of large amounts of water from the body. The water lost from the digestive system cannot be absorbed into the blood, and as a result, blood plasma volume drops.
   
   b) As blood volume increases, blood pressure increases. They are thus positively correlated. If blood volume decreases, blood pressure decreases. This is because the lower volume in the vessels exerts less pressure on the vessel walls.

3. Read the passage below and then answer the questions based on it.

When the ventricles of the heart pump blood into the arteries, the pressure of the blood in the arteries is high. This is called systolic pressure (average 120 mm Hg). When the heart muscle relaxes, the pressure in the arteries is much less. This is called diastolic pressure (average 80 mm Hg). The average blood pressure of a healthy person is 120 over 80.

It is normal for a person’s blood pressure to differ slightly from the average. If blood pressure is too high or too low there is medication that can be used to control this. High blood pressure is called ‘hypertension’ and low blood pressure is called ‘hypotension’. There are several contributing factors to heart disease, namely hypertension, strokes, lack of exercise, smoking, rich fatty diets, obesity and diabetes.

Research has shown that 25% of the South African population suffer from hypertension and that this is on the increase. The treatment for hypertension is expensive and has a great impact on the health system and on the economy.
a) Explain what causes the pressure in the arteries to rise and fall.
b) Why is it essential that blood pressure in the capillary vessels be much lower than that in the artery?
c) List THREE reasons why heart disease is on the increase in South Africa.
d) Suggest ONE way in which the government could reduce the number of people with heart disease.

Solution:

a) Blood pressure rises and falls because of the contraction and relaxation of the heart. In particular, it is ventricular systole and ventricular diastole that changes arterial blood pressure.

b) Low blood pressure in the capillaries slows blood down, so it gives enough time for diffusion of substances between the blood and cells. The walls of capillaries are also much thinner than those of arteries (squamous epithelium only), so they could rupture / break if the blood pressure is too high in them.

c) Any three of the following:
   - Increasing obesity
   - High rates of diabetes associated with obesity
   - Diets rich in fats and red meat – having a braai often
   - Greater intake of fast food, e.g. fried chicken and burgers with chips
   - Lack of enough exercise amongst most people even after hours
   - A more sedentary lifestyle behind computers / desks all day
   - Smoking

d) Any one of the following:
   - Education programs to inform people of the link between diet, obesity and heart disease.
   - Make gym membership cheap [or free at government owned gyms].
   - Encourage sport at school or make it compulsory.
   - Clinics can hand out free or very cheap medication to treat heart disease, so it won’t get worse.
   - Remove all taxes on fresh fruit and vegetables.
   - Add extra taxes on fast food.
   - Etc – there are several others. Accept anything relevant.

4. Study the diagrams which show two cross-sections of mammalian blood vessels and answer the questions that follow:
a) Which vessel, A or B is the artery?
b) Provide TWO reasons for your answer to the previous question.
c) Which vessel carries blood at low pressure?
d) Provide an explanation for your answer to the previous question.
e) Identify the parts numbered 1 to 4.
f) How do capillaries differ from larger blood vessels?
g) In which vessel, A or B would you expect to find valves?
h) What is the function of the valves in the previous question?
i) Name the blood vessel that:
   i. carries deoxygenated blood from the heart to the lungs
   ii. carries oxygenated blood from the heart for systemic circulation
   iii. carries blood from the digestive system to the liver

Solution:

a) B

b) • It stays round when drained of blood (doesn’t collapse).
   • It has a thicker muscle wall than the vein.

c) The vein / A

d) Blood has just left the capillaries when it enters veins, so it had been travelling slowly and at much lower pressure than in arteries. When blood enters the veins (wider than capillaries), the pressure drops even further. Blood in the veins is also not under direct pressure from the beating of the heart, so the pressure is lower than in arteries.

e) • 1 = fibrous layers / connective tissue
   • 2 = squamous epithelium / endothelium layer
   • 3 = smooth involuntary muscle layer
   • 4 = lumen

f) Capillaries:
   • Are much narrower than large blood vessels
   • Have no muscle or connective tissue in their walls (have extremely thin walls made only of squamous epithelium)
- Are highly branched and have a very large surface area
- Never have semi-lunar valves.

g) A

h) They prevent backflow of blood, as most of the transport of blood in veins occurs against gravity – e.g. from the legs and lower torso towards the heart.

i) i. Pulmonary artery
   ii. Aorta
   iii. Hepatic portal vein

5. Study the diagram of the lymphatic system and answer the questions that follow:

![Diagram of the lymphatic system]

a) Name the components of the lymphatic system.
b) Identify the:
   i. blood vessel numbered 3
   ii. duct numbered 4
   iii. structure numbered 6
c) Name TWO factors that assist movement of the lymph fluid.
d) State FOUR functions of lymph in the human body.
Solution:

a) Lymph capillaries, lymph ducts with semi-lunar valves and lymph nodes.

b) Identify the:
   i. 3 - Left sub-clavian vein
   ii. 4 - Thoracic duct
   iii. 6 - Lymph nodes

c) Any two of the following:
   - Movement of voluntary muscles / skeletal muscles (any body movement) – this creates pressure on the lymph ducts that run in between the muscle fibres.
   - Semi-lunar valves prevent lymph backflow, and since liquids are incompressible, if it is constantly absorbed from between the cells into lymph ducts, any new lymph moving into the ducts will cause existing lymph to keep moving towards the heart.
   - Breathing causes the development of a low pressure in the chest cavity, which creates a slight suction on lymph ducts to carry lymph towards the thorax.

d) Any four of the following:
   - Transports blood plasma with plasma proteins back to the blood stream.
   - Transports absorbed lipids from the villi to the blood stream.
   - Lymph nodes manufacture white blood cells / lymphocytes as part of immunity or defense against pathogens or disease.
   - Lymph transports these white blood cells to the blood stream.
   - It drains tissue fluid from between cells, containing dissolved wastes that need to get to the blood stream.

6. Multiple-choice questions

a) The left side of the heart:
   i. transports deoxygenated blood to the lungs
   ii. is more muscular than the right-hand side
   iii. has a built in pacemaker
   iv. is a mixture of oxygenated and deoxygenated blood

Solution:
   ii

b) Angina is:
   i. a panic attack caused by the release of too much adrenalin
   ii. a fatal heart attack
   iii. a serious heart cramp caused by a lack of oxygen in the cardiac muscles
   iv. the result of a clot in the blood vessels going to the brain
c) The stage in the cardiac cycle when the blood is pumped into the aorta and the pulmonary artery is:
   i. atrial systole
   ii. ventricular diastole
   iii. general diastole
   iv. ventricular systole

**Solution:**

iv

d) The valve between the left ventricle and the left atrium of the heart is called the:
   i. mitral valve
   ii. tricuspid valve
   iii. aortic semi-lunar valve
   iv. pulmonary semi-lunar valve

**Solution:**

i

e) The accompanying graph indicates that changes in adrenalin secretion and the pulse rate, before, during (0 to 10 minutes) and after a cigarette was smoked. Use the given graph to indicate which one of the following deduction is a valid interpretation of the graph.

- Smoking directly causes an increase in the basal metabolic rate.
- The cardiac muscles relax during smoking.
iii. Smoking directly stimulates the pulse rate.
iv. There is no relationship between adrenalin secretion and pulse rate.

**Solution:**

iii

f) Explain why there is a relationship between smoking and adrenalin secretion.

**Solution:**

*Smoking reduces the amount of oxygen available for diffusion at the lungs, so less oxygen gets absorbed and blood is oxygenated to a lesser degree. This causes the delivery of less oxygen to the cells, and this stimulates the heart rate via adrenalin, so that pulse rate increases in an effort to deliver enough oxygen to cells.*

7. Study the accompanying diagram of the ventral view of the external structure of the heart and answer the questions that follow.

![Diagram of the heart](image)

a) Label parts numbered 1, 2, 7, 8.2 and 9.2

b) What type of blood (oxygenated or deoxygenated) is transported by blood vessels 1, 3 and 6?

c) What possible danger to human health exists if the lumen of structure 4 is obstructed with a thick layer of cholesterol?

d) Discuss what happens during ventricular systole in the cardiac cycle.

**Solution:**

a) 
- 1 - aorta
- 2 - coronary artery
- 7 - inferior vena cava
- 8.2 - (right) pulmonary artery
- 9.2 - pulmonary veins

b) 
- 1 - oxygenated blood
- 3 - deoxygenated blood
• 6 - deoxygenated blood

c) Blood cannot flow freely as it leaves the heart muscle, so blood backs up at the obstruction and flows away in front of it. This causes a fairly large section of heart muscle to be without adequate blood supply and the heart cells may die from lack of oxygen and accumulation of carbon dioxide.

d) Both ventricles contract simultaneously. Blood is pumped from the left ventricle into the aorta and to the entire body, and from the right ventricle into the pulmonary artery to the lungs. The mitral and tricuspid valves close to prevent backflow into the atria, being prevented from opening backward by chordae tendinae. The semilunar valves at the base of the aorta and pulmonary artery open and allow blood into these major arteries.

8. Study the diagrams below illustrating the structure of different types of blood vessels. Graph A shows the average blood pressure in different blood vessels in the human body, while graph B indicates the rate of blood flow in the different blood vessels.

a) Tabulate three structural differences between an artery and a vein.
b) Study graph B and give a reason why the rate of blood flow in the capillaries is very low.
c) What is the systolic and diastolic pressure in the aorta? (graph A)
Solution:

<table>
<thead>
<tr>
<th>Artery</th>
<th>Vein</th>
</tr>
</thead>
<tbody>
<tr>
<td>thick muscle wall</td>
<td>thin muscle wall</td>
</tr>
<tr>
<td>round in cross section</td>
<td>flatter in cross section</td>
</tr>
<tr>
<td>no valves, except bases of</td>
<td>semi-lunar valves present at</td>
</tr>
<tr>
<td>pulmonary artery and aorta</td>
<td>regular intervals</td>
</tr>
</tbody>
</table>

NB: Do not accept the type of blood they carry, or direction of blood, i.e. to/from the heart as these are not structural differences.

b) The diameter of capillaries is very narrow, and has high resistance. Therefore blood flows more slowly through them.

c) Systolic - 120 mm Hg; Diastolic - 80 mm Hg

9. The accompanying diagram represents the basic human blood circulation. Study the diagram and answer the questions.
a) Name the chambers of the heart illustrated as R and T.

b) Name the arteries indicated as I and K. (organ C is the liver and organ E is the kidney)

c) Name the vein indicated as J.

**Solution:**

a) \( R = \) right atrium; \( T = \) left ventricle 

b) \( I = \) hepatic artery; \( K = \) renal artery 

c) \( J = \) hepatic portal vein 

10. Answer the following questions with a word or phrase that corresponds to the description given.

a) The membrane surrounding the heart.

b) The valve situated between the left atrium and left ventricle.

c) The phase in the cardiac cycle when the atria contract.

d) The name of the artery taking deoxygenated blood to the lungs.

e) The blood circulatory system that supplies the heart muscle with oxygenated blood.

f) The disorder / condition that results from a blockage in a blood vessel in the brain.

g) The instrument used to measure blood pressure.

h) The blood system that supplies oxygen to body cells

i) The structure that separates the left and right sides of the heart.

j) The ability of the heart to contract at its own inherent rhythm.

k) The layer found on the inside of veins.

l) The blood vessel connecting the stomach and intestine to the liver.

m) Veins that have lost their elasticity and form small sacs of blood.

n) The smallest blood vessels in the body.

o) The pacemaker of the heart

**Solution:**

a) pericardium 

b) mitral valve / bicuspid valve 

c) atrial systole 

d) pulmonary artery 

e) coronary circulation 

f) stroke 

g) sphygmomanometer 

h) systemic circulation 

i) septum 

j) automatism 

k) endothelium / squamous epithelium
| l) hepatic portal vein                      |
| m) varicose veins                           |
| n) capillaries                               |
| o) SA node / sinoatrial node                |

Check answers online with the exercise code below or click on 'show me the answer'.

1. 2CV7  2. 2CV8  3. 2CV9  4. 2CVB  5. 2CVC  6a. 2CVD  6b. 2CVF  6c. 2CVG  6d. 2CVH  6e. 2CVJ  6f. 2CVK  7. 2CVM  8. 2CVN  9. 2CVP  10. 2CVQ

[www.everythingscience.co.za](http://www.everythingscience.co.za)  [m.everythingscience.co.za](http://m.everythingscience.co.za)
Biospheres to ecosystems

10.1 Overview
10.2 Biosphere
10.3 Biomes
10.4 Ecosystems
10.5 Energy flow
10.6 Nutrient cycles
10.7 Ecotourism
10.8 Summary
10.1 Overview

Time Allocation: 6 weeks (24 hours)

This chapter consists of the following sections:

1. Overview
2. Biosphere
3. Biomes
4. Environment
5. Ecosystems
6. Energy flow
7. Nutrient cycles
8. Ecotourism
9. Summary
10. End of Chapter Exercises

Introduction

In this chapter learners are introduced to some of the interactions that occur in nature, and to the terminology that describes them. The interaction of organisms with each other, and with their environment, is known as the study of ecology. Learners will grasp the meaning of these terms and concepts by using them to describe the familiar contexts of both Southern Africa and their local area. This section builds on the knowledge that was taught in the Senior Phase, and links to Grade 11 across all the appropriate strands.

Learners will revisit the concept of the biosphere and the inter-connections that occur between the components of global ecosystems (the hydrosphere, lithosphere and atmosphere).

Learners will then be introduced to the terrestrial and aquatic biomes of Southern Africa. They should understand how climate, soil types and vegetation influence the organisms found in each biome. The learners also need to know the location of the different biomes in South Africa.

The concept of environment will be introduced and the effect of human activities on the environment will be discussed. The concept, structure and functioning of ecosystems needs to be discussed in detail with the learners. This will include a detailed descriptions of abiotic and biotic factors.
Energy flow through the ecosystems and the relationship to trophic structure is also covered. Here the learners are introduced to the different trophic levels. Skills in drawing flow diagrams can be included in this section. Learners will also learn how all the important nutrients are cycled through the environment.

Finally ecotourism and its impact on the economy will be discussed. The ethics of responsible ecotourism and opportunities that arise from it can be debated in a class discussion.

Key concepts

- The biosphere consists of all the living organisms on Earth.
- The biosphere interacts with the hydrosphere, the lithosphere and the atmosphere.
- Biomes are natural habitats for flora and fauna that extend to both aquatic and terrestrial regions.
- The location of biomes across southern Africa, and in South Africa itself, is governed by climate, soils and vegetation.
- The environment consists of living (biotic) and non-living (abiotic) components which interact.
- The ecosystem brings together the various interactions between living organisms.
- Abiotic factors affect the nature of an ecosystem. Such factors include physiographic factors, soil quality, light, temperature, water, atmospheric gases and wind.
- Biotic factors that affect the ecosystem include producers, consumers and decomposers.
- Energy flows through the trophic levels of an ecosystem tracing the relationships that exist in an ecosystem.
- Oxygen, carbon, nitrogen and water also cycle through the ecosystem.

item Ecotourism presents both opportunities and challenges for the preservation of our ecosystems.

\begin{array}{c}
\text{atom} \rightarrow \text{molecule} \rightarrow \text{cell} \rightarrow \text{tissue} \rightarrow \text{organ} \rightarrow \text{system} \rightarrow \text{organism} \rightarrow \text{ecosystem}
\end{array}

10.2 Biosphere

The biosphere refers to all living organisms on Earth and is often called the global ecosystem. The biosphere interacts with other spheres, such as the lithosphere, atmosphere and hydrosphere. Each of these spheres is discussed briefly.
In this section learners will focus on summarising the importance of terrestrial and aquatic biomes of Southern Africa. They will study how climate, soil and vegetation influence the organisms found in each. The location of the different biomes in South Africa will also be introduced.

Activity: Burning of grassland

Aim:

Compare and analyse the advantages and disadvantages of burning grassland.

Materials:

- Internet
- articles
- books

Instructions:

1. Using these resources, tabulate the advantages and disadvantages of burning grassland.
2. Remember to cite your references correctly.

THIS ACTIVITY IS OPTIONAL

Answers

Below are a couple of advantages and disadvantages related to the burning of grassland. However, learners may also come up with different examples, and as long as they can cite their source, their answers should be accepted.

<table>
<thead>
<tr>
<th>Advantages</th>
<th>Disadvantages</th>
</tr>
</thead>
<tbody>
<tr>
<td>Some types of seeds actually germinate better after a fire, as their hard seed pods crack open. Species that were being crowded or overwhelmed by other species have a chance to recolonise.</td>
<td>Valuable seeds may be destroyed and then they cannot germinate.</td>
</tr>
<tr>
<td>Animals and plants are injured, damaged or killed. Fire kills indiscriminately and may kill endangered plant / animal species.</td>
<td></td>
</tr>
<tr>
<td>Advantages</td>
<td>Disadvantages</td>
</tr>
<tr>
<td>---------------------------------------------------------------------------</td>
<td>------------------------------------------------------------------------------</td>
</tr>
<tr>
<td>Plants that grow aggressively (weeds) are restricted.</td>
<td>Organisms in the soil are destroyed, humus is reduced. Loss of nitrogen and sulphur from the soil.</td>
</tr>
<tr>
<td>Younger plants provide better nutrition (green grass after a severe winter). Fire destroys unpalatable grass types and allows new palatable (better tasting) grass to grow out.</td>
<td>Grasses are weakened if burning is practised or occurs at the wrong time.</td>
</tr>
<tr>
<td>Blackened soil heats up quickly in the sun and speeds up the growth of new plants.</td>
<td>Destroys the soil cover and can lead to erosion.</td>
</tr>
<tr>
<td>Destroys insect pests, ticks and parasitic worms.</td>
<td>Fires may get out of control and burn useful farmland or endanger lives and property. Air pollution and smoke may irritate the lungs of people and animals.</td>
</tr>
<tr>
<td>Phosphate in the ash acts as soil fertiliser and improves plant growth.</td>
<td></td>
</tr>
</tbody>
</table>

**Project: Poster project to illustrate the role players in a forest ecosystem**

**Instructions:**

1. Bring pictures of animals, trees and other plants to class.
2. The teacher will divide the class into groups.
3. Each group will prepare a poster to illustrate the mutual dependence of the trees, other plants and animals.
4. Each group must present their poster to the rest of the class.
5. Answer the following questions / follow the instructions arising from the class discussion:

**Questions:**

1. Supposing the tree on your poster was to fall over.
   - Which organisms would die?
   - Which organisms would move away?
   - Which organisms would increase in number?
2. Describe the role played by trees in an ecosystem.
3. Ecologically speaking, why is it bad practice to rake up leaves under trees?
4. Name three more examples where humans harm ecosystems.
5. Identify components of the ecosystem, including each trophic level. Represent this in the form of a diagram.

**THIS ACTIVITY IS OPTIONAL**

The answers to the questions will depend on the poster the learners have done. Each poster should have different answers to the questions.

**Answers**

1. If the tree falls:
   - The following organisms would die:
     - Probably the tree itself, if it was still alive.
     - Also young birds in nests in the tree.
     - Anything on which the tree falls.
   - The following organisms would move away:
     - Adult birds that were nesting or sleeping in the tree.
     - Any animals that used the tree as a food source or habitat.
     - Animals in the immediate vicinity of the tree (for a short while, anyway).
   - The following organisms would increase in number:
     - Fungi and bacteria that would decompose the fallen tree.
     - Ants and termites, that may use the dead tree as food source.
     - Probably mosses and lichens that may grow on the surface of the tree.
     - Smaller green plants in the area, as they would now get more sunlight.

2. The role played by trees in an ecosystem:
   - Play a role in the gas balance of the atmosphere (remove CO2 and produce O2).
   - Form a habitat for many animals, e.g. squirrels, insects and birds.
   - Many trees form fruits that act as a food source for animals, while leaves are eaten by herbivores. Nectar is eaten by bats, bids and insects.
   - Provide shade and shelter against hail, sleet, snow and rain.
   - Prevent soil erosion by holding back soil when it rains
   - Thick stands of mangrove trees prevent much of the damage caused by tsunamis.
   - They provide a screen against harsh winds
   - Fallen leaves decompose to form compost, enriching the soil.
• Trees absorb much water and reduce surface runoff, allowing soil water sources to replenish slowly.
• There are several other learner-dependent answers.

3. Leaves should be left to decompose slowly, releasing nutrients into the soil. This provides fertiliser to enrich the soil with humus and recycles nutrients in nature.

4. Examples where humans harm ecosystems:
   • Uncontrolled burning / accidental damage to ecosystems.
   • Deliberate burning as a form of deforestation.
   • Pollution in all its forms, including litter.
   • Noise due to people, machines and vehicles unsettles animals.
   • Planting invasive alien plants / not removing them from ecosystems destroys the natural species balance of an area.
   • Monoculture removes biodiversity, e.g. on farms / golf estates
   • There are several other learner-dependent answers.

Learner dependent answer. This may be shown as a food pyramid.

---

**Project: Research fynbos in South Africa**

The astonishing richness and diversity of the Western Cape’s natural resources is matched only by the resourcefulness and diversity of its many people. Historical patterns of unsustainable use of resources have led to the Cape Floristic Region (CFR) being listed as one of the world’s threatened bioregions, and the scars are deeply etched in the land and its people.

Western Cape residents are exploring new and sustainable ways to value and benefit from these globally important assets.

South Africa’s Cape Floristic region is legendary, and the unique nature of the fynbos biome has been celebrated by biologists, conservationists, development experts, and ecologist worldwide.

(Adapted from speech by Tasneem Essop the Western Cape Provincial Minister for Environment, Planning and Economic Development)

**Instructions**

Write an essay on the fynbos biome and discuss the following aspects:

1. What is the meaning of the term “fynbos”?
2. Identify features of families/indicator species that make up this vegetation
type.
3. Describe its ecological role in the environment.
4. Describe the environmental impacts of destroying this type of vegetation.
5. Describe the economical importance of fynbos for the people of the Western Cape.
6. Describe management strategies involved in protecting it.

**THIS ACTIVITY IS OPTIONAL**

Essay may be written or typed. Marks will be awarded for originality and own interpretation. Include a bibliography of three or more resources.

The exact content of such an essay cannot be specified and is up to the individual teacher. The following may serve as a guideline only:

**Fynbos Biome**

**Definition**

Fynbos is the natural shrubland or heathland vegetation occurring in a small belt of the Western Cape of South Africa, in coastal and mountainous areas with a Mediterranean climate. The soil is acidic and nutrient-poor and while the climate is marked by cold wet winters and hot dry summers. It is the smallest of the world’s six floral kingdoms.

**Indicator Species**

Small, fine-leaved, low-growing and tough evergreen plants. Fynbos includes legumes and bulbous plants (like Watsonias and Chincherinchees), but the three main / indicator species are **Ericas, Restios** and **Proteas**.

1. **Ericas** Ericas are related to European heathers - over 600 species, of which 100 rely on sunbirds for pollination. All are noted for their flowers. These are either open or closed bells or tubes that vary from a pinhead to about 6cm. Most are small, some are smooth, some hairy and some covered in a sticky secretion. Colours cover the spectrum, except for blue.

2. **Restios** Restios are reed or rush-like plants. They are found in dense stands in areas of poor drainage. Being hardy, they are not grazed, but locals harvest them for thatching.

3. **Proteas** Proteas are among the oldest flowering plants and come in many shapes and sizes. The most familiar are the Sugarbushes, with up to a hundred small flowers clustered together to create magnificent heads of various sizes. This also includes Conebushes, notably the widespread Geelbos and the Sunshine cone bush, which grows only on the windswept salt flats. Pincushions, the third species in the group, may be tiny, low-lying and inconspicuous or large, tree-like plants. They produce a jelly-like substance irresistible to ants.
Ecological role

This biome can’t support large animals due to lack of enough nitrogen, but the area has many smaller animals like baboons, klipspringers, grysbok, dassies, mongooses and mice. Many endemic sunbirds are found here, also highly endangered butterfly species, like those whose larvae actually eat ants and live inside the ant colonies. The geometric tortoise, the world’s second rarest tortoise, is found only here, as well as several endangered frog species.

Biological impact of destruction

Again, possible answers vary widely. They should mention the loss of biodiversity, the threat to our natural heritage, possible cures for disease in plants that have not yet been studied scientifically, the loss of ecotourism and the jobs / income associated with this, the fact that extinction is forever and cannot be reversed, etc.

Economic impacts of this area for people

- Products such as rooibos tea and honeybush tea are grown here.
- Buchu plants provide oil for medicines and perfume.
- Many fynbos flowers are exported in fresh / dry form, as they last so long.
- Area provides recreational and relaxation opportunities.
- Huge numbers of research opportunities exist in the fynbos area.
- The natural beauty of the area cannot be overemphasized.
- There are several others – accept anything relevant.

Management strategy and Protection

- Removal of alien plants like pine trees, vines and oaks.
- No developments like roads / power lines may happen here without approval.
- No agriculture will be allowed.
- No picking of flowers or removal of any plant parts.
- Encourage ecotourism to generate income and create jobs.
- Discourage the sale of curios, like shells of geometric tortoises for key rings.
- Several other relevant points may be accepted.

Below is a list of other miscellaneous facts that students may choose to include in their essays:

- Fynbos, meaning “fine bush”, is a unique and strikingly beautiful group of flora endemic to a small section of the Western Cape of South Africa.
• Fynbos grows in a 100-to-200-km-wide coastal belt stretching from Clanwilliam on the West coast to Port Elizabeth on the Southeast coast forms part of the Cape floral kingdom, where it accounts for half of the surface area and 80% of the plant varieties.

• The fynbos in the western regions is richer and more varied than in the eastern regions of South Africa.

• Of the world’s six floral kingdoms, this is the smallest and richest per area unit. The diversity of fynbos plants is extremely high, with over 9000 species of plants occurring in the area, around 6200 of which are endemic, i.e. they do not grow anywhere else in the world.

• Soil is made of rock and sandstone.

• Fire is required for seed germination and is also important to clear accumulated growth.

• Ants are important for seed dispersal and birds assist in pollination.

• Other animals found in the fynbos biome are the cape golden mole, geometric tortoise and ostrich.

No marks should be awarded for plagiarism.

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Activity: Biomes Advertisment

Aim:

Getting to know the biomes of South Africa.

Materials:

• posters
• maps
• reference books
• adverts
• brochures
• Internet

Instructions:

You work for an Advertising Agency that is bidding for the account of a top travel agency. The bid includes designing a full page advert (A4) for the Getaway Magazine. Presentation, appeal and accuracy will therefore be of top priority. Study some advertisements for ideas.

The travel agency has specified that they would like the following to be included in the ad, which is geared towards people looking for a different and fascinating holiday in a specific biome:
1. A region in the biome of your choice, including cities and/or towns worth a visit
2. Climate (of interest to tourists)
3. Well-known geographical features in the region
4. Mention of some interesting wildlife (i.e. birds, animals, plants) that may be seen
5. Pictures
6. Tour dates
7. The name of the travel agency, with contact information

This is an **OPTIONAL ACTIVITY** that teachers may include if they want to. Assessment will be based on the fulfilment of the criteria given and may require the assistance of a member of the Language and /or Art department of the school, to ensure that the adverts are assessed for scientific accuracy, as well as artistic appeal and visual impact. It is recommended that a rubric be drawn up to guide assessment, such as the example given below. The teacher just ticks the relevant box and allocates the mark above that column:

**Rubric to assess the biome poster**

<table>
<thead>
<tr>
<th>Criteria to be assessed</th>
<th>3</th>
<th>2</th>
<th>1</th>
<th>0</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Name of biome:</strong> Assess for impact and relevance (2)</td>
<td></td>
<td></td>
<td>X</td>
<td></td>
</tr>
<tr>
<td><strong>Climate:</strong> Clearly and accurately described (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Geographical features:</strong> Accuracy and relevance taken into account (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Wildlife:</strong> Accuracy, not overly detailed, flora AND fauna (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Pictures:</strong> – important: double marks Assess colour, layout, clarity, size, relevance, captions given (6)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Tour dates:</strong> Clearly indicated, all details present, correct size (3)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td><strong>Agent details:</strong> All given? Check carefully! (3)</td>
<td></td>
<td></td>
<td></td>
<td>X</td>
</tr>
<tr>
<td><strong>Overall impression:</strong> (2)</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

**Total out of 25 marks:**
Project: Biome Poster

The following activity is to be done in groups of four.

Instructions

1. Brainstorm a suitable set of criteria for assessment for poster and verbal report
2. Select one biome from the list given and do the following:
3. Use suitable references to obtain as much information as possible on the plant and animals found in your selected biome.
4. Make notes about the climate, landscape, flora and fauna, stating how some of these are adapted to their environment.
5. Design an attractive poster to illustrate the landscape as well as the dominant plants and animals that make up a food chain.
6. Display your poster on the classroom wall and each person of the group is to give a verbal presentation on an aspect of the biome you studied.

THIS IS AN OPTIONAL ACTIVITY

It is suggested that a rubric similar to the above be drawn up for assessment of the project. Such rubrics go a long way in standardising the assessment for different projects and they ensure that learners are given adequate feedback about what was correct / wrong about their project.

All teachers who have learners in this grade should come together and have a brainstorming session themselves, deciding on what the criteria are they will assess and what aspects will be taken into account within each criterion. The more clearly the criteria and sub-topics are defined in the beginning, the better. This cannot be over-emphasised.

It should be made clear to learners that group work DOES NOT involve one or two members doing all the work and others sitting back as spectators. ALL of them have to get involved and make a contribution to the project. The teacher may ask that they allocate specific tasks, e.g.

- **ALL**: Decide on which biome to select and compile the food chain at the end.
- **Person 1**: Collect pictures and information on plants of the area.
- **Person 2**: Collect pictures and information on animals of the area.
- **Person 3**: Collect pictures and information on climate and landscape.
- **Person 4**: Design the poster and put it together.
- **ALL**: Each member gives a verbal report on one aspect of this biome (max 1-2 minutes each).
The environment refers to everything that surrounds us, including the place where we live. We usually use the term ‘environment’ to refer to the physical aspects of our surroundings, which may be living (biotic) or non-living (abiotic). However it may also refer to the biotic aspects of our surroundings.

10.4 Ecosystems

An ecosystem is a complex system that consists of all the living organisms in a particular area, as well as the environment with which the organisms interact. The living organisms and non-living components of the ecosystem interact in such a way as to maintain balance. Ecosystems are divided into biotic (living) and abiotic (non-living) components respectively. Each component should be discussed.

- **Biotic:** producers, consumers, decomposers
- **Abiotic:** physiographic, edaphic, climactic factors and atmospheric gases

The difference between the environment and an ecosystem should be emphasised to avoid confusion. An ecosystem is a environment that is in a dynamic equilibrium due to the interaction of living and non-living organisms.

**TEACHER RESOURCES:**

- INTERACTIVE QUIZ: This link is useful for consolidating the concepts of ecology.
  [http://www.oercommons.org/courses/ecology-quiz](http://www.oercommons.org/courses/ecology-quiz)
- INTERACTIVE QUIZ: This link is useful for consolidating the concepts of ecosystems.
- In this exercise, you will utilise an online calculator to examine your ecological footprint, compare it to the average footprint in your country and other countries, and critically examine ways to reduce it.
  [http://www.oercommons.org/courses/ecological-footprint-calculator](http://www.oercommons.org/courses/ecological-footprint-calculator)
- Video that examines the types of interactions that exist among organisms in a community, from competition between consumers for specific resources to the relationship between predators and prey.
  [http://www.curriki.org/xwiki/bin/view/Coll_NROCscience/APBiologyIIChapter33Lesson64CommunityEcology?bc=;Coll_NROCscience.APBiologyIIChapter33PopulationsandEcosystems](http://www.curriki.org/xwiki/bin/view/Coll_NROCscience/APBiologyIIChapter33Lesson64CommunityEcology?bc=;Coll_NROCscience.APBiologyIIChapter33PopulationsandEcosystems)
- In this Interactive Exercise, you will use a marine ecosystem to investigate the dynamic nature of ecosystems. You will explore the various regions of the bay, and then investigate some of the natural and human-imposed changes to which the bay responds.
  [http://www.curriki.org/xwiki/bin/view/Coll_NROCscience/APBiologyIIChapter34Ecosystems](http://www.curriki.org/xwiki/bin/view/Coll_NROCscience/APBiologyIIChapter34Ecosystems)
- The study of the interaction between organisms and their environment
  [http://www.curriki.org/xwiki/bin/view/Coll_NROCscience/APBiologyIIChapter33PopulationsandEcosystems](http://www.curriki.org/xwiki/bin/view/Coll_NROCscience/APBiologyIIChapter33PopulationsandEcosystems)
Learn more about biotic and abiotic components:

See video: 2CVS

<table>
<thead>
<tr>
<th>Investigation: Investigating the water-retaining properties of soil</th>
</tr>
</thead>
<tbody>
<tr>
<td>This activity may be counted towards one of the investigations in the term project. Learners should bring soil samples from their chosen ecosystem to test in addition to the sand, loam and clay samples provided.</td>
</tr>
</tbody>
</table>

**Aim:**

To investigate the water retaining properties of three soil types.

**Apparatus:**

- loam, sand and clay soil samples
- filter funnels and filter paper
- measuring cylinders
- water
- stop watches

**Method:**

1. Set up the three different 100 ml measuring cylinders, each with a funnel lined with filter paper.
2. Label each of the measuring cylinders either loam, sand or clay.
3. Add the same amount (e.g 50 gm) of each specific soil sample to the corresponding labelled funnel with filter paper.
4. Carefully pour the same amount (50 ml) of water into each funnel.
5. Immediately start the stopwatch.
6. Allow the water to pass through the soil sample.
7. Wait until the water is no longer dripping into the cylinder before you record the time for each soil type.
8. Record how much water there is in the measuring cylinder.
Results:

1. Write down your results in a table:
   a) The time taken for the water to pass through the soil.
   b) The amount of water in the measuring cylinder.

2. Draw a bar graph to represent your results.

Results

This is easily shown as a table. Learners can copy this table before they start the investigation:

Table showing drainage and water retention of three different soil types:

<table>
<thead>
<tr>
<th>Soil type</th>
<th>Volume water poured into soil sample (ml)</th>
<th>Volume of water that ran into cylinder (ml)</th>
<th>Volume of water retained by soil (ml)</th>
<th>Time for complete drainage of water (sec)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Sand</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Loam</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>Clay</td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

Bar Graph comparing the water retention capacities of of three soil types:

Learners should draw a bar graph to show the amount of water retained by the three types of soil. They may also choose to draw a second bar graph showing how quickly each soil-type drained. One would expect clay to retain the most water, and sand to retain the least.

Observations:

1. Which sample of water retained the most water?
2. Which sample of water retained the least water?
3. Is the speed at which the water drains related to the amount of water that gets retained? Describe the relationship using your results.

Observations

1. Clay retained the most water.
2. Sand retained the least water.
3. Clay soil drains the slowest and retains most water – very little runs through it; sandy soil drains very quickly and retains little water – most water runs through it; loam soil is intermediate – it retains a medium amount of water and hold back quite a lot. Therefore, it appears that the greater the water-retaining capacity of the soil, the slower water drains through it.
Conclusions:

Explain your observations. Try to describe three properties that result in the different water-retaining capacities of different soil types. Use your experimental results to recommend which soil would you use for your pot plants.

Conclusions

Three reasons for the difference in the water retention capacities of the soil types include:

1. size of the soil particles
2. air spaces between the particles
3. the amount of organic matter (humus)

- Clay soil has small particles and tiny air spaces, so it easily becomes waterlogged (muddy) and holds very little air for plant growth.
- Sandy soil has large particles and big air spaces, so it cannot retain much water. It dries out very quickly after rain, as soon as the sun shines on it.
- Loam soil has medium sized particles or a mixture of particle sizes. It retains a fair amount of water and does not become waterlogged easily. It also does not dry out very quickly.

Loam is the best soil for plant growth because it retains a fair amount of water but doesn’t become water logged.

ALTERNATIVE METHOD:

1. Place 30 g of each soil type in a filter funnel which is lined with filter paper.
2. Place each funnel on top of a 100ml measuring cylinder.
3. Pour 50ml of water into each funnel (slowly until all the water has been added to the soil).
4. Leave to stand for 2 minutes - record how much water is in the measuring cylinder.
5. After a further 2 minutes record any change to the amount of water in the cylinder.
6. After a further 2 minutes record any changes to the amount of water in the cylinder.
7. Record your results in a table. Add an extra column in which you calculate the amount of water retained.
### Project: Identifying abiotic, biotic and cultural characteristics of a natural environment

**Aim:**

Identify abiotic, biotic and cultural characteristics of a natural environment near you.

**Instructions:**

1. Select an area that is undeveloped (e.g. no buildings, no pavement, no bulldozing, no spraying of pesticides, no farming, no grazing, etc.). Your area must be at least the size of a soccer field.
   - Make a map of your province and show, approximately, where your area is located.
   - Identify at least 10 abiotic features of your area. Consider factors such as:
     1. Edaphic factors
     2. Physiographic factors
     3. Physical factors

2. Identify at least 15 biotic features of the area. Consider things such as:
   - Plants (trees, shrubs, grasses, flowers etc.)
   - Insects (ants, bees, praying mantis etc.)
   - Amphibians, reptiles, and/or fish
   - Mammals
   - Identify at least 3 cultural components. Look for evidence of human influence. Consider things such as:
     1. Recycling and conservation efforts
     2. Pollution
     3. Introduced species

**Analysis:**

Examine the data you collected when making your profile of your area. Use your collected data to answer the following questions. Discuss your answers afterwards in your group/with your partner.
1. What effect does the environment (abiotic) have on the organisms (biotic) living there? Give FIVE specific examples from your profile. For example: Lily pads (biotic) are able to grow in my area because it is a natural wetland that has standing, stagnant water (abiotic) all year long.

2. What effect do the organisms (biotic) have on the environment (abiotic)? Give THREE specific examples from your profile. For example: The area is heavily shaded by spruce trees (biotic). The shade keeps the soil moist (abiotic) and reduces the air temperature.

3. How do natural forces affect the area? Give ONE specific example from your profile. Consider the direction of the prevailing winds, the direction from which the sun’s rays come, gravity (if you are on a slope) etc.

4. Predict how your area would change if the amount of rainfall doubled. Be sure to mention how this increase in rainfall would affect the abiotic and biotic factors.

5. How have humans affected your area (cultural)? Give ONE specific example.

NOTES TO TEACHERS:

- Due to its similarity to the Studying a terrestrial ecosystem Project, this activity was not included in the learner book.
- There are many possible projects offered in this section. This activity is optional.
- It is suggested that this is done as group work, not individually.
- It may be very valuable to just examine an area near the school as a class group and answer the questions verbally in a class discussion.
- It is not necessary to assess this project formally if done as a class exercise.

GUIDELINES:

- The map can be hand drawn and can be relatively simple. Should include an arrow to indicate North and should preferably have a scale or indication of size. It is probably better to have a map of the local AREA, as part of the province.
- **ABIOTIC factors**: Should include Edaphic factors, Physiographic factors and Physical factors.
- **BIOTIC factors**: Any animals and plants that are found in the area. They may not be able to find FIFTEEN. This should not be penalised – teachers just need evidence that they have tried to find different animals and plants. It may be useful to ask them to take photos of the organisms they find. This helps with later identification.
- **CULTURAL components**: Learner-dependent answers. Encourage them to find DIFFERENT cultural components, not just litter, for example.
- **ANALYSIS section**: It is clear enough what is expected. Learners may not be able to give detailed answers here.
Aim and background information

You are required to choose one ecosystem within a local biome for special study. The study will be conducted over two terms and will involve a number of investigations. You may work in groups. Each group will have to plan, collect, record, present, analyse and evaluate the data.

1. Soil

The type of soil found in your ecosystem will have an influence on the types of plant that will grow in that ecosystem. It is important to identify the types of soil found in your ecosystem by doing the following soil tests.

1.1 How to identify soil texture

1. Roll some wet soil into a ball.
2. Then try to roll the ball into a sausage shape.
3. Bend the sausage into a ring.

How to interpret your observations:

- if the sausage breaks as you bend it, the soil is sandy.
- if the sausage bend slightly, and then breaks, the soil is loamy.
- if the sausage bends easily the soil contains a lot of clay.

1.2 How to measure pH

You will need the following materials:

- spoon
- water
- jar with a lid
- plastic teaspoon
- soil sample
- red and blue litmus paper or universal litmus paper

1. Collect a small sample of soil to test.
2. Place a teaspoon of soil into the jar, stir it to loosen all the particles.
3. Carefully add water to fill the jar approximately half way.
4. Screw the lid onto the jar and shake the jar gently.
5. Stand the jar on a flat surface and wait until the soil settles and the water becomes clear. This may take a few days.
6. Unscrew the cap and using the plastic spoon, carefully remove some
water from the jar.

7. Test the pH of the water by using the litmus paper.

How to interpret litmus paper observations:

- blue litmus paper will turn red when placed in an acid solution.
- red litmus paper will turn blue when placed in an alkaline solution.
- if using universal litmus paper read the pH of the pH scale.

1.3 Measure the water-holding capacity of your soil sample/samples

You will need the following apparatus:

- filter paper
- water
- soil sample (preferably dry)
- a two litre plastic cool drink bottle with the top of the bottle cut off (the top will act as your funnel and the bottom will act as a water-collecting vessel)

1. Remove the bottle cap from the top part of the bottle (funnel).
2. Place the ‘funnel’ inside the bottom half of the bottle.
3. Measure out your soil sample to be tested (measure by mass or volume).
4. Place the piece of filter paper into the neck of the bottle.
5. Add the soil sample into the ‘funnel’.
6. NOTE: If testing more than one soil sample, the same amount of soil and water must be added to each bottle top.
7. Very slowly add water to the bottle.
8. Observe how much water runs through the soil into the bottom of the bottle.
9. Once the soil has drained of the water, measure the amount of water that was filtered using a measuring cylinder.

2. Temperature

You will need the following apparatus:

- thermometer

1. Measure the air temperature using a thermometer. Record the temperature in your ecosystem at two different times of day.
2. Try and record the temperature at the same time on every day for one week in the third term and repeat the process for one week in the fourth
3. A table similar to the table below needs to be completed for your temperature recordings.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time</th>
<th>Temperature</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Use the information in the table to draw a line graph of the temperature over the study period.

5. Discuss whether there are any differences or general patterns in the daily temperature between the third and fourth terms.

3. Light

You will need the following apparatus:

- watch or clock

1. To measure the photoperiod of your ecosystem, you are required to keep a record of the times of sunrise and sunset.
2. Record the times of sunrise and sunset for one week in the third term, and for one week in the fourth term.
3. Record the effects of the photoperiod on the behaviour of plants. An example is: daisies open during the day and close at night. Record what happens to your plants. Complete a table similar to the table below.

<table>
<thead>
<tr>
<th>Date</th>
<th>Time Flower Opens</th>
<th>Time Flower Closes</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
</tbody>
</table>

4. Draw two line graphs showing the times the flowers open and the time the flowers close.
5. Also record the times of sunrise and sunset.
6. From your graph discuss if the opening and closing of the flowers are related to sunrise and sunset.
7. Discuss whether you found any differences between the third and fourth terms.

4. Physiographic Factors

You will need:

- compass
1. If your ecosystem is on a slope, record the direction of the slope.

5. Studying biotic factors

If the ecosystem you are studying covers a large area, it may be difficult to observe all the living organisms. If this is the case, you can get some idea of the plant and animal diversity in the ecosystem you are studying by choosing a smaller sample area to study.

You will need:

- pencil
- wooden sticks
- string
- metre stick or measuring tape or string
- field guide to plants and animals in your ecosystem (if necessary)

1. Mark out an area of 4 square metres in your ecosystem.
2. Choose an area you think will contain the most plants and animals.
3. Wind the string around the wooden sticks so that you create a grid to study within your ecosystem.
4. Make a list of all the plants and animals found in your ecosystem.
5. Try and name the plants and animals. Use a reference book or the Internet to identify the plants and animals in your ecosystem.
6. Draw a distribution map showing where the different organisms were found in the ecosystem.
7. Give each organism you found a code.
8. Use the codes to make a map by showing where in the grid each organism was found.
9. Record how many different plants and animals were found in your ecosystem.
10. Which parts of your grid recorded the most plants and animals?
11. Briefly discuss which abiotic factors influenced your ecosystem.
12. Investigate what the animals in your ecosystem eat and then draw a food web for the ecosystem.
13. Why do the organisms you found in your ecosystem live in this habitat?
14. Write a short paragraph describing the ecological niche of one of the organisms you observed.

6. The effect of humans on the ecosystem

Determine if humans have had any effect on the ecosystem. These effects may be positive, negative, or a combination of both.
1. Write a short paragraph of 200 words on the effect of humans on your ecosystem.

**Write a scientific report on the ecosystem you have studied.**

Your report should include the following:

- A title
- Introduction
- Equipment or materials used
- Results (including tables)
- Observations
- Discussion
- Conclusion
- References
- You can use drawings and photographs to illustrate your report.

**Project: To study a terrestrial ecosystem**

**NOTES TO TEACHERS:**

- This is the type of project that has been recommended by CAPS. It provides learners with important links to the Grade 11 syllabus, and it is highly recommended that learners complete as many of the sections as possible.
- In this investigation learners are to choose a terrestrial ecosystem either at school or close to where they live.
- Educators to note that this investigation can be given to learners at the beginning of a term and then allow the learners to hand in their completed written report towards the end of the term.
- Alternatively if this investigation is done on the school property various deadline dates can be set for each section to be investigated.
- Learners to comment on their own findings and their work to be marked accordingly.

**GUIDELINES:**

- **Soil texture:** Note that some soils are so sandy, that they cannot even be rolled into a sausage – the ball breaks if one even tries to roll or squeeze it into a sausage shape.
• **Measuring pH:** It is acceptable to just dip the litmus or universal indicator into the water once it has settled – one does not have to remove water with a spoon. It is vital that the jar must be clean before the soil is added, as food remains etc inside the jar will affect the pH reading. It may yield surprising results to check the soil pH of different parts of the same general area – it is not necessarily the same across the entire area.

• **Water holding capacity:** The basic procedure is the same as that described in the previous investigation on the water-holding capacity of soil. Learners should use 3 DRY soil samples – the same amount of soil and water is used in each case. If using 100 ml of water, the percentage water retained and drained can be calculated easily for comparison.

• **Temperature:** Ensure that the thermometers are placed in the same place at different times, not sometimes in the sun and at other times elsewhere in the shade. This is a better indication of the range of temperatures in the area at different times.

• **Photoperiod:** The Time flowers open / close goes on the vertical axis, and Day 1 / 2 / 3 goes onto the horizontal axis. Two separate graph lines will show Opening and Closing times – include a key. It is not strictly necessary to graph this – if they just record sunrise / sunset times, valid conclusions can be drawn.

• **Slope:** This should be noted in terms of direction, e.g. the area slopes down towards the east, etc.

• **Grid marked out:** This can be done in groups over different parts of the area. They are likely to find only small animals like insects. The groups can combine to draw a composite map of the area as a class.

• **Report:** The class as a whole can do a single report or separate groups can do their reports on their own if the teacher requires this.

---

### 10.5 Energy flow

In ecology, energy flow refers to the flow of energy through a food chain. In an ecosystem, we attempt to establish the feeding relationships between organisms living together. Each organism belongs to a ‘trophic level’ which refers to the position occupied by an organism in the food chain. Energy is passed on from every trophic level to the next.

**TEACHERS RESOURCE:**

- Use this lab to allow learners to “build their own” ecosystem, and explore the effects of these interrelationships:
  

---

232 10.5. Energy flow
• Source of some food chain and food web examples to use in class:

Watch a catchy song about food chains to help you remember:

عناصر

See video: 2CVT

<table>
<thead>
<tr>
<th>Activity: Understanding Food Chains</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Activity 1:</strong></td>
</tr>
<tr>
<td>Trace a food chain of the vegetables, fruit, cheese, eggs or meat that you had for breakfast or will have for dinner.</td>
</tr>
<tr>
<td><strong>Activity 2:</strong></td>
</tr>
<tr>
<td>1. In the food chain shown in the text which of the three organisms is the</td>
</tr>
<tr>
<td>a) herbivore</td>
</tr>
<tr>
<td>b) carnivore</td>
</tr>
<tr>
<td>c) producer</td>
</tr>
<tr>
<td>2. Draw in the decomposers in the above food chain. Ensure that the direction of the arrows is correct.</td>
</tr>
<tr>
<td>3. What organism(s) will feed on the leopard?</td>
</tr>
<tr>
<td>4. Construct a new food chain showing at least four organisms.</td>
</tr>
<tr>
<td>5. Producers use sunlight to manufacture their own food. Write a word equation to depict this process. [Hint: think of the requirements and outcomes of the process of photosynthesis]</td>
</tr>
</tbody>
</table>

**Answers**

**Activity 1:**

Any logical food chain will be acceptable:

• rice → man → bacteria
• seeds → chicken → man → bacteria
• grass → cow → cream from milk becomes cheese → man → fungi

Do not accept ANY part of the food chain if it does not start with a producer or part of a producer.

**Activity 2:**
1. a) Impala  
   b) Leopard  
   c) Green Plant  
2. → bacteria  
3. Bacteria  
4.  
   • Flower bulbs → rabbit → eagle → bacteria  
   • Leaves → locust → pigeon → owl → cat → bacteria  
   • Any other acceptable food chain.  
5. Sunlight + water + carbon dioxide → sugars or starch + oxygen

Activity: Understanding food chains and food pyramids

Aim:
Gain conceptual understanding of food chains and food pyramids

Materials:
• textbook  
• resources provided by teacher

Instructions:
1. Look at any of the food webs or food chains in this chapter, or use a food chain or food web provided by your teacher.

Questions:
1. Identify a food chain that has three trophic levels.  
2. Identify a food chain that has four trophic levels.  
3. Name two:  
   a) producers  
   b) primary consumers  
   c) secondary consumers  
   d) tertiary consumers  
4. There are very few tertiary consumers compared to the primary consumers. Why?  
5. What will happen if the hyena is removed from the food web?
Answers

1. • acacia / tree → giraffe → lion
   • any other suitable example
2. • algae → fish → frog → crane
   • Grass → zebra → hyena → vulture
   • any other suitable example
3. Learner-dependent answers. Some examples are provided below. Any two of:
   a) grass, trees, algae, aquatic plants
   b) insects, fish, snails, zebra, termites, elephant, giraffe
   c) rat, frog, fish, cheetah, hyena, lion
   d) snake, crane, duck, sparrow, vulture, decomposers, detritus feeders
4. The amount of energy available decreases as one moves up a food chain, so the number of organisms also decreases. An ecosystem cannot support equal numbers of tertiary consumers and primary consumers – there would be too many top predators. Predators would wipe out their food supply and then starve.
5. There are a few possibilities:
   • The number of herbivores would increase, as they are not being predated so heavily – they will only be eaten by cheetahs.
   • The place of the hyena will be filled by other predators or scavengers, such as lions and vultures. Predators and scavengers will increase in number, as they have more food available.
   • Regardless of whether one or both the above occur in an ecosystem, the result will be the same – a new balance will be achieved in the long term, even if the hyenas are removed.

Bill Nye the science guy talks about the food web:

(See video: 2CVV)

10.6 Nutrient cycles

A nutrient cycle refers to the movement and exchange of organic and inorganic matter back into the production of living matter. The process is regulated by the food web pathways previously presented, which decompose organic matter into inorganic nutrients. Nutrient cycles occur within ecosystems. Nutrient cycles that we will examine in this section include water, carbon, oxygen and nitrogen cycles.
FACT
Learn more about the carbon cycle in this video:
See video: 2CVY

FACT
This video summarises the nitrogen cycle.
See video: 2CVZ

TEACHER RESOURCES:

- This page is a part of PhysicalGeography.net, an educational website maintained by Dr. Michael Powdery, a member of the Geography Department at Okanagan University in British Columbia. In addition to this excellent introduction with tables and diagrams, the site also includes a glossary of terms, additional readings, and links to outside resources.
  http://www.physicalgeography.net/fundamentals/8b.html
- The Georgia state office of the US Geological Survey provides a very basic and kid-oriented site to explain various aspects of the water cycle, including following a single drop of water through the cycle’s main stages. US Geological Survey: The Water Cycle:
  http://ga.water.usgs.gov/edu/watercycle.html
- This is an animation of the water cycle
  ANIMATION: http://www.epa.gov/ogwdw/kids/flash/flash_watercycle.html

Watch a video about the oxygen cycle. Focus on the first part of the video clip and the summary at the end.

See video: 2CVX

TEACHER RESOURCES:

- This is a game you can play to learn more about the carbon cycle. GAME:
  http://www.windows2universe.org/earth/climate/carbon_cycle.html

TEACHER RESOURCES:

Below are some excellent interactive animations of the nitrogen cycle:

- https://www.classzone.com/books/ml_science_share/vis_sim/em05_pg20_nitrogen/em05_pg20_nitrogen.html
- http://www.teachersdomain.org/asset/lsps07_int_nitrogen/

10.7 Ecotourism

This section enables learners to discuss the positive aspects of our country. In particular, learners need to focus on how South Africa’s natural, cultural and historical treasures are a means of attracting tourists.

Learners will also need to critically assess how our environment and resources are managed. Specifically: are they managed sustainably, and according to sound principles?
The attraction of tourists can boost the economy and create employment for South African citizens. Tourism is not merely a cover for money-making ventures, but it is also a means to boost awareness of our indigenous plants and animals and the importance of conservation.

10.8 Summary

- The biosphere is the sphere in which all ecosystems on Earth exist. It interacts with the atmosphere, lithosphere and hydrosphere.
- Biomes contained within biospheres are regions with similar climatic and geographic conditions. Broadly, biomes are either aquatic or terrestrial.
- South Africa’s major aquatic biomes include freshwater and marine biomes, based on their salt concentrations. Terrestrial biomes of South Africa include Grassland, Savannah, Succulent and Nama Karoo, Forest, Fynbos, Desert and Thicket Biomes. Each is located differently across South Africa and has its own distinctive plant and animal life.
- Ecosystems refer to environments that consist of abiotic factors and biotic factors (organisms) that interact to maintain a balance.
- Abiotic factors including physiographic (slope, altitude and aspect) and edaphic (soil pH, texture, humus content) factors.
- Energy flows through ecosystems from the sun through to producers (plants), primary consumers (typically herbivores), secondary consumers (carnivores), ultimately terminating at decomposers.
- The food chain describes the relationships linking producers, consumers and decomposers. Food pyramids can also be used to represent this relationship. Pyramids of biomass, energy and numbers of organisms can also be used to describe the biotic relationships in ecosystems.
- Nutrient cycles describe the flow of particular nutrients (C, O, N and water) through the ecosystem.
- Ecotourism produces widespread benefits to South Africa, creating jobs, preserving its natural beauty and improving infrastructure. There are ethical considerations involved in ensuring that the ecological and cultural diversity of South Africa’s ecosystems is preserved.
1. Study the sketch of the forest ecosystem below:

a) Name the:
   i. producer
   Solution: grass or tree
   ii. primary consumer
   Solution: mice / rats / rodents
   iii. secondary consumer
   Solution: owl or bird
   iv. tertiary consumer
   Solution: jackal / fox / wolf / dog

b) The ecosystem consists of living organisms together with the _
   Solution: environment or abiotic factors

2. Read the article below and answer the questions that follow:
a) Describe what you understand by the term algal bloom

**Solution:**

*An algal bloom is a massive (very large) growth in the number of algae in an area, usually due to an unnatural increase in nutrients in the water.*

b) With reference to above article, name the abiotic factor that is responsible for the bloom and how the factor reached the Antarctic Ocean.

**Solution:**

*The abiotic factor is extra iron that blew into the sea from the Antarctic mainland.*

c) Discuss the role decomposers could play in this ecosystem.

**Solution:**

*Decomposers like bacteria will later come to the top and break down the algae and reduce the algal bloom.*

3. Earthworms will burrow into the soil if they are on the surface and it is daylight. We can explain this behaviour by saying that they are either repelled by light or because they are attracted to the soil.

Describe an experiment that you could do to determine which explanation is correct. When designing your experiment, bear in mind that earthworms are living organisms.

Set out your design under the following headings:
a) Hypothesis
   **Solution:**
   Earthworms burrow into the soil because they are repelled by light OR Earthworms are attracted to the darkness that soil depth offers them.
   (Accept any hypothesis directly related to the aim, as long as it is a statement, not a question and it is written in the future tense.)

b) Aim
   **Solution:**
   To investigate if earthworms are attracted to soil and/or repelled by light.
   (Accept any aim, as long as it is related to the instructions and MUST start with “To find out / To determine / To see . . . etc.”)

c) Apparatus and Materials
   **Solution:**
   Learner dependent answers. The answer depends on their design, but should be written in a bulleted list, be appropriate to the task, include at least 4 pieces of apparatus.
   - earthworms of the same species
   - lamp/ light source
   - black basins with covers or other containers that block light
   - black paper/ black plastic sheet
   - soil
   - sawdust
   - timing device / stopwatch

d) Method
   **Solution:**
   Method Example 1:
   i. Earthworms were divided into 4 groups.
   ii. Two basins were filled with nutrient rich soil (A and B), two with sawdust (C and D).
   iii. A and C were covered with black paper on their covers.
   iv. B and D were placed under a neon lamp.
   v. Earthworms were placed on the surface of the medium, appropriate covers were put in place.
   vi. After a 10 minute interval the number of worms at the surface of the medium were counted.
   vii. The procedures were repeated 5 times.
   viii. Counts were averaged and results compared.
Method Example 2:

i. Divide earthworms into two equal groups.

ii. Put equal amount of soil into the large box on either side of the plastic separator sheet.

iii. Put one group of worms onto the soil on each side of the sheet.

iv. Shine a light onto one group and leave the other group in darkness.

v. Observe whether the worms have moved into the soil in the light or in darkness or in both cases.

Marking Rubric:

<table>
<thead>
<tr>
<th>Criterion</th>
<th>Marks</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. List of points/bullets</td>
<td>1</td>
</tr>
<tr>
<td>2. Meets the aim that the pupil has given</td>
<td></td>
</tr>
<tr>
<td>3. Independent variables catered for (light/dark or soil/sawdust)</td>
<td>1</td>
</tr>
<tr>
<td>4. Dependent variables mentioned (number of worms at the surface of the medium)</td>
<td>1</td>
</tr>
<tr>
<td>Controlled variables evident</td>
<td></td>
</tr>
<tr>
<td>Sufficient equipment used</td>
<td>1</td>
</tr>
<tr>
<td>5. Equipment used appropriately</td>
<td></td>
</tr>
<tr>
<td>Logical – recipe like</td>
<td>1</td>
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</table>

4. Read the following information taken from UWC Enviro Fact sheet on the Fynbos and answer the questions that follow:

Fynbos is the major vegetation type of the small botanical region known as the Cape Floral Kingdom. The Cape Floral Kingdom is both the smallest and the richest floral kingdom, with the highest known concentration of plant species: 1 300 per 10 000 km². The nearest rival, the South American rain forest has a concentration of only 400 per 10 000 km². Conservation of the Cape Floral Kingdom, with its distinctive fynbos vegetation, is a national conservation priority demanding urgent action.
Over 7 700 plant species are found in fynbos, an astonishing number for such a small area. Of these roughly 70% are endemic to the area. Many of these are threatened with extinction. The richness of the fynbos is well demonstrated by its ericas or heaths, of which there are over 600 different species. There are just 26 in the rest of the world. Although the most striking features of the composition of fynbos are the presence of many conspicuous members of protea, erica and reed family that fill the niche usually occupied by grasses, the largest family in number of species is Asteraceae (daisy family), with just under 1000 species of which more than 600 are endemic. Furthermore, fynbos is very rich in geophytes (bulbous plants) and many species from the family Iridaceae have become household names, freesia, gladiolus, iris, and watsonia. Another remarkable feature of fynbos is the number of species found within small areas. For example, the total world range of some species consists areas smaller than half a soccer or rugby field!

Fynbos cannot support herds of large mammals since the nutrient poor soils on which it grows do not provide enough nitrogen for the protein requirements of large mammals. However, smaller mammals common to fynbos are baboons, grysbok, dassies, and the striped mouse. Fynbos does not support high numbers of birds. Fynbos also supports large numbers of butterfly species. Many are however at risk. The early stages (larvae) of many of these butterfly species are entirely carnivorous and live on a diet of ant brood. The butterfly larvae actually live inside the nest of their host ant. Although fynbos is not particularly rich in reptiles and amphibians, many of the species living there are both endemic and threatened. The very rare geometric tortoise is found in only a few surviving fynbos areas and is regarded as the world’s second rarest tortoise.

The Cape has more than half of South Africa’s frog species. Fynbos also has a high concentration of threatened fish species, particularly in the Olifants River system. With the widespread occurrence of alien vegetation which use up more water than indigenous fynbos plants, many habitats are becoming restricted leading to local extinction of certain species of fish because isolated tributaries are drying up.

http://www.bcb.uwc.ac.za/envfacts/fynbos/

a) The fynbos is said to be a very bio diverse habitat. List any three pieces of evidence from the text that show the idea of a rich biodiversity.

Solution:
• “The Cape Floral kingdom is the smallest and richest floral kingdom with the highest known concentration of plant species”.
Fynbos has the highest known concentration of plant species: 1 300 per 10 000 km².

There are 7 700 plant species are found in fynbos, 70% of which are endemic.

The Asteraceae (daisy family), has just under 1000 species, of which more than 600 are endemic.

Fynbos has over 600 different species of Ericas - the rest of the world has 26 species.

Fynbos is very rich in geophytes (bulbous plants).

Fynbos is home to more than half of South Africa’s frog species.

The total world range of some plants is an area smaller than half a soccer field.

The geometric tortoise is found here and is the 2nd rarest tortoise in the world.

There may be others that are relevant as well.

b) Give three distinctive abiotic characteristics (excluding edaphic factors) of this biome.

**Solution:**

- Fire
- Hot, dry summer and cold, wet winter
- Low altitude/ coastal location
- Poor, infertile soil

c) Define the following terms mentioned in the text:

i. endemic

**Solution:**

An organism found only in that area, nowhere else in the world.

ii. alien species

**Solution:**

A species that doesn’t naturally occur in that area, but was introduced from elsewhere in the world. They are usually harmful to the ecosystem.

iii. indigenous

**Solution:**

A species that has always been part of the natural flora/fauna of the area. This is not the same as ‘endemic’ – an indigenous species may occur in other areas as well.

iv. extinct

**Solution:**

A species that has been completely eliminated or destroyed. There are no more living specimens anywhere in the world.

d) Construct a possible food chain of at least four organisms that would be found in this biome, use some organisms mentioned in the text.
Label the levels of the organisms mentioned.

**Solution:**

- **Grass seeds → ants → butterfly larvae → birds**
- **Geophyte → striped mouse → baboon → leopard**
- **Ericas → ants → butterfly larva → birds**

*Label can include: producer/autotroph, consumer/heterotroph-primary, secondary, tertiary*

*There are of course several others that can be constructed from the test. This is just an example.*

e) Discuss the characteristics of the soil found in the fynbos and the implications for animals in the area.

**Solution:**

*The soil is very nutrient-poor (low nitrogen), sandy, porous and well aerated. Its poor quality makes it insufficient to sustain large animals.*

5. Which of the following are biotic components in an ecosystem?

a) air and water
b) plants and animals
c) light and temperature
d) rocks, soil and climate.

**Solution:**
b

6. Which combination of the following processes takes place in the nitrogen cycle?

- i) Herbivores consume plant protein.
- ii) Decomposers break down dead organisms.
- iii) Bacteria change nitrites to nitrates.
- iv) Plants absorb nitrates from the soil.

a) i, ii and iii
b) i, ii, iii and iv
c) i and iv
d) i, ii and iv

**Solution:**
b

7. A soil has the following characteristics: large particles, large air spaces, holds little water, feels gritty. The type of soil is:

a) clay
b) sand
c) loam
d) silt
8. Plants that are suited to live in areas with little water are called:
   a) terrestrial
   b) fynbos
   c) xerophytes
   d) hydrophytes

   **Solution:**
   c

9. In a food chain, energy flows in the following direction:
   a) producers → primary consumers → secondary consumers → decomposers
   b) decomposers → producers → primary consumers → secondary consumers
   c) primary consumers → secondary consumers → producers → decomposers
   d) producers → secondary consumers → primary consumers → decomposers.

   **Solution:**
   a

10. In a stable ecosystem, a wide variety of:
    a) producers depend on plants for shelter and camouflage
    b) micro-organisms depend on plants for carbon dioxide and nitrogen
    c) animals depend on plants for food and oxygen
    d) plants depend on micro-organisms for pollination and seed dispersal

   **Solution:**
   c

11. When a jackal kills and eats a rabbit, the jackal is the:
    a) producer
    b) prey
    c) predator
    d) saprophyte

   **Solution:**
   c

12. Which of the following refers to an organism’s whole way of life and the use to which it puts the available environmental resources?
    a) niche
    b) habitat
c) community
d) ecosystem

**Solution:**
a
13. Organisms that live in water are called:
   a) terrestrial
   b) xerophytes
   c) buoyant
d) aquatic

**Solution:**
d
14. A giant oil tanker was wrecked at sea. The shallow waters of the coastline provided a rich source of edible crabs. Oil does not kill the crabs but harm their flesh, making them inedible and they cannot be sold. Samples of crabs were collected at sites A to D. The number of crabs were collected at sites A to D. The number of crabs is indicated by the size of the circle. The extent of the shaded part at each site represents the proportion of crabs with diseased flesh after the disaster.

<table>
<thead>
<tr>
<th></th>
<th>A</th>
<th>B</th>
<th>C</th>
<th>D</th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td><img src="image1.png" alt="Circle A" /></td>
<td><img src="image2.png" alt="Circle B" /></td>
<td><img src="image3.png" alt="Circle C" /></td>
<td><img src="image4.png" alt="Circle D" /></td>
</tr>
</tbody>
</table>

a) Which sample site (A to D) had the highest number of crabs?

**Solution:**
Sample site D

b) In which sample site was the crabs only rarely found?

**Solution:**
Sample site C

c) Name the agent of pollution that affected the crabs.

**Solution:**
Oil

d) In which sample site was the most crabs affected compared to the population size?

**Solution:**
Sample B

e) Explain your answer to the question above
Solution:
Sample B has a greater shaded portion

f) List TWO strategies that could reduce the effects of oil pollution at sea.

Solution:
Regular service of oil tankers; Legislation on the amount of oil the oil tankers transport; Monitoring of travel routes; Use bacteria to dissolve the oil spill.

Check answers online with the exercise code below or click on ‘show me the answer’.

1ai. 2CW2 1aii. 2CW3 1aiii. 2CW4 1aiv. 2CW5 1b. 2CW6 2a. 2CW7
2b. 2CW8 2c. 2CW9 3a. 2CWB 3b. 2CWC 3c. 2CWD 3d. 2CWF
4a. 2CWG 4b. 2CWH 4ci. 2CWJ 4cii. 2CWK 4ciii. 2CWM 4civ. 2CWN
4d. 2CWP 4e. 2CWQ 4fi. 2CWR 4fii. 2CWS 4fiii. 2CWT 5. 2CWV
6. 2CWW 7. 2CWX 8. 2CYY 9. 2CWZ 10. 2CX2 11. 2CX3
12. 2CX4 13. 2CX5 14a. 2CX6 14b. 2CX7 14c. 2CX8 14d. 2CX9
14e. 2CXB 14f. 2CXC
Biodiversity and classification

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11.4 Five kingdom system 253
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11 Biodiversity and classification

11.1 Overview

**Time Allocation:** 1 week (4 hours)

This chapter consists of the following sections:

1. Overview
2. Biodiversity
3. Classification schemes
4. Five kingdom system
5. Summary
6. End of Chapter Exercises

Introduction

‘Biodiversity is the greatest treasure we have. Its diminishing is to be prevented at all costs’. — Thomas Eisner, US environmental scientist, who has made interesting findings into how organisms produce chemicals to fight off predation.

So far learners have studied life from the molecular to the ecosystem level. This chapter examines the fantastic variety of life that exists on Earth, and introduces the systematic way of classifying organisms based on their evolutionary relationships. This sets the scene for the next chapter on the ‘History of Life on Earth’ where we will explore how this variety emerged.

**Key concepts**

- There is enormous biodiversity on Earth, consisting of different ecosystems, containing a variety of species, which each have genetic differences.
- South Africa is a ‘hotspot’ of diversity and has a large diversity of species endemic to the region.
- Classification schemes are a way of categorising biodiversity based on common characteristics.
- The history of classification began with Aristotle.
- Currently, the most widely used classification system is the five-kingdom scheme consisting of the kingdoms: Animalia, Plantae, Fungi, Protista and Monera (or Bacteria).
• In Science we name living organisms using a naming system called binomial nomenclature, which is written in the form: Genus, species
• Based on cell structure, there are key differences between prokaryotes and eukaryotes.
• The main groupings of living organisms are bacteria, protists, fungi, plants and animals. Each of these categories of organisms have distinctive features that differentiate them.

11.2 Biodiversity

Biodiversity is the term we use to refer to the variation in life forms in an ecosystem, biome or the entire planet. The term also describes the genetic wealth within each species, the inter-relationships between them and the natural areas in which they occur.

11.3 Classification schemes

The diversity of life on Earth has fascinated scientists for generations. The earliest scientists attempted to understand life by categorising it according to a range of common traits. Over time these classification systems have changed based on the new evidence gathered. This section introduces learners to the concept of taxonomy, which is the classification of living organisms.

In this unit, learners will study the history of the system of classifying organisms, starting with Aristotle and progressing to the current five-kingdom system devised by Whittaker. They will also be introduced to the scientific convention of referring to organisms in Latin using two names - referred to as binomial nomenclature. It is important to try and draw connections between this section and the previous one in which you studied the plant and animal life common to each biome.

Activity: Classification

Aim:
To understand how classification systems work.

Materials:
Pen and paper

Instructions:
1. Listed below are different TV programmes:
   • Carte-Blanche
FACT
Watch a video about taxonomy: life’s filing system
See video: 2CXD

- Rocky
- Isidingo
- Rambo
- Hitler’s Bodyguards
- Generations
- Vietnam: Lost Films
- BBC news

2. Divide these TV programmes above into 2 groups, under the headings: Entertainment and Documentary.
3. Now further subdivide the Entertainment group into Action and Soapies groups.
4. Do the same for Documentary using the headings: News/Current Affairs and History.

You have just drawn an example of a dichotomous branching diagram/tree. All objects can be divided in this way. We call this a classification system.

Activity: Classification

In this activity learners are to try and think of the problems that arise while classifying the items below. Can BBC news be entertaining too? If so, should it not be under entertainment? Do you think that the final level of classification is the most definitive?

ANSWERS

<table>
<thead>
<tr>
<th>Entertainment</th>
<th>Documentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Rocky</td>
<td>Carte Blanche</td>
</tr>
<tr>
<td>Isidingo</td>
<td>Hitler’s Bodyguards</td>
</tr>
<tr>
<td>Rambo</td>
<td>Vietnam: Lost Films</td>
</tr>
<tr>
<td>Generations</td>
<td>BBC News</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entertainment</th>
<th>Documentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>Action</td>
<td>Soapies</td>
</tr>
<tr>
<td>Rocky</td>
<td>Isidingo</td>
</tr>
<tr>
<td>Rambo</td>
<td>Generations</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Entertainment</th>
<th>Documentary</th>
</tr>
</thead>
<tbody>
<tr>
<td>News/Current Affairs</td>
<td>History</td>
</tr>
<tr>
<td>Carte Blance</td>
<td>Hitler’s Bodyguards</td>
</tr>
<tr>
<td>BBC News</td>
<td>Vietnam: Lost Films</td>
</tr>
</tbody>
</table>
Activity: Construct a mnemonic to remember the sequence of the classification system

Instructions:
Make an easy to remember memory aid to remember the sequence of levels of the classification system.

Activity: Make you own mnemonic to remember the sequence of the classification system

This activity allows the learners to be creative. Give the learners the freedom to choose which platform suits them best e.g. learners can do diagrams or rap songs. The learners have fun and learn the classification system at the same time.

Watch a video about Carolus Linnaeus

See video: 2CXF

11.4 Five kingdom system

In this section learners are introduced to the most common way of grouping living organisms based on simple distinctive characteristics. Classification systems are always changing as new information is made available. Modern technologies such as electron microscopy make it possible to observe microscopic organisms in greater detail. The current system was developed by Robert H. Whittaker in 1969 and was built on the work of previous biologists such as Carolus Linnaeus.

The five kingdom system is the most common way of grouping living things based on simple distinctive characteristics.

According to this system, living things can be classified into five major kingdoms:

- **Kingdom Animalia**
- **Kingdom Plantae**
- **Kingdom Fungi**
- **Kingdom Protista**
- **Kingdom Monera (Bacteria)**

Learners need to know the defining characteristics of each of the five kingdoms.

A video showing a brief summary of the five kingdoms
See video: 2CXG

A TED video on the many uses of Fungi

See video: 2CXH

TEACHER RESOURCES:

- **Tree of life project**: collaborative effort of biologists and nature enthusiasts from around the world providing information about biodiversity, the characteristics of different groups of organisms, and their evolutionary history (phylogeny). Link: [http://tolweb.org/tree/phylogeny.html](http://tolweb.org/tree/phylogeny.html)
- **ARKive project**: For pictures and information on a wide range of life forms
- [http://bugscope.beckman.uiuc.edu/](http://bugscope.beckman.uiuc.edu/): For high magnification pictures of insects using a scanning electron microscope.

Activity: Investigate examples of life forms from each kingdom

**Aim:**

To investigate examples from each kingdom.

**Instructions:**

1. Research one beneficial and one harmful application of one member from each kingdom, with examples from their use in South Africa. Students can be grouped into smaller groups and each one is given one kingdom to research. (Use www.arkive.org as a research tool for your favourite animal or plant or [http://bugscope.beckman.uiuc.edu/](http://bugscope.beckman.uiuc.edu/) for nice pictures of insects). Results can be presented in the form of a poster.

2. Go to your nearest supermarket or garden and find one representative organism for each kingdom. Present this information by drawing a diagram.

In this activity learners are to research one beneficial and one harmful application of one member from each of the kingdoms including examples of their use in South Africa. Learners can be grouped into smaller groups and each one is given one kingdom to research. Learners can present their results in the form of a poster.

Since this is an OPTIONAL activity, no detailed memorandum is provided. If teachers are keen to have learners do this, they will have to provide some form of guidance to learners about what level of detail is expected, e.g. a short
paragraph on one beneficial and one harmful member of each kingdom. It is suggested that this be done in GROUPS of two or four, so each group gets only one kingdom to research (learner 1 and 2 find a beneficial plant and learner 3 and 4 find a harmful plant, for example. One can find the information and the other finds a picture.) Teachers should ensure that all 5 kingdoms are covered by the class, so it will be important to do some planning beforehand.

**Dichotomous Key**

**Activity: Identifying arthropods using a dichotomous naming key**

**Aim:**

To use a dichotomous key to identify arthropods.

**Instructions:**

1. Study the organisms in the table of specimens provided to you.
2. Use the dichotomous key to find out to which taxonomic group each of these arthropods belong.
3. Write the letter corresponding to the arthropod, and then your answer.

**Table of specimens**
<p>| | | |</p>
<table>
<thead>
<tr>
<th></th>
<th></th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>A</td>
<td>B</td>
<td>C</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>D</td>
<td>E</td>
<td>F</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>G</td>
<td>H</td>
<td>I</td>
</tr>
<tr>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>J</td>
<td>K</td>
<td>L</td>
</tr>
<tr>
<td>Characteristic</td>
<td>Instruction</td>
<td></td>
</tr>
<tr>
<td>------------------------------------------------------------</td>
<td>------------------------------------------</td>
<td>---</td>
</tr>
<tr>
<td>1a Arthropod has eight legs</td>
<td>go 2 (Arachnids)</td>
<td></td>
</tr>
<tr>
<td>1b Arthropod does not have 8 legs</td>
<td>go 4</td>
<td></td>
</tr>
<tr>
<td>2a Arachnid has pedipalp with pincers</td>
<td>SCORPION</td>
<td></td>
</tr>
<tr>
<td>2b Arachnid does not have pedipalp with pincers</td>
<td>Go 3</td>
<td></td>
</tr>
<tr>
<td>3a Arachnid drinks blood</td>
<td>TICK</td>
<td></td>
</tr>
<tr>
<td>3b Arachnid does not drink blood</td>
<td>SPIDER</td>
<td></td>
</tr>
<tr>
<td>4a Arthropod has more than 16 legs</td>
<td>Go 9 (Myriapoda)</td>
<td></td>
</tr>
<tr>
<td>4b Arthropod does not have more than 16 legs</td>
<td>Go 5</td>
<td></td>
</tr>
<tr>
<td>5a Arthropod has 3 pairs of legs</td>
<td>Go 6 (Insects)</td>
<td></td>
</tr>
<tr>
<td>5b Arthropod does not 3 pairs of legs</td>
<td>CRUSTACEAN</td>
<td></td>
</tr>
<tr>
<td>6a Insect has hardened fore-wings</td>
<td>COLEOPTERA</td>
<td></td>
</tr>
<tr>
<td>6b Insect does not have hardened fore-wings</td>
<td>Go 7</td>
<td></td>
</tr>
<tr>
<td>7a Insects are social and/or live in a hive</td>
<td>HYMENOPTERA</td>
<td></td>
</tr>
<tr>
<td>7b Insects are not social, do not live in a hive</td>
<td>Go 8</td>
<td></td>
</tr>
<tr>
<td>8a Insects does not have a sponge-like proboscis</td>
<td>LEPIDOPTERA</td>
<td></td>
</tr>
<tr>
<td>8b Insects have a sponge-like proboscis</td>
<td>DIPTERA</td>
<td></td>
</tr>
<tr>
<td>9a Myriapod with one pair of legs per segment</td>
<td>CENTIPEDE</td>
<td></td>
</tr>
<tr>
<td>9b Myriapod with two pairs of legs per segment</td>
<td>MILLIPEDE</td>
<td></td>
</tr>
</tbody>
</table>

Answers:

- **A**: Hymenoptera
- **B**: Millipede
- **C**: Crustacean
- **D**: Tick
- **E**: Spider
- **F**: Centipede
- **G**: Lepidoptera
- **H**: Coleoptera
- **I**: Hymenoptera
- **J**: Scorpion
- **K**: Diptera
- **L**: Hymenoptera

This website shows you an exercise with answers, using a dichotomous key: [http://www.tellusmuseum.org/education/preandpostactivities/animaldichotomouskey.pdf](http://www.tellusmuseum.org/education/preandpostactivities/animaldichotomouskey.pdf)
By the end of this chapter you should know the following:

- The definition of the biological classification system and hierarchical manner of grouping of living organisms based on similarities and differences.
- A brief history of major developments in the classification of organisms.
- The scientific method of naming of organisms using the binomial nomenclature. All organisms have only one scientific name but many common names.
- The division of organisms into prokaryotes (simple, unicellular) and eukaryotes (mostly multicellular) and the major differences between the two.
- The classification of living organisms into five major kingdoms: Monera, Protista, Fungi, Plantae and Animalia and the unique characteristics of each kingdom.

Exercise 11 – 1: End of chapter exercises

1. Which of the following in a classification system is the smallest?
   a) Kingdoms
   b) Species
   c) Family
   d) Class
   
   Solution: 
   b

2. Which Swedish botanist and physician named plants and animals in Latin?
   a) Casper Bauhin
   b) Aristotle
   c) Robert Whittaker
   d) Carolus Linnaeus

   Solution: 
   d

3. The five kingdom classification system was suggested by:
   a) Whittaker
   b) Linnaeus
   c) Darwin
d) Pasteur

**Solution:**

a

4. The following example is the scientific name of a lion: *Panthera leo*. The first part of the scientific name represent the...

a) Genus name
b) Kingdom name
c) Species name
d) Family name

**Solution:**

a

5. Write down the correct biological term for the following descriptions.

a) Type of system by modifying many of the Latin descriptions to two words.
   **Solution:**
   binomial nomenclature
b) Group of organisms which are able to interbreed and produce fertile offspring.
   **Solution:**
   species
c) The scientific name of our human race.
   **Solution:**
   *Homo sapiens sapiens* - (Answer must be underlined if handwritten)
d) The type of asexual reproduction in the Kingdom Monera.
   **Solution:**
   binary fission
e) Highest grouping in a classification system.
   **Solution:**
   Kingdom

6. Give the definition of the term **Biodiversity**.

   **Solution:**
   Biodiversity is a term describing the entire range of plants and animals found in a particular area – it includes all forms of life in an area. Biodiversity can also be used to describe the degree of variation of life forms within a given species, ecosystem, biome, or entire planet.

7. Tabulate three differences between prokaryotes and eukaryotes.
**Solution:**

<table>
<thead>
<tr>
<th>Prokaryotes</th>
<th>Eukaryotes</th>
</tr>
</thead>
<tbody>
<tr>
<td>small cells</td>
<td>large cells</td>
</tr>
<tr>
<td>unicellular or simple</td>
<td>often (but not always)</td>
</tr>
<tr>
<td>multicellular</td>
<td>multicellular</td>
</tr>
<tr>
<td>genetic material not contained</td>
<td>genetic material membrane</td>
</tr>
<tr>
<td>within nucleus</td>
<td>bound-usually within nucleus</td>
</tr>
<tr>
<td>simple membranous system with</td>
<td>distinct membrane-bound</td>
</tr>
<tr>
<td>few organelles</td>
<td>organelles</td>
</tr>
</tbody>
</table>

Check answers online with the exercise code below or click on ‘show me the answer’.

1. 2CXJ  2. 2CXK  3. 2CXM  4. 2CYN  5a. 2CXP  5b. 2CQX  5c. 2CXR  5d. 2CXS  5e. 2CTX  6. 2CXV  7. 2CW

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History of Life on Earth

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12 History of Life on Earth

12.1 Overview

**Time Allocation:** 5 weeks (20 hours)

This chapter consists of the following sections:

1. Overview
2. Representations of life’s history
3. Life’s History
4. Mass extinctions
5. Impact of humans on biodiversity and the environment
6. Fossil tourism
7. Summary
8. End of chapter exercises

**Introduction**

In this final chapter, learners will be introduced to the history of life on Earth. This chapter should be linked to the previous chapters ‘Biospheres to Ecosystems’ and ‘Biodiversity’. Learners need to understand that biodiversity varies not only from region to region, but also across time. The biodiversity on Earth at any given time is related to the prevailing climate and geography. The effect of climate and geography on the type of life forms seen can be linked to the interaction of biotic and abiotic factors that maintain balance in an ecosystem.

This chapter makes mention of many dates, and refers to species that may be unfamiliar to learners. Apart from a few key events and species (mentioned in the CAPS document) learners need not memorise specific dates or species, but should understand the sequence of events and underlying processes that shaped life on Earth.

**Key concepts**

- Scientists use deductive reasoning to understand fossils and the history of life on Earth.
- Geological events often caused changes in climate, which in turn influence the emergence and disappearance of species.
• It takes special circumstances for fossils to form, and fossils can be dated by radiometric, radiocarbon or relative dating.
• Climate and geography helped shape the evolution of life on Earth.
• Geological timescales are divided into eons, eras and periods.
• The Cambrian explosion was a rapid explosion in the diversity of life-forms. All animal groups have their origin in the Cambrian explosion.
• Mass extinctions are massive losses in life, and there have been five mass extinction events in history.
• In the last 4 million years significant changes have occurred in species occurring in Africa, including the evolution of humans.
• Humans have a massive effect on biodiversity and the natural environment and are partially responsible for the ’6th mass extinction’. item South Africa is rich in many fossils from diverse time periods.
• Fossil tourism is a source of income and employment in fossil localities.

12.2 Representations of life’s history

The major focus of this section is to help learners understand how scientists use deductive reasoning to understand the past. Scientists can never know exactly what happened in the past, but they are able to use various forms of evidence (clues) to piece together a coherent picture. When evidence from many different areas start to agree with each other it lends more credibility to the theory. Different forms of evidence, such as that provided by geological records and fossil evidence, will be introduced.

Activity: Construct a timeline of the key events in the history of life on Earth (Essential CAPS)

Aim:

In this exercise you will learn to combine all the information given on the history of life and depict it on a simple geological timescale of your own.

Materials:

• exercise book or cardboard
• coloured pens and pencils
• pictures and information from the Internet and books

Instructions:

Draw a timescale that stretches from ‘0 years ago’ to 530 million years ago.
Depict the history of life on this timescale. On your timeline, show:

- Mesozoic, Paleozoic and Cenozoic eras
- Two major climate changes characteristic of each era
- Major changes to plant and animal life that took place during this time

In this exercise learners are required to combine all the information given on the history of life and to depict this information onto a simple geological timescale of their own.

Learners can do this in poster format or as a class exercise. They may work individually or in small groups of 2 to 4. Pictures from the Internet to illustrate their time scale can be used.

Any time line drawn by a learner may be acceptable, provided that it meets the following criteria:

- It must have a TIME scale e.g. if it is a straight line, the times can written directly onto the line itself. If it is a circle, sections can be labelled with years.
- It must show all three recent eras, i.e. Palaeozoic, Mesozoic and Cenozoic.
- Colour use is optional, but it will make the scale look more attractive.
- It is essential that the relative sizes of the three eras is more or less correct.
- It must show two major climatic changes during each of the three eras.
- It must have major changes to the plant and animal life during the 3 eras.

Continental Drift

Learners do not need to know the dates involved in continental drift. These dates are only approximate and are given as a guideline and to give a sense of the time-scale.

**TEACHER RESOURCES:**

Watch an animation of continental drift at the following link: [http://en.wikipedia.org/wiki/File:Pangea_animation_03.gif](http://en.wikipedia.org/wiki/File:Pangea_animation_03.gif)

This video explains how natural selection takes place!

* See video: 2CXX

**TEACHER RESOURCE:**

This website has a video detailing the fossilisation of Lucy: [http://www.teachersdomain.](http://www.teachersdomain.)
Activity: Comparing the skeleton of a modern bird to the *Archaeopteryx*

**Aim:**

To compare the skeletons of a modern bird (chicken) and *Archaeopteryx*

**Instructions:**

1. Use the pictures below to compare the skeletons of a dinosaur (Theropod), *Archaeopteryx* and a chicken (modern bird). Give four differences and four similarities between *Archaeopteryx* and dinosaurs, and between *Archaeopteryx* and modern birds.
FACT
Watch this fascinating video about some of the interesting organisms that lived after the Cambrian Explosion and left beautiful fossil remains. See video: 2CY2

Solution to activity:

<table>
<thead>
<tr>
<th>Archaeopteryx vs Dinosaur: SIMILARITIES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Jaws have teeth</td>
</tr>
<tr>
<td>2. Hand / arm has claws</td>
</tr>
<tr>
<td>3. Long bony tail present</td>
</tr>
<tr>
<td>4. Presence of gastralia or dermal ribs (not attached to spine)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Archaeopteryx vs Dinosaur: DIFFERENCES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Long forelimbs, like wings</td>
</tr>
<tr>
<td>2. Feathers present</td>
</tr>
<tr>
<td>3. Hand has three claws</td>
</tr>
<tr>
<td>4. Furcula / wish bone present</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Archaeopteryx vs Dinosaur: SIMILARITIES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Presence of gastralia or dermal ribs (not attached to spine)</td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Archaeopteryx vs Dinosaur: DIFFERENCES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Long forelimbs, like wings</td>
</tr>
<tr>
<td>2. Feathers present</td>
</tr>
<tr>
<td>3. Hand has three claws</td>
</tr>
<tr>
<td>4. Furcula / wish bone present</td>
</tr>
</tbody>
</table>

Archaeopteryx vs Modern bird SIMILARITIES:

<table>
<thead>
<tr>
<th>Archaeopteryx vs Modern bird DIFFERENCES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Feathers are present</td>
</tr>
<tr>
<td>2. Forelimbs are long and wing-like</td>
</tr>
<tr>
<td>3. Furcula / wish bone present (fused clavicles)</td>
</tr>
<tr>
<td>4. Bones of the lower forelimb are separate</td>
</tr>
</tbody>
</table>

Archaeopteryx vs Modern bird DIFFERENCES:

<table>
<thead>
<tr>
<th>Archaeopteryx vs Modern bird DIFFERENCES:</th>
</tr>
</thead>
<tbody>
<tr>
<td>1. Teeth in jaws</td>
</tr>
<tr>
<td>2. Claws on forelimbs</td>
</tr>
<tr>
<td>3. Long bony tail</td>
</tr>
<tr>
<td>4. No breast bone</td>
</tr>
</tbody>
</table>

12.3 Life’s History

The section on the Hadean, Archean and Proterozoic are for interest only. Learners are not expected to learn these sections for exams. The educator is to discuss some of the major eras, such as Paleozoic, Mesozoic and Cenozoic. However, it must be emphasised to the learners that the periods within each era need not be memorised.

Watch a video about trilobites.

See video: 2CY3
Activity: Is the Coelacanth the missing link between fish and amphibians?

Aim:

This activity is designed to help you to understand whether coelacanths represent a link between fish and amphibians.

Instructions:

1. Use resources such as the Internet, encyclopaedias and magazines.
2. Find out what structural features lead scientists to suggest that coelacanths represent a link between fish and amphibians.
3. Once you have completed their research, have a class discussion.

This activity is designed to help you to understand whether coelacanths represent a link between fish and amphibians. Use resources such as the Internet, encyclopaedias and magazines.

They are to find out what structural features lead scientists to suggest that coelacanths represent a link between fish and amphibians.

Once learners have completed their research, have a class discussion.

The following is some useful information:

- Coelacanths grow to approximately 180 cm and weighs up to 95 kg
- Coelacanths live to between 30 and 40 years
- They are dark blue in colour and have distinctive pinkish white patterns on the body
- Coelacanths have eight fins:
  - two dorsal fins
  - two pectoral fins
  - two pelvic fins
  - anal fin
  - caudal fin
- The first dorsal fin can be folded down or lifted.
- Most of the skeleton is made of cartilage
- They have a notochord, rather than a vertebral column
- The body is covered with hard scales with small tooth-like growths called denticles, which provide protection
- Fertilisation takes place internally, and the eggs remain inside the mother until birth (ovoviviparous)
12.4 Mass extinctions

This section introduces the learners to the mass extinctions that planet earth has experienced. Learners need to understand that a mass extinction is defined by a sharp decrease in the amount of plant and animal life. There have been five major mass extinction events in Earth’s history.

Watch a video about the meteor impact that may have caused the extinction of the dinosaurs.

See video: 2CY7

See video: 2CY8

Activity: What caused the mass extinctions?

Aim:

To use understanding of fossil evidence and scientific method to demonstrate how each of the hypotheses for mass extinction arrives at its conclusion.

Instructions:

- What are the key requirements of a theory that attempts to explain the mass extinctions?
- Choose one of the two hypotheses discussed and describe it in your own words. List the evidence that supports the theory.
- Through your research on the Internet and by reading books in the library, list any other evidence that you found in support of your chosen hypothesis.

In this activity learners are to use their understanding of fossil evidence and scientific method to demonstrate how each of the hypotheses for mass extinction arrives at its conclusion. Learners can choose either the Impact Theory or the Volcanic Theory as an explanation for the mass extinction. Their description / discussion must be in their own words, not copied from the text given.

The key requirements of a theory that attempts to explain the mass extinctions must:

- Explain all the losses of species at the time, not just a few.
- Explain why some species survived, while others did not.
- Be based on natural events that are known to have occurred at about the same time as the extinction event.
By conducting their own research on the Internet and by reading books in the library, they are to list any other evidence that they found in support of their chosen hypothesis.

The learners can then present their information to the class which in turn can lead to further discussion.

Activity: Understanding evolutionary history based on evidence from South Africa

Aim:

We want to locate where the key events in the history of life occurred in South Africa, based on our earlier discussion of fossil evidence found in South Africa.

Instructions:

1. The table below lists evidence from South Africa on the history of life.
2. Draw a map of South Africa.
3. On your map, show where each piece of evidence listed in the table is located.
4. Also show what this evidence indicates about the history of life.
5. In the third column of the table, write down the era from which these fossils are likely to have emerged. The first part has been done for you.

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Location</th>
<th>Era</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stromatolites</td>
<td>False Bay, Cape Town</td>
<td>Paleozoic, Pre-Cambrian</td>
</tr>
<tr>
<td>Soft-bodied animals</td>
<td>Northern Cape</td>
<td></td>
</tr>
<tr>
<td>Early land plants</td>
<td>Grahamstown</td>
<td></td>
</tr>
<tr>
<td>Primitive plants e.g. Glossopteris</td>
<td>Mooi River, Estcourt</td>
<td></td>
</tr>
<tr>
<td>Coelacanth</td>
<td>Northern KZN Coast</td>
<td></td>
</tr>
<tr>
<td>Mammal-like reptiles e.g. Lystrosaurus, Thrinadoxon</td>
<td>Karoo</td>
<td></td>
</tr>
<tr>
<td>Dinosaurs Euskylosaurus</td>
<td>Drakensberg and Maluti mountains, Ladybrand, Free State</td>
<td></td>
</tr>
<tr>
<td>First mammals</td>
<td>Lesotho, Eastern Cape</td>
<td></td>
</tr>
<tr>
<td>Humans and pre-humans</td>
<td>Gauteng, North West, Free State, KwaZulu-Natal, Limpopo</td>
<td></td>
</tr>
</tbody>
</table>
In this activity the learners are required to locate where the key events in the history of life occurred in South Africa, based on earlier discussion of fossil evidence found in South Africa.

Learners should:

- Draw a map of South Africa
- Show where each piece of evidence listed in the table is located on the map.
- Show what this evidence indicates about the history of life.
- Write down the period from which these fossils are likely to have emerged.

<table>
<thead>
<tr>
<th>Evidence</th>
<th>Location</th>
<th>Era</th>
</tr>
</thead>
<tbody>
<tr>
<td>Stromatolites</td>
<td>False Bay, Cape Town</td>
<td>Paleozoic, Pre-Cambrian</td>
</tr>
<tr>
<td>Soft-bodied animals</td>
<td>Northern Cape, Grahamstown</td>
<td>Pre-Cambrian, Paleozoic</td>
</tr>
<tr>
<td>Early land plants</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Primitive plants e.g.</td>
<td>Mooi River, Estcourt, KZN Coast</td>
<td>Paleozoic</td>
</tr>
<tr>
<td>Glossopteris</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coelacanth</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Mammal-like reptiles e.g. Lystrosaurus, Thrinadoxan</td>
<td>Karoo</td>
<td>Lystrosaurus: Late Paleozoic to Mesozoic; Thrinadoxan: Mesozoic</td>
</tr>
<tr>
<td>Dinosaurs Euskylosaurus</td>
<td>Drakensberg and Maluti mountains, Ladybrand, Free State Lesotho, Eastern Cape</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>First mammals, Megazostrodon</td>
<td>Gauteng, North West, Free State, KwaZulu-Natal, Limpopo</td>
<td>Mesozoic</td>
</tr>
<tr>
<td>Humans and pre-humans</td>
<td></td>
<td>Cenozoic</td>
</tr>
</tbody>
</table>

Activity: Observing fossils

Aim:

Examine fossils at a museum or fossil site or look at photographs of fossils.

Materials:
These websites provide a list of museums that contain fossils:
http://www.southafrica.info/travel/cultural/museums.htm
http://www.museumsonline.co.za/

A list of fossil sites around the world is given below. Identify the ones that are within South Africa:

If you are unable to visit the fossil sites or museums, the following website gives photographs and explanations of the major fossils that have shaped our understanding of the history of life:

**Instructions:**

Travel to your nearest museum, fossil site or the website listed and observe any fossils on display. Find out how they have been preserved, describe the key features of each fossil, how they were dated and what they tell us about our past.

Learners can be taken to museums or fossil sites or look at photographs of fossils to examine various fossils.

Depending on how you are going to do this activity with your learners, they will need to find out how they have been preserved, describe the key features of each fossil, how they were dated and what they tell us about our past.

This can be presented in a research report format, or may simply be done as a class exercise. Formal assessment is not necessary.

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12.5 Impact of humans on biodiversity and the environment

Humans have impacted the biodiversity and environment in several crucial ways. The broad term used to describe this effect is known as the **anthropogenic effect**.

Discuss with the learners the activities that humans are involved in and how these activities contribute to the changes in the environment.
FACT
A brief video about Maropeng and what you can do there. We can rightly be proud of this world class centre!
See video: 2CWT

Group discussion: How do we manage the impact of humans on the planet?

The table above presents the various human activities that have impacted on the environment and on biodiversity. In groups, discuss possible methods by which the impacts listed above could be reduced. How can we reduce the impact humans have on the environment? After your discussion, re-draw the table and add a third column to the right listing these different ways you have discussed among yourselves.

This can be a quick, 5-10 minute discussion. It is recommended that the teacher divides the learners into seven groups and allocates a topic to each group. After 5-10 minutes, each group gives a verbal report-back to the class and they then complete the last column as a group. Other suggestions may be added at this stage. It is not necessary to make this a formal assessment.

12.6 Fossil tourism

Fossil tourism is an important source of income and employment in areas in which fossils are located.

TEACHER RESOURCES:
- The following link shows information about the Maropeng Visitors’ Centre near Krugersdorp in Gauteng: http://www.maropeng.co.za/index.php/maropeng/
- Watch a short video interview with Prof Lee Berger, who found a fossil of Australopithecus sediba near Sterkfontein in 2008: http://www.maropeng.co.za/index.php/media/

12.7 Summary

- Scientists use deductive reasoning to understand fossils and the history of life on Earth.
- Geological events often caused changes in climate, which in turn influence the emergence and disappearance of species.
- It takes special circumstances for fossils to form, and fossils can be dated by radiometric or relative dating.
- Climate and geography helped shape the evolution of life on Earth.
- Geological timescales are divided into eons, eras and periods.
- The Cambrian explosion was a rapid explosion in the diversity of life-forms. All animal groups have their origin in the Cambrian explosion.
• During the Paleozoic the first fish, animals with shells and insects evolved and plants first colonised land.
• The Mesozoic was the ‘age of dinosaurs’, later in the era birds evolved, and gymnosperms evolved.
• The Cenozoic is the most recent era and was the ‘age of mammals’.
• Mass extinctions are massive losses in life, and there have been five mass extinction events in history.
• In the last 4 million years significant changes have occurred in species occurring in Africa, including the evolution of humans.
• Humans have a massive effect on biodiversity and the natural environment and are partially responsible for the ‘6th mass extinction’.
• South Africa is rich in many fossils from diverse time periods.
• Fossil tourism is a source of income and employment in fossil localities.

Exercise 12 – 1: End of chapter exercises

1. In each of the following cases write down the letter of the most correct alternative.
   a) Which of the fossils have been found in Namibia?
      i. Mammal-like reptiles
      ii. Glassopteris leaves
      iii. Soft-bodied animals
      iv. Early mammals
   Solution: c
   b) A problem in the accuracy of radiocarbon dating is that:
      i. scientists are not sure that radioactive decay actually occurs
      ii. the decay rate of minerals can change without warning
      iii. the rocks that contain the fossils can’t be dated
      iv. the half-life of carbon-14 is relatively short, and most fossils are millions of years old
   Solution: d

2. Study the table below that shows the decay of carbon-14 over time and then answer the questions that follow:


Decay of carbon-14

<table>
<thead>
<tr>
<th>Years from present</th>
<th>0</th>
<th>5730</th>
<th>11460</th>
<th>17190</th>
<th>22920</th>
<th>X</th>
<th>34380</th>
<th>40110</th>
</tr>
</thead>
<tbody>
<tr>
<td>Number of half-lives elapsed</td>
<td>0</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4</td>
<td>5</td>
<td>6</td>
<td>7</td>
</tr>
<tr>
<td>Percentage of original carbon-14 remaining</td>
<td>100</td>
<td>50</td>
<td>25</td>
<td>12,5</td>
<td>6,25</td>
<td>Z</td>
<td>1,56</td>
<td>0,78</td>
</tr>
</tbody>
</table>

a) State two types of methods used to determine the age of fossils.
b) Calculate the value of:
   i. X = 5 x 5730 = 28650 years
   ii. Z = 6,25% / 2 = 3,125%

   Explain why it would not be possible to date the fossil of an organism that existed 80 million years ago using the decay of carbon-14.
d) Give two reasons why there are gaps in the fossil record.

**Solution:**

a) Any two of the following:
   - Radiometric dating using minerals in volcanic rock
   - Radiocarbon dating using organic fossils like bones
   - Relative dating, where one fossil is stated as being ‘younger or older’ than another, without giving a specific date / age

   Calculate the value of:
b) i. X = 5 x 5730 = 28650 years
   ii. Z = 6,25% / 2 = 3,125%

c) A fossil that is 80 million years old has almost no carbon-14 left in it – the amount will be too small to be detected. Therefore carbon-14 dating would not give a reliable date / age.

d) Any two of the following:
   - Not all fossils have been found yet.
   - Fossilisation is rare, so not all dead organisms fossilise (conditions may have been wrong for them to fossilise).
   - Many fossils have been destroyed by movements of the Earth’s plates or by human activities like digging and dam building.
   - Soft-bodied organisms do not usually fossilise, so very few of them are present in the fossil record
   - Any other relevant fact may be accepted, e.g. people may not recognise an item as a fossil, so it goes unnoticed.
3. Study the graph on the following page which shows the major extinction events answer the questions that follow.

**Biodiversity during the Phanerozoic**

- All Genera
- Well-Resolved Genera
- Long-Term Trend
- The "Big 5" Mass Extinctions
- Other Extinction Events

![Graph of mass extinctions](image)

**Figure 12.1: Graph of mass extinctions**

a) When did the Cenozoic era begin?
b) Which mass extinction took place towards the end of the Paleozoic era?
c) Approximately how many genera of species went extinct at the end of the Paleozoic era? Show ALL working.
d) Explain why the number of genera of organisms increased rapidly after each mass extinction.

**Solution:**

a) Around 65 mya, after the last major extinction.
b) The Permian extinction.
c) Learners are required to read-off of the number of genera present at the start of the extinction and the number of genera remaining at the end of the extinction. The difference between these two figures would be the number of genera lost during the extinction. Learners will have to estimate from the graph as the axes are not clear. A range of answers should therefore be accepted. The answer should be around 80%.
d) The number of genera increased rapidly after each extinction event, because many genera were wiped out completely during the extinction, so their niches were left open. These niches were rapidly taken over by other genera, who diversified and formed new genera by natural selection.

4. The following questions are about the extinction of dinosaurs on Earth.

a) What evidence do scientists use to show that dinosaurs once existed on Earth?
b) How long ago did the dinosaurs become extinct?

   c) Describe a hypothesis that has been proposed for the extinction of many species, including the dinosaurs during the extinction event at the end of the mesozoic.

   **Solution:**

   a) Fossils that were formed when the dinosaurs died, also animals like sharks, birds and crocodiles, that are closely related to dinosaurs.

   b) Dinosaurs became extinct 65 mya.

   c) The Earth was struck by an asteroid from outer space (at the Yucatan Peninsula off Mexico). This caused massive fires, earthquakes and tsunamis, as well as dust clouds that blocked the sun, so photosynthesis was severely reduced and global climate changed. Few animals survived, and these diversified to fill the vacant niches and multiplied to repopulate the earth. The mammals and flowering plants became the dominant life forms after the last mass extinction.

Check answers online with the exercise code below or click on 'show me the answer'. 1a. 2CYB  1b. 2CYC  2. 2CYD  3. 2CYF  4. 2CYG

www.everythingscience.co.za  m.everythingscience.co.za
List of Definitions