ORDINARY LEVEL SECONDARY EDUCATION BIOLOGY PRACTICALS

USING LOCALLY AVAILABLE MATERIALS

TEACHER’S GUIDE
As the era of “Alternative to Practical” comes to an end, it is my hope that science teachers nationally embrace the new paradigm, that a science lesson should be student-centred, competence-based, activity-oriented, and connects with student’s life experience. Every student in Tanzania should perform practical exercises, not just the few tested on national exams, but the wider range of hands-on activities teachers should employ to build a deep understanding in their students.

Educational research has identified two obstacles to the universal implementation of hands-on science education. First, many teachers themselves learned in Alternative to Practical schools and therefore lack essential experience with hands-on science. Every effort is already under way to overcome this deficiency. A national in-service training program reaches tens of thousand of educators annually, and a Teachers’ Guide has already been written to explain to teachers the standard execution of dozens of hands-on activities in Biology.

The remaining challenge is a fallacy rooted in ignorance and complacency: the idea that the materials required for hands-on science teaching are unavailable to most schools. We reject the notion that science education requires expensive, imported materials. Everything required to teach modern science is already available in our villages and towns. The challenge is simply to begin.

Science belongs to Tanzania as much as any country in the world. The law of gravity respects no national boundaries; we all feel its effect and can measure its strength. Those who decry the use of locally available materials as “stone age science” misunderstand the meaning of Science - that it applies universally, in any situation, with any materials. Dependence on expensive imported materials teaches students that Science is a foreign concept, to be memorized rather than understood, and that Science lacks application to daily life. Science is the birthright of humanity, as much as Language or Mathematics or Music, and the time has come to embrace what we already own.
This Companion Guide was written to equip teachers with the knowledge and skills to deliver hands-on science lessons in any school, especially those without standard science laboratories. I hope that this Companion Guide will also inspire school inspectors, examiners, curriculum developers and college tutors to increase their emphasis on the importance of hands-on education, and to reject material deficiencies as an excuse for any absence of students’ practical work. In the same spirit, this Companion Guide seeks to expand the range of approaches to learning Biology and it is my hope that many stakeholders in science education will embrace alternative methods that enable quality science education for every student.

Prof. Hamisi O. Dihenga
Permanent Secretary
Ministry of Education and Vocational Training
April 2011
Background

Motivation for Writing this Companion Guide

Quality science education requires students to perform experiments with their own hands. Unfortunately, research on the situation of secondary science education shows that many students do not get such opportunity. This is due to several factors, all of which we believe can be addressed.

First, many teachers themselves do not have adequate requisite experience with science experiments, largely due to the absence of practical education when they themselves were students. Teacher training programs and the new Biology Teachers’ Guide seek to address this shortcoming.

Second, this lack of experience leads to low confidence in trying new experiments. Science can only be learned through experimentation – just as students must perform activities to truly understand the concepts in the syllabus, so too must teachers. The teacher using this book is strongly encouraged to perform every one of these experiments to deepen his or her fundamental understanding of Biology.

Third, most schools lack traditional laboratory facilities. Many educators therefore assume that this means hands-on activities are impossible.

To address this misconception, the Ministry of Education and Vocational Training has decided to prepare this Biology Teacher’s Practical Guide. The objective is to ensure that all secondary school biology teachers can conduct practical work even if they do not have access to a standard Biology laboratory. Specifically, this book demonstrates that many quality hands-on science experiments are possible with very basic materials. The experiments in these pages require materials available in villages or, at worst, in a regional capital. Standard laboratory materials certainly add value to science teaching; this book merely makes it clear that they are not as a condition required for provision of quality education.
Procedures Followed in Developing the Companion Guide

This Companion Guide builds on the work of the Biology Teachers’ Guide. In preparation for the Teachers’ Guide, educators and subject experts identified activities for most of the topics on the ordinary level syllabus. To prepare this Companion Guide with Local Materials, a team of secondary school teachers and science experts from TIE devised methods for performing the activities of the Biology Teachers’ Guide using low cost and locally available materials.

Description of the Companion Guide

Practical investigations address specific syllabus content. Each topic begins with a short summary of relevant syllabus material. Each activity is introduced in that context as a method for students to experiment with the topic of the day. Each activity then states clearly its objective(s). Generally, these objectives match the objectives in the Biology Teachers’ Guide. The teacher should use both resources, side by side, when preparing activities.

Each activity description then lists the required materials. Instructions for the local manufacture of several items are given in the first section of this book in the section called “Manufacture of Apparatus”. If an activity requires the use of materials from this section they will be marked with a star (*) in the materials list. The same is true for chemicals that are mentioned in the “Sources of Chemicals” section. For example, the materials list may look like this: “Materials: beakers*, copper (II) sulphate*, plastic spoon...” If you see this, you can refer to the materials list to see a suggested method for making your own beakers. In the sources of chemicals list you will find a common place where copper (II) sulphate can be found.

After listing the objectives and materials, the description lists any hazards associated with the activity and precautions teachers should take to minimize these hazards to ensure safety. Next are procedures, both for preparing the activity and for executing the experiment. While preparation steps are generally to be performed by the teacher, the activity steps are often to be performed by the students themselves.

The description next provides the expected results and what conclusions may be drawn from them. Then follow the instructions for cleaning up, including methods for disposing of any waste. The section closes with questions useful for guiding classroom discussion. Students should discuss these questions in groups and share their answers with the class.

Many of the activities also include a “Notes” section to provide the teacher with additional information about the activity. This information may be practical or theoretical.
Application of the Companion Guide

This guide is written for teachers to acquire the knowledge and skills needed to lead students in hands-on science learning. While all of the experiments in this companion guide may be performed as demonstrations, the intention is for many of the activities to be performed by the students themselves, individually or in small groups, under the supervision of the teacher.

To prepare for such lessons, the teacher should attempt these experiments first. Especially for teachers who are new to hands-on science experimentation, these experiments should, in themselves, provide a useful training. If there are multiple subject teachers at the school, they are encouraged to experiment together. Once the teacher has achieved comfort and proficiency with the given activity, the teacher should integrate the activity into relevant lesson plans.

The vision is not for students to be spectators of science, but active players themselves.

Finally, the teacher is advised to not regard the activities in this book as the only possible activities nor even the only possible activities for these particular objectives. Every educator has ideas for effective teaching and new ideas are the substance of development. After trying an activity, the teacher is strongly encouraged to devise and attempt alternatives. Where possible, teachers should collaborate with each other on such experiments, and share with each other the ideas they develop.

The vision is not for teachers to be passive implementers, but innovators themselves.
## Contents

1. Laboratory Equipment .................................................. 9
2. Sources of Chemicals .................................................... 17
3. Making Biology Solutions ............................................ 19
4. Collecting Biology Specimens ....................................... 22
   - Kingdom Fungi .......................................................... 22
     - Phylum Basidiomycota ............................................. 23
     - Phylum Zygomycota ............................................... 23
     - Phylum Ascomycota ............................................... 23
   - Kingdom Plantae ..................................................... 24
     - Division Bryophyta ............................................... 24
     - Division Filicinophyta ........................................... 25
     - Division Coniferophyta ......................................... 26
     - Division Angiospermophyta ..................................... 26
   - Kingdom Animalia .................................................... 27
     - Phylum Platyhelminthes .......................................... 28
     - Phylum Nematoda or Aschelminthes ............................. 29
     - Phylum Annelida .................................................. 29
     - Phylum Arthropoda ............................................... 30
     - Phylum Chordata ................................................ 35
5. Biology Activities with Specimens .................................. 44
   - Characteristics of Living Things ................................. 44
   - Introduction to Classification .................................. 46
   - Classification System ............................................. 47
   - Investigation of Kingdom Fungi ................................... 49
   - Investigation of Division Coniferophyta ......................... 51
   - Investigation of Division Angiospermophyta .................... 52
     - Identification of the Reproductive Parts of the Flowers .... 52
Examination of Structures of Representative Dicotyledons and Monocotyledons ........................................ 55
Investigation of Phylum Arthropoda ........................................ 57
Investigation of Phylum Chordata ........................................ 59
Dissection of a Rat ......................................................... 61

6 Biology Activities .................................................................. 65
Introduction to Biology .............................................................. 65
Measuring and Recording Mass, Temperature, Pulse Rate, and Volume ............................................................... 65
Cell Structure and Organization ................................................ 67
Examining Animal and Plant Cells ............................................ 67
Nutrition .................................................................................. 69
Food Test for Lipids ................................................................. 70
Food Test for Proteins ............................................................... 72
Food Test for Starch ................................................................. 74
Food Test for Reducing Sugars ................................................ 75
Food Test for Non-Reducing Sugars .......................................... 77
Investigating the Structures of a Leaf ........................................ 79
Test for Starch in Leaves ........................................................... 81
The Importance of Carbon Dioxide in Photosynthesis .............. 84
The Importance of Chlorophyll in Photosynthesis .................... 86
The Importance of Light in Photosynthesis .............................. 89
Oxygen as a By-product of Photosynthesis ............................... 91
Essential Minerals in Plants ..................................................... 93
Interaction of Living Organisms .................................................. 97
Investigation of Abiotic and Biotic Components in the Environment ............................................................... 97
Construction of Food Webs and Food Chains .......................... 98
Transport of Materials in Living Things ..................................... 100
Demonstration of Diffusion ...................................................... 101
Osmosis .............................................................................. 102
Demonstration of Capillarity .................................................... 104
Demonstration of Mass Flow .................................................... 105
Demonstration of Transpiration Pull ......................................... 107
Examination of the Vascular System in Plants ......................... 109
Examination of Root Hair in Germinated Seeds ..................... 111
Determination of Pulse Rate ................................................... 112
Gaseous Exchange and Respiration ......................................... 114
Identification of Carbon Dioxide in Exhaled Air .................... 114
Anaerobic Respiration ........................................................... 115
Chapter 1

Laboratory Equipment

Throughout this book you will see materials that have been marked with an asterisk (*). These are materials required for multiple activities that can be found or assembled from locally available materials. Instructions for finding and making these materials are listed below to avoid repetition in the subsequent sections.

Beakers

Use: To hold liquids
Materials: Water bottles, juice containers, lids for bottles or jars, and a knife.
Procedure: Take empty plastic bottles of different sizes. Cut them in half. The base can be used as a beaker.

Blotting/Filter Paper

Use: To use remove/wipe excess water.
Materials: Tissue paper.

Cages

Use: To capture different animals.
Materials: Cardboard box, wire mesh, string, and bottles.
Procedure: Make a cut in the bottle without cutting completely through the bottle.
Get an empty box and cut it on top. Cover the top with wire mesh and
secure it with string. Then make a small cut like a box with three sides so that the door can open and close.

Figure 1.1: A bottle cage, which can be used to collect and display specimens

Figure 1.2: A box cage, which can be used to display live specimens

Carbon Paper

Use: To prevent light from entering.
Materials: Aluminium foil from cigarette packets, gift paper can be used as a substitute for carbon paper.

Delivery Tube

Use: For the movement and collection of gases.
Materials: Straws, pen tubes, IV infusion tubes and pumpkin or pawpaw petioles.
Dissection Needles

Use: To hold a specimen in place while performing a dissection.
Materials: Office pins, needles from syringes, or acacia thorns.

Dissection Trays

Use: To hold a specimen in place while performing a dissection.
Materials: Take away food container, candles.
Procedure: Melt the candle wax in a take away container to create a dissection tray.

Droppers

Use: To add liquids in drops.
Materials: 2 mL syringes.
Procedure: Take a syringe. Remove the needle.
Hazard: Remove the needle from the syringe. Never use syringes with the needles. Never provide needles to the students.

Figure 1.3: Small syringes from pharmacies can be used as droppers

Funnel

Use: To guide liquid or powder into a small opening.
Materials: Empty water bottles, knife.
Procedure: Take an empty water bottle and remove the cap. Cut them in half. The upper part of the bottle can be used as a funnel.
Heat Source
Use: Heating substances.
Materials: Candles, kerosene stoves, charcoal burners, metal can and moto poa.
Procedure for making a Moto Poa stove: Cut a metal can in half and add a little moto poa, then light for quick heat.

Petri Dishes
Use: To grow cultures or display small specimens.
Materials: Water bottle and scissors.
Procedure: Take empty plastic bottles of different sizes. Cut about 1 inch up from the bottom of the bottle. Lids of different containers can also be used at petri dishes.

Scalpels
Use: To dissect different organisms.
Materials: Knife, box cutter, or razor blades.

Spatula
Use: To transfer small amounts of a solid substance.
Materials: Wooden, plastic, or metal spoon, a knife and plastic bottle.
Procedure: Cut a thin rectangle from plastic water bottle half way so that it resembles a spatula.

Stopper
Use: To close a bottle or make an airtight seal.
Materials: Bottle caps, Sandals (ndala), and a knife.
Procedure: Cut a spherical piece of a sandal according to the size of the stopper you need.
**Sweep Net**

Use: To catch insects.
Materials: Large stick, scissors, mosquito net, string.
Procedure: Get a mosquito net with a ring. Stitch the ring to the net to the net to make it firm. Cut out a rectangular notch from the center of the stick. Insert the ring together with the net into the notch in the stick, then secure them with a string. Tie a string around the bottom of the net and remove the excess net with scissors.

![Sweep Net Diagram](image)

Figure 1.4: A sweep net can be made from a mosquito net and used to collect many different organisms

**Test Tubes**

Use: To hold a small amount of liquid for examination or testing.
Materials: Syringe, candle or heat source, and a hard surface.
Procedure: Buy syringes of different volume from a pharmacy. Remove the plunger and the needle. Burn the bottom with a candle till the plastic begins to melt, then press the melted bottom against a hard surface to close.
Hazards: Remove the needle from the syringe. Never use syringes with the needles. Never provide needles to the students.

**Test Tube Holders**

Use: To hold test tubes while heating.
Materials: A small piece of wood and a rubber band.
Procedure: Tie a rubber band to a piece of dry wood, then wrap the rubber band around the test tube. Fold a piece of paper in such a way that it can
hold a test tube.

Figure 1.5: Simple local materials can be used to make a test tube holder

Watch Glass
Use: To display small specimens.
Materials: Water bottles and scissors.
Procedure: Take empty plastic bottles of different sizes. Cut about 1 inch up from the bottom of the bottle. Lids of different containers can also be used as watch glasses.

Water Bath
Use: To heat substances without using a direct flame.
Materials: Heat source, water, and a cooking pot.
Procedure: Bring water to a boil in a small aluminium pot, then place the test tubes in the water to heat the substance inside the test tube.

White Tile
Use: To easily observe colour changes in leaves.
Materials: Glue or cellotape, wood block, white paper, and plastic sheeting
Procedure: Using cellotape or glue, cover a wood block with white paper. Then cover the white paper with a plastic sheet to prevent water from wetting the paper.

Water Drop Microscope
Use: To magnify very small organisms so they are easier to observe.
Materials: Stiff sheet of plastic sheeting, clothes pins, block of wood, sheet of metallic gift paper, cardboard box, glue, and light source, blotting paper,
hole punch, knife or razor blade, and water.

Procedure:

1. Cut a rectangular piece of stiff plastic sheeting, about 3 cm x 7 cm.
2. Using a paper hole punch, make a round hole in the plastic rectangle.
3. Glue the plastic rectangle to the end of a clothes pin so that the hole hangs over the end of the clothes pin.
4. Glue this clothes pin to the centre of a block of wood.
5. Take apart another clothes pin and use the two pieces to make the slide holder. Glue them to the board on either side of the first clothes pin such that a slide can rest on top of them just below the water drop hole.
6. Cut a small piece of gift paper/aluminium foil to act as a mirror.
7. Glue one edge of the foil into the cardboard box.
8. When the glue has dried, lift the other end so that the mirror is at an angle directing light towards the “microscope”.
9. Place a drop of water on the hole you punched in the plastic sheeting by using your finger.
10. Optional: Take apart a clothes pin and use it as a wedge in the jaw of the first clothes pin. Slide it in to lower the drop of water towards the slide and pull it out to raise the drop. This acts as a course adjustment knob.
11. Another clear piece of stiff plastic can be used as the slide for holding a specimen.
Figure 1.6: Side view of a water-drop microscope

Figure 1.7: Top view of a water-drop microscope
Chapter 2

Sources of Chemicals

The following is a list of chemicals you will need in the biology laboratory. For each we note local sources of these chemicals, low cost industrial sources of these chemicals, methods to manufacture these chemicals at your school, and/or functional alternatives to these chemicals. We also list information like other names, common uses, and hazards. Chemicals are generally listed alphabetically by IUPAC name.

**Citric Acid**
IUPAC Name: 2-hydroxypropane-1, 2, 3-tricarboxylic acid
Formula: C$_6$H$_8$O$_7$ = CH$_2$(COOH)COH(CHOOH)CH$_2$COOH
Local Name: Ndimu ya unga
Description: White crystals soluble in water
Use: All purpose weak acid, manufacture of Benedict’s solution
Hazard: Keep out of eyes
Source: Markets, Supermarkets

**Copper Sulfate**
IUPAC Name: Copper (II) Sulphate pentahydrate
Formula: CuSO$_4$
Local Name: Mruturutu
Description: white (anhydrous) or blue (pentahydrate) crystals
Use: Manufacture of Benedict’s solution, test for Proteins
Source: Local medicine supply shops

**Gentian Violet (GV)**
Description: Purple Liquid
Uses: Staining xylem cells
Sources: Pharmacies or hospitals
Glucose
Formula: C₆H₁₂O₆
Description: White powder
Uses: Food test
Sources: Shops or pharmacies
Note: For food tests, the vitamins added to most glucose products will not cause a problem.

Iodine
Formula: I₂(s)
Description: Brown liquid
Uses: Food test for starch and lipids
Sources: Pharmacies
Note: Pyrodine iodine tincture without ethanol is the best option. An iodine tincture containing ethanol might not work for some uses.

Sodium Carbonate
Formula: Na₂CO₃
Local name: Soda ash, washing soda
Description: White powder completely soluble in water
Use: Manufacturing Benedict’s solution
Hazard: Caustic, corrosive
Source: Commercial and industrial chemical supply companies or Batik manufacturers

Sodium Hydroxide
Formula: NaOH
Local name: Caustic soda
Description: White deliquescent crystals
Uses: Food tests for protein, absorbs carbon dioxide in photosynthesis experiments
Hazard: Corrodes metal, burns skin, and can blind if it gets in to the eyes
Source: Industrial supply shops, supermarkets, hardware stores (drain cleaner)

Sodium Hydrogen Carbonate
Formula: NaHCO₃
Local name: Baking soda
Description: White powder
Uses: To add CO₂ in photosynthesis experiments
Hazard: Corrodes metal, burns skin, and can blind if it gets in to the eyes
Source: Industrial supply shops, supermarkets, hardware stores (drain cleaner)
Chapter 3
Making Biology Solutions

Activities in the topics of Nutrition and Respiration require specific analytical solutions. In this section you will find materials and instructions on how to prepare common solutions for the Biology laboratory.

For local and low cost sources of the chemicals mentioned in these preparations, see the section on Sources of Chemicals.

**Benedict’s Solution**
Description: Bright blue solution
Use: To test for reducing and non-reducing sugars
Result: Gives orange precipitate when boiled with reducing sugar
Hazard: Copper ions are poisonous if they enter the body. Use tools to avoid contact between copper (II) sulphate and skin. Wash hands after using this chemical.
Procedure: Dissolve 5 teaspoons of sodium carbonate, 3 teaspoons of citric acid, and one teaspoon of copper sulphate in half a litre of water. Shake until everything is fully dissolved.
Note: The addition of the citric acid and sodium carbonate should be done slowly as they cause effervescence when mixed quickly.

**Calcium Hydroxide Solution (Lime Water)**
Description: Opaque white liquid
Use: To test for CO₂
Result: This liquid will change from clear to cloudy if CO₂ is present.
Procedure: Add 3 spoonfuls of white cement into about half a litre of water. Stir the solution and let it settle. Decant the clear solution and transfer it to a reagent bottle.
Citric Acid Solution
Description: Colourless solution
Use: To hydrolyse non-reducing sugars to reducing sugars
Procedure: Dissolve 2 1/2 spoonfuls of citric acid in half a litre of water.

Copper Sulphate Solution
Description: Light blue solution
Use: To test for proteins, to prepare Benedict’s Solution
Result: Gives a purple colour when combined with NaOH in protein solution
Hazard: Copper ions are poisonous if they enter the body. Use tools to avoid contact between copper (II) sulphate and skin. Wash hands after using this chemical.
Procedure: Dissolve 1 spoonful of CuSO₄ crystals in 1/2 litre of water. Dissolve the CuSO₄ completely.

Iodine Solution
Description: Light brown solution
Use: To test for starch and lipids
Result: Gives a red ring with lipids and a black-blue with starch
Procedure: Dilute 1 part concentrated iodine tincture with 9 parts water. Keep the solution in a labelled reagent bottle.

Figure 3.1: Iodine solution can be easily prepared and stored for later use.
Sodium Hydroxide Solution
Description: Slightly cloudy white solution
Use: To test for proteins
Result: Gives a purple colour when combined with CuSO₄ in protein solution
Hazard: Corrodes metal, burns skin, and can blind if it gets into the eyes
Procedure: Combine 1 spoon of NaOH with 1/2 litre of water.
Local manufacture: Burn dry grass and collect the ash. Dissolve 3 spoonfuls of ash into a litre of water. Stir the solution and let it settle. Decant the solution, then place the solution in a labelled reagent bottle.
Note: Local manufacture is not very practical because it will make a very dilute solution. This can be performed just to demonstrate the nature of ashes. It is best to buy industrial caustic soda.
Chapter 4

Collecting Biology Specimens

When teaching Classification, we will need a variety of organisms that may not always be available. Below is information about each Kingdom, Phylum, and Class on the O-level syllabus and how to collect, preserve, kill, and dissect examples in each.

Kingdom Fungi

The following are features of Kingdom Fungi:

1. They have no roots, stems, or leaves.

2. They lack chlorophyll, are non-photosynthetic and have to get their own food by feeding on dead plants or animals. (Notice the lack of green colour, because of lack of chlorophyll).

3. Most fungi have cell walls made of chitin, which is a polysaccharide.

4. Their body is made of a network of small, tube-like filaments called hyphae.

5. Fungi store carbohydrates as glycogen.

6. Fungi reproduce asexually by small structures called spores.

There are 3 major phyla in Kingdom Fungi. These are Phylum Basidiomycota, Zygomycota, and Ascomycota.
Phylum Basidiomycota

Mushrooms and Toadstools (Uyoga)
Basidiomycota is the most common division of the Fungi Kingdom. Mushrooms and toadstools are in this division. The part of the mushroom that grows above the ground is the reproductive body and is divided into a stem, cap, and gills. Spores are released from the gills and are dispersed by wind.

Collection
Mushrooms should be collected during the rainy season. Mushrooms can be found on dead and decaying materials like logs in the forest. Mushrooms may also be purchased in supermarkets.

Preservation
Dry mushrooms in sunlight or preserve them in alcohol (a clear methylated spirit that is 70 % alcohol and 30 % water).

Dissection
For the dissection of a mushroom, remove the cup of the mushroom and observe the gills. Cut the stem vertically with a razor blade and observe the inside.

Phylum Zygomycota

Bread Mould and Mucor (Ukungu wa mkate, ukungu wa muhogo)
Zygomycota grows on rotting material and looks like small white thread. An example of Zygomycota is bread mould or mucor.

Collection
Bread mould may be cultured by exposing some slices of bread to moisture. If you live in a dry area, add a few drops of water to the bread and close in a clear bag. For mucor culture from fruits like tomatoes, keep in warm and moist conditions. In dry areas, enclose in clear bags.

Phylum Ascomycota

Yeast (Hamira)
Ascomycota are single-celled organisms called yeast that grow on the surface
of rotting fruit and reproduce by budding. Yeast is used to bake bread and create alcohol.

**Collection**

Yeast can be purchased at any shop.

**Preservation**

Keep yeast in an air-tight container.

**Kingdom Plantae**

Organisms in Kingdom Plantae are eukaryotic. Kingdom Plantae is very large and contains many plants. Although organisms in this group look very different, they all get their nutrition from a process called photosynthesis. Photosynthesis is a way to manufacture food from simple materials with the help of the sun. The following are features of Kingdom Plantae:

1. In all plants, the cell walls are made up of cellulose.
2. They demonstrate autotrophic nutrition – they manufacture their own food through photosynthesis.
3. They have chlorophyll.
4. They are multicellular and the plant body is separated into tissues, organs, and systems.

There are 4 major divisions in Kingdom plantae. These are Division Bryophyta, Filiciniophyta, Coniferophyta, and Angiospermophyta.

**Division Bryophyta**

**Mosses and Liverworts**

Bryophyta are mosses and liverworts. They live on the land, but can only grow in wet places because they have no way to carry water. They also need water to reproduce. These are the features of Division Bryophyta:

1. They have no true roots, stems, or leaves.
2. They have no vascular tissue.
3. They reproduce by using spores.
Collection
In dry places, moss should be collected during the rainy season. Moss and liverwort can be found on rocks or trees in moist climates or in rocky riverbanks.

Preservation
Once moss or liverwort has been collected, it can be kept for several days on a rock placed in a container with water.

Division Filicinophyta
Ferns
Division Filicinophyta are ferns. Ferns grow in moist, shady environments like ground beds of forests.
The following are the features of Division Filicinophyta:

1. They have true roots, stems, and leaves.
2. They have vascular tissue (xylem and phloem).
3. The leaves make sori which will later produce spores so the fern can reproduce.
4. The leaves are called fronds.
5. They grow in damp and shady places.

Collection
Ferns can be found in shady and humid environments, usually in forests.

Preservation
Ferns can be dried inside a book for future use. Place a fern between two pieces of paper and then place them into a book. Add more weight on top of the book and wait a few weeks. These specimens will be very delicate but will last a long time.
Division Coniferophyta

Pine Trees (Mivinje)
Coniferophyta is a division of Kingdom Plantae. Coniferophyta are cone bearing plants with needle-shaped leaves. The male cones are smaller and produce a yellow powder called pollen. The female cones are larger and have small seed-like structures called ovules.
The following are the features of Division Coniferophyta:

1. They are mostly shrubs and trees with needle shaped leaves.
2. Their reproductive structures are cones.
3. The ovule are not enclosed inside an ovary wall.
4. The majority are evergreens, which means they keep their leaves all year round.

Collection
Coniferophyta can be found in cooler, higher climates like Mbeya, Iringa, and Lushoto. Choose a branch that includes both needle shaped leaves and a cone.

Preservation
Coniferophyta can be dried in the sun and stored in a dry place for future use.

Division Angiospermophyta

Flowering Plants (mimea itayo maua)
Division Angiospermophyta consists of all flowering plants. The following are the features of Division Angiospermophyta:

1. Their reproductive structures are flowers.
2. Ovules are enclosed in an ovary and seeds are enclosed in a fruit.

Division Angiospermophyta can be divided into two classes; Monocotyledons and Dicocotyledons.
Monocotyledons

Monocotyledon seeds have only one cotyledon. Monocots have a fibrous root system, leaves with parallel venation, three part floral systems, and vascular bundles which are scattered. Examples of monocotyledons are maize and grasses.

Dicotyledons

Dicotyledons seeds have two cotyledons. They also have a tap root system, leaves with net-like veins, floral parts in four or fives, and vascular bundles which form a ring in the stem. Examples of dicotyledons are mangoes, cashews, beans, and okra.

Collection

Angiosperms are easily found in your surrounding environment. Monocotyledons are organisms like maize plants and grasses. Dicotyledons are organisms like mango trees, cashew nut trees, and okra.

Preservation

Flowers and leaves can be dried in a book. Place the flower or leaf between two sheets of paper and then press these in the centre of a book. Place the book in a safe place and add more books on top. Leave for a few weeks and then remove.

Dissection

Hibiscus flowers can be easily dissected using a razor blade to identify the reproductive parts.

Kingdom Animalia

Organisms in Kingdom Animalia are eukaryotic. There are many organisms and phyla in Kingdom Animalia. However, for practical purposes, students will only study Phylum Platyhelminthes, Annelida, Nematoda, Arthropoda, and Chordata.

The following are the features of Kingdom Animalia:

1. Animals are multicellular.

2. Animals are differentiated into tissues.
3. Animals are heterotrophic feeders.

4. Animals are capable of locomotion.

5. Animals have a nervous system (with the exception of sponges.)

Phylum Platyhelminthes

Flatworms
Phylum Platyhelminthes defining characteristic is that their bodies are dorso-ventrally flattened and most are parasitic and feed off other organisms. This phylum is divided into three classes: Trematoda (Flukes), Cestoda (Tapeworms), and Turbellaria.

1. Class Trematoda or flukes (minyoo bapa) are parasitic. They are flat and use suckers to feed.

2. Class Cestoda or tapeworms (minyoo yenye pingili) are flat, tape-like and have segmented or divided bodies. They are parasitic and use suckers and hooks to feed. Tapeworms live in the human intestines and affect humans by absorbing partly digested food. They can cause disease as well as malnutrition.

3. Class Turbellaria are flat and have cilia which help them move.

Collection

Flukes can be collected when a cow, pig, or sheep is slaughtered by examining the liver or intestines. There are some species of flatworm that can be found in shallow tide pools along the beach.

Preservation

Organisms in Phylum Platyhelminthes can be kept in labelled air-tight containers with formaldehyde solution.

Killing

Place the Platyhelminthes into a formaldehyde solution.

Dissection

You can observe the unbranched gut of a Plathelminthes by making a lateral cut along the body and observing the internal structure of the organism.
Phylum Nematoda or Aschelminthyes

Roundworms
Phylum Nematoda, also known as Aschelminthyes, includes round parasitic worms that cause infections in humans.

The following are the features of the Phylum Nematoda

1. They have unsegmented, cylindrical bodies with pointed ends.
2. Their body is covered in a cuticle of protein.
3. They have an unbranched gut from mouth to anus.

Collection
Roundworms can be found in the stomach of fish, in soil or stagnant water, or in the intestines of locally raised chicken.

Preservation
Organisms in Phylum Nematoda can be kept in labelled air-tight containers with formaldehyde solution.

Killing
Place the Nematoda into a formaldehyde solution.

Dissection
You can observe the unbranched gut of a Nematoda by making a lateral cut along the body and observing the internal structure of the organism.

Phylum Annelida

Earthworms (Chambo) and Leeches (Ruba)
Phylum Annelida are eukaryotic organisms. Earthworms have a mouth at their anterior end and anus at the posterior end with a bulge called a clitellum in the middle that holds eggs. The earthworm uses bristles (small hair like structures) to burrow through the dirt.

The following are the features of the Phylum Annelida:

1. They are segmented. They have separate internal organs and body walls.
2. They have a thin, moist, non-chitinous cuticle.

3. Their body has external bristles.

**Collection**

Earthworms can be found after a rain by digging under rocks or in other damp places. Leeches can be found in a river.

**Preservation**

You can keep earthworms in a container with fresh soil to preserve live specimens. If killed, these organisms can be preserved in ethanol alcohol for a few months.

**Killing**

Place the Annelida into a closed bottle in which is suspended a ball of cloth or mosquito net soaked in methylated spirits. Avoid direct contact with the spirit.

**Dissection**

You can observe the internal structures of an earthworm by making a lateral cut along the body.

**Phylum Arthropoda**

Organisms in this phylum have jointed appendages and an exoskeleton made of chitin. There are 5 classes in this phylum: Insecta, Crustacea, Arachnida, Diplopoda, and Chilopoda.

**Class Insecta**

**Beetles, Houseflies (Nzi), Grasshoppers (Panzi), Ants (Sisimizi), and Termites (Mchwa)**

The following are the features of Class Insect:

1. Insects have a head, thorax, and abdomen.

2. They have one pair of antennae.

3. They have three pairs of jointed legs.

4. Most adult insects have wings.
Collection
Many insects can be caught in a field using a sweep net.

Preservation
Live insects can be kept in a clear bottle and fed grass clippings. Dead insects can be preserved for a few months by placing them in methylated spirits.

Killing
Seal in an airtight container until the insect suffocates.

Dissection
First remove wings, antennae, and legs of the insect. Then cut down the sides of the insect to open the body cavity and observe the digestion and reproductive systems.

Class Crustacea
Crabs (Kaa), Prawns (Kamba), and Lobsters (Kamba Kochi)
The following are the features of Class Crustacea:
1. Crustacea have bi-forked appendages.
2. They have 2 pairs of antennae.

![Crab Image](image)

Figure 4.2: Crabs are an example of Class Crustacea

**Collection**

Fresh water crabs, prawns, and shrimp can be found in most rivers, lakes, dams and swamps. Otherwise, they can be purchased in many markets.

**Preservation**

Crustacea can be preserved in methylated spirits. Crustacea can also be dried for preservation purposes.

**Killing**

Crustacea can be killed by being left in an airtight container or boiled in water.

**Dissection**

For crabs, turn it so that its abdomen is facing up. Wedge a knife under the triangular abdomen and twist, so that the abdomen opens. Examine the internal organs.
Class Arachnida

Spiders (Buibui) and Scorpions (Nge)
The following are the features of Class Arachnida:

1. Arachnids have four pairs of jointed legs.
2. Arachnids have a cephalothorax (head and thorax) and abdomen.

Figure 4.3: Spiders are an example of Class Arachnida.

Collection
Spiders can be found in almost any environment. Scorpions can be found in dark, dry and cool areas, usually at night.

Preservation
Arachnida can be dried or preserved in methylated spirits.

Killing
To kill Archnida, place them in an airtight container for a few days or use insecticide.
Class Chilopoda

Centipedes (Tandu)
The following are the features of Class Chilopoda:

1. Chilopoda have long bodies consisting of many segments.
2. Each segment contains a pair of legs.

Figure 4.4: A centipede

Collection
Centipedes can be found under rocks, in tree bark, and in leaf litter.

Preservation
Chilopoda can be dried or preserved in methylated spirits.

Killing
To kill Chilopoda, place them in an airtight container for a few days or use insecticide.

Class Diplopoda
Millipedes (Jongoo)
The following are the features of Class Diplopoda:

1. Diplopoda have long bodies consisting of many segments.
2. Each segment contains 2 pair of legs.
Collection
Milipedes can be found under rocks, in tree bark, and in leaf litter.

Preservation
Diplopoda can be dried or preserved in methylated spirits.

Killing
To kill Diplopoda, place them in an airtight container for a few days or use insecticide.

Figure 4.5: Class Diplopoda contains organisms like millipedes.

Phylum Chordata
Chordata are eukaryotic organisms that contain a backbone. These organisms have 4 distinct features:

1. They have a notochord in the embryonic stage. In most chordates this will be replaced with a vertebral column.
2. They have a nerve chord.
3. They have gill slits during the embryonic stage.
4. They have a tail which is behind the anus.

In this phylum, there are 6 classes: Chondrichthyes, Osteichthyes, Amphibia, Aves, Reptilia, and Mammalia.

Class Chondrichthyes

Sharks (Papa), Skates (Taa), and Rays
Chondrichthyes are also known as cartilagous fish. Chondrichthyes include sharks, skates, and rays.
The features of Class Chondrichthyes are:
1. The skeleton is made of cartilage.
2. The body is covered with placoid scales.
3. The tail fin is asymmetrical.
4. The gill slits are visible.
5. The mouth and two nostrils are centrally placed.
6. They are cold blooded or ectothermic. This means their body temperature changes with the environment.

Collection
Chondrichthyes can be found in most fish markets by the ocean.

Preservation
Chondrichthyes can be preserved in a formaldehyde solution.

Killing
Chondrichthyes can be killed by removing them from water.

Dissection
For sharks, make a lateral cut from the mouth down to the anus. Make another cut from the left pectoral fin to the right. Peel back the layer of skin and examine the internal organs. You can also examine the brain by shaving off thin layers from the top of the head until you reach the brain.

Figure 4.6: A shark
Class Osteichthyes

Tilapia (Sato) and small fish (Dagaa)

Osteichthyes are also known as bony fish. The following are the characteristics of Class Osteichthyes:

1. The skeleton is made of bone.
2. The body is covered with scales.
3. The gills are covered by an operculum.
4. The tail fin is symmetrical.
5. Most have an air sac or swim bladder.
6. They are cold blooded or ectothermic. This means their body changes temperature with the environment.

Collection

Osteichthyes can be found in both fresh water and the ocean. Fresh killed fish can also be purchased at the fish market.

Preservation

Osteichthyes can be preserved in a formaldehyde solution. Osteichthyes can also be dried and smoked. To smoke a fish, make a fire and put fish on a rack over the fire. Smoke the fish until it is dry. This takes from hours to days depending on the size of the fish.

Killing

Osteichthyes can be killed by removing them from water.

Dissection

Make a lateral cut from the mouth to the anus of the fish. Open the cut and observe the digestive system. Then, peel back the gill cover, operculum, and observe the structure of the gills.
Class Amphibia

Frog (Chura wa majini), Toad (Chura wa nchi kavu), and Salamander (Boromondo au Tunutunu)

The features of this class are:

1. They have to spend part of their life in water during the larva stage.
2. Their skin is always moist and without scales.
3. Their life cycle involves a form called a tadpole.
4. They are cold-blooded or ectothermic.

Collection

These organisms can be found near rivers or ponds. Toads can also be collected at night during the rainy season. Use cages or sweep nets to capture amphibians.
Preservation

Make an aquarium or pond for live specimens, providing small insects for food and a source of water. For the preservation of dead specimens inject formaldehyde or leave in the sun for a few days until they are dried.

Killing

To kill Amphibians, keep them in an airtight container or prick their head with a nail or pin.

Dissection

For frogs, make a lateral cut from the mouth to the anus. Then make two intersecting cuts, one that is under the arms and one that is above the legs. Peel back the layer of skin and observe the internal organs.

![Frog illustration]

Figure 4.8: Frogs have moist skin and are ectothermic.

Class Reptilia

Lizards (Mjusi), Crocodiles (Mamba), Snakes (Nyoka), Turtles (Kasa), and Tortoise (Kobe)

The following are the features of Class Reptilia:

1. They have dry skin with horny scales.

2. They are cold blooded or ectothermic.

3. They lay their eggs on land and the eggs have a soft shell.
Collection

Reptiles can be found on rocks or in caves, inside cracks in the wall, forests, and in or nearby rivers and lakes. They can be collected by using sweep nets, traps, or fishing nets.

Preservation

Live specimens can be held inside a cage or aquarium. Snakes should be fed small rodents and turtles can be given grass or leaves. For dead specimens, preserve them by placing them in an airtight container with formaldehyde solution.

\begin{figure}[h]
\centering
\includegraphics[width=0.5\textwidth]{snake.png}
\caption{Snakes are an example of a reptile.}
\end{figure}

Killing

Reptiles can be killed by placing them in an airtight container, submerging them in bucket of water, or hitting the back of their head with a pin or nail.

Dissection

For dissection, follow the same guidelines as amphibian dissection.

Class Aves

Eagle (Tai), Owl (Bundi), Crow (Kunguru), and Chicken (Kuku)

Class Aves contains the organisms commonly known as birds. The following are the features of Class Aves:

1. Their body is covered with feathers.
2. They have wings.

3. They have a bill or beak.

4. They lay hard-shelled eggs.

5. They are warm blooded or homothermic, which means they maintain a constant body temperature.

**Collection**

Chicken are kept domestically and can be easily purchased or raised. Wild birds usually live in the forest and can be killed using a sling shot or captured live with the use of a sweep net or fishing net.

**Preservation**

To preserve dead specimens, place them in an airtight container with formaldehyde solution. You can also keep and dry bones of dead bird for studying.

**Killing**

To kill birds, break their neck, drown them in water, or use a slingshot.

**Dissection**

Make a lateral cut starting at the lower abdomen up to the sternum. Cut through the rib cage and pin it back to the dissection tray to examine the heart, respiratory system, and digestive system.
Mammalia

Rats (Panya), Cats (Paka), Goats (Mbuzi), Bats (Popo), Whale (Nyangumi), and Humans (Binadamu)

The following are the features of Class Mammalia:

1. They have a developed brain.
2. They have hair or fur on their body.
3. They have mammary glands which in females, produce milk.
4. They have teeth.
5. They have a diaphragm.
6. They are viviparous, which means the fetus develops inside the mothers body.
7. They have sweat glands.
8. They are warm blooded or homoeothermic.

Collection

Rats can be captured overnight using a trap. Bats can be collected during the day, when they are sleeping, by using a sweep net.

Figure 4.11: Rats are a common example of a mammal and can be used in many dissection activities.

Preservation

Mammals can be preserved in a formaldehyde solution.
Killing

Specimens should be killed by drowning. Place the mammal inside a cage or trap and submerge in a bucket of water. Wait at least 10 minutes. After the animal is dead, add one cap full of bleach for every five litres of water in the bucket (e.g. 2 caps of bleach for a 10 litre bucket). Stir the contents of the bucket. Wait 20 minutes. The bleach will kill harmful organisms on the outside of the specimen.

Dissection

Make a lateral cut from the mouth to the anus. Then make 2 cuts, one from hand to hand and another from foot to foot so that both cuts cross the first lateral cut. Separate the skin and pin it to the dissection tray to examine the internal organs.
Chapter 5

Biology Activities with Specimens

There are a number of activities in O-Level Biology that require students to observe, identify, and classify different organisms. In this section, you will find a number of those activities and how to execute each in small groups with your students. You can refer to the previous chapter for collection and preservation ideas.

Characteristics of Living Things

There are 7 characteristics of living things; respiration, reproduction, excretion, irritability, movement, nutrition, and growth. The following activity can be done by students in small groups to show the characteristics of living things and enforce observation skills.

Learning Objectives

- To outline the characteristics of living things.
- To differentiate between living and non-living things.

Materials

Plastic water bottles, traps, plastic cups, non-living things like a pen and a rock, and a cardboard box.

Specimens

- Grasshopper, lizard, ant, or any other living things
Hazards and Safety

- Some organisms may be poisonous and should be avoided.

Preparation Procedure

1. Prepare cages and traps from the plastic water bottles. Purchase rat traps from the market.
2. Collect living things by using the traps and cages.
3. Collect non-living things to observe.
4. Put the collected organisms in cages, petri dishes, and plastic cups for students to observe.

Activity Procedure

1. Observe the specimens, draw and label each.
2. Record the characteristics of life you have observed in each specimen.
3. Categorize the specimens as living or non-living using your observations.

Results and Conclusion

Using the seven characteristics of life and observation skills, you should be able to determine which specimens are living and which are non-living.

Clean Up Procedure

1. Collect and clean all the used materials, storing items that will be used later. No special waste disposal required.

Discussion Questions

1. How can you determine if a specimen is a living organism?
2. What are the differences between plants and animals?

Notes

The collection of the specimens and thorough observation is very important. You may not see all of the characteristics in one day, but through observation students will have a general understanding of the characteristics of life.
Introduction to Classification

Based on the fact there are so many different living things in the world, biologists put these organisms into groups to make it easier to study and identify them. This process is called classification. Classification enables scientists to make predictions. When we know the characteristics of a group we can predict the features of an organism in that group. For example, an owl and chicken are both birds. If we know what the heart of a chicken looks like we can predict what the heart of an owl will look like even if we have not seen it.

Learning Objectives

• To group living things according to their similarities and differences.

Materials

Marker pen, cardboard, bread, and a tomato.

Specimens

• Rat, ants, hibiscus or another type of flower, beetle, fish, worm.

Hazards and Safety

• When collecting and observing specimens, avoid dangerous animals like snakes, black ants, wasps, and bees. Stay away from poisonous plants like deadly nightshade and poisonous fungi like Amonita.

Preparation Procedure

1. Collect different living things like fungi, plants of different shapes and sizes, and animals.

2. Place a piece of moist bread near a window to culture bread mould.

3. Cut a tomato in half and leave it overnight to prepare mucor.

4. Mount the different specimens on a piece of cardboard box and label each specimen with a single letter.
Activity Procedure

1. Display the specimens for observation.

2. Group the organisms based on their similarities and differences.

3. Classify the organisms, naming their Kingdom, Phylum/Division, and Class. Refer to the previous chapter as a guide.

Results and Conclusion

Students are expected to observe and group living things according to their similarities and differences.

Clean Up Procedure

1. Collect all the used materials, storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. Why do you think it is important to classify living things?

2. Draw and label a specimen from each Phylum.

Classification System

Organisms are classified basing on two systems of classification which are artificial and natural systems of classification. Artificial system group organisms according to observable features, eg. presence or absence of wings. Natural system group organisms according to external as well as internal features. Natural system is the best way of classifying living organisms.

Learning Objectives

- To carry out practical activity of classifying living things according to natural and artificial system.

Materials

Cardboard box, marker pen.
Specimens

- Varieties of living things like insects, lizard, preserved snake, dried fish, earthworms, preserved ascaris, preserved beetles, rat, pictures of reptiles, yeast cells, mushrooms, cultured bread mould and mucor from cut tomatoes, Bidens pilosa (black jack plant), maize plant, Commelina spp plants, conifers branch and cones, cactus stem, variegated leaf, hibiscus flower, and moss plant

Hazards and Safety

- Be careful with poisonous organisms during their collection as specimens.

- Be careful with the preservatives as they can irritate or damage your skin.

Preparation Procedure

1. Collect varieties of specimens (live or preserved).

2. Collect pictures showing variety of reptiles.

Activity Procedure

1. Display the collected specimens by mounting them in cardboard boxes. Label them with letters using a marker pen.

2. Display the pictures showing varieties of reptiles.

3. Observe the external features from each specimen collected and group them.

4. Discuss on how to group organisms basing on Artificial and Natural system.

Results and Conclusion

Students are expected to group organisms by using the observable features and the behaviour of the organisms. They also need to understand how the internal features help to give a better way of grouping organisms.
Clean Up Procedure

1. Remove all unwanted materials left after observation.
2. Return specimens on specimen’s bottles for preservation.

Discussion Questions

1. What are the differences between artificial and natural systems of classification?
2. What are the advantages and disadvantages of the two systems of classification?

Notes

Classification should be based on features which show evolutionary relationships. Otherwise few features and external features may lead to a wrong grouping of organisms.

Investigation of Kingdom Fungi

Kingdom Fungi has many effects on other organisms, like humans. They can cause diseases that directly affect humans and also indirectly affect our way of life through the destruction of crops. This activity can be done in groups of four to six students to teach them about fungus, how to prevent its negative effects, and increase its benefits.

Learning Objectives

• To describe the structures of the representative organisms of each phylum of Kingdom Fungi.

Materials

Petri dishes*, water drop microscope*.

Specimens

Instructions for collecting and preserving these specimens are described in the previous chapter

• One specimen from Phylum Basidiomycota
• One specimen from Phylum Zygomycota
• One specimen from Phylum Ascomycota

Hazards and Safety
- Some mushrooms are poisonous. Wash your hands with soap after this activity.

Preparation Procedure
1. Assemble the required materials and specimens.

Activity Procedure
1. Collect at least one sample for each phylum.
2. Using a knife and a drop of water, mount bread moulds and yeast cells on the plastic slides and cover with a cover slip.
3. Observe the specimens using the water drop microscope and draw what you see.
4. Observe the mushroom with the naked eyes and draw a labelled diagram.

Discussion Questions
1. What features are common to all species in Kingdom Fungi?
2. What are the distinctive features of each phylum in Kingdom Fungi?
3. What are the advantages and disadvantages of Kingdom Fungi?
4. How do organisms in Kingdom Fungi reproduce and why is this advantageous?

Results and Conclusions
You should be able to observe the common and distinctive features of the phyla in Kingdom Fungi that are described in the proceeding chapter. Advantages of Kingdom Fungi are in the area of food, bread, alcohol making and are inputs in the chemical preservative industry. Disadvantages of Kingdom Fungi include the spoilage of food, damage to crops, and infections like Athlete’s foot or Ringworm. The organisms in Kingdom Fungi reproduce asexually by the use of spores.
Investigation of Division Coniferophyta

Conifers are shrubs and trees with needle shaped leaves found in cool climates like Iringa, Mbeya and Ruvuma. Their reproductive structures are cones. Male cones are smaller in size, closely packed, and produce pollen grains. Female cones are larger in size, openly packed to receive pollen grains, and produce naked seeds. This activity is especially easy for students to conduct and can be conducted in groups or individually depending on the number of specimens available.

Learning Objectives

- To explain the general and distinctive features of Division Coniferophyta.

Materials

Razor blades

Specimens

Instructions for collecting and preserving these specimens are described in the previous chapter.

- One specimen from Phylum Coniferophyta.

Hazards and Safety

- Razor blades are extremely sharp and should be used with care to prevent injury.

Preparation Procedure

1. Collect a few branches from a conifer tree with both male and female cones. If no conifer trees are available, use dried specimens.

Activity Procedure

1. Observe branches of conifers, their leaves, and their cones. Then draw what is seen and identify the male and female cones.

2. Cut a longitudinal section of male and female cones using a razor blade.
3. Observe the internal parts of the male and female cones, drawing a diagram of each.

Results and Conclusion
You should understand where conifers are found and how they reproduce. You should also be able to identify male and female cones and state the differences between them.

Clean Up Procedure
1. Place conifer specimens in a cool, dry place to use for future activities. No special waste disposal required.

Discussion Questions
1. What are the features of a conifer plant?
2. How are conifers adapted to their environment?
3. What are the differences between male and female cones?
4. What is the economic importance of Division Coniferophyta?

Notes
Conifers may be difficult to find in some areas. Therefore, teachers should dry these specimens when they are found so they may be used repeatedly.

Investigation of Division Angiospermophyta
Identification of the Reproductive Parts of the Flowers
Angiosperms develop specialized structures called flowers used for reproduction. A flower is a modified part of a stem in which the primary sex organs are found. A flower has the following parts; peduncle, receptacle, calyx (sepal), corolla (petals). The male reproductive organ called the stamen consists of filament and anthers which form pollen grains. The female reproductive organs consisting of an ovary, style and stigma. Hibiscus flowers are bisexual because they have both male and female organs in one flower. Some pawpaw flowers have either female or male flowers and are referred to as unisexual flowers. Plants with both male and female flowers on the same plant
are called monoecious like maize. Plants with male and female flowers on separate plants are deciduous like a pawpaw plant.

**Learning Objectives**

- To identify the reproductive parts of the flowers.

**Materials**

A variety of flowers like hibiscus, rose, or morning glory, razor blade, hand lens, cardboard box, and a labeled diagram of a flower.

**Hazards and Safety**

- During collection of flowers from plants be careful with bees and you should not destroy other parts of the plant.

**Preparation Procedure**

1. Collect a variety of flowers from a nearby garden.

2. Prepare cardboard mounts from empty boxes by cutting the cardboard into small squares using a razor blade.

**Activity Procedure**

1. Examine the external structures of the flowers collected, look for similarities and differences.

2. Draw and label the external structures of a hibiscus flower.

3. Cut a hibiscus flower in longitudinal section by starting the cut at the base and cutting along the carpel to the stigma.

4. Observe the flower using a hand lens, then draw and label the observed internal structures of the flower.

**Results and Conclusion**

The female reproductive organs, the stigma, style, and ovary should be visible. You will also see the male reproductive parts which are the anthers and filament.
Figure 5.1: The reproductive structures of a bisexual angiosperm.

Clean Up Procedure

1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. Is the flower that you examined male or female or bisexual?

2. Mention the reproductive parts of the flower and state their functions.

Notes

Cutting the longitudinal section of the hibiscus flower should be done carefully to avoid destroying other floral parts.
Examination of Structures of Representative Dicotyledons and Monocotyledons

Monocot and dicot plants are flowering plants and are found in division Angiospermaphyta. They differ in morphological structures from roots, stems, leaves, and flowers, e.g., root size, leaf shape, floral parts, arrangement of vascular bundles and number of cotyledons in their seeds.

Learning Objectives

• To describe the structures of representative dicotyledons and monocotyledons.

Materials

Razor blade, maize grain, bean seed, petri dishes*, GV stain*, cardboard boxes, water drop microscope*, scalpel, monocot and dicot plants.

Hazards and Safety

• Care must be taken when cutting the specimens as you may cut yourself.

Preparation Procedure

1. From a nearby field or garden, collect dicot plants (hibiscus plant, bean plants, black jack plant) and monocot plants (grasses, maize plants, Commelina spp).

2. Place the plants into a beaker with a few drops of GV.

Activity Procedure

1. Observe the dicot and monocot plants from the external appearance by considering roots, leaves and flowers.

2. Record the features seen from each plant.

3. Cut a transverse section of a stem and roots of monocot and dicot that can be mounted on a slide and observe the arrangement of the vascular bundles on a water drop microscope.

4. Draw the vascular bundles as seen under water drop microscope (for monocot and dicot roots and stem).
5. Cut maize grain and bean seeds longitudinally to see how many cotyledons are in each specimen and draw them.

**Results and Conclusions**

All of the common features of each class should be easily observed. Refer to the previous chapter for the characteristics of monocots and dicots.

![Figure 5.2: Cross section of a dicot root](image)

![Figure 5.3: Cross section of a dicot stem](image)

**Clean Up Procedure**

1. Remove all waste materials from the bench.

**Discussion Questions**

1. With the aid of diagrams, differentiate monocots from dicots.
2. What is the economic importance of monocots and dicots?
3. Classify maize and bean plants.
Investigation of Phylum Arthropoda

There are five classes of Arthropods: Arachnida, Chilopoda, Crustacea, Diplopoda, and Insecta. All of these organisms have jointed appendages and a hard exoskeleton. This phylum has many different varieties of organisms, which have both positive and negative effects for the human race. Some Arthropoda act as pollinators or a source of food, while others can cause humans pain and destroy crops. This activity is a introduction to Phylum Arthropoda and is most effective when students collect the specimens themselves. Classifying the organisms can also be done in small groups with minimal administration from the teacher.

Learning Objectives

- To explain the general features of Phylum Arthropoda.
- To explain the distinctive features of each class in Phylum Arthropoda.
Materials
Variety of live and preserved specimens from Phylum Arthropoda, pictures of organisms in Phylum Arthropoda, bottle cages*, and petri dishes*.

Specimens
Instructions for collecting and preserving these specimens are described in the previous chapter

- Specimen from phylum arthropoda

Hazards and Safety

- Be aware of dangerous organisms when collecting specimens in the field. For example, some arthropods may bite or sting - care should be taken when handling them. Avoid specimens known to be poisonous.
- Preservatives like formalin are poisonous and should only be handled by the teacher in a well-ventilated room.

Preparation Procedure
1. Put the specimens in bottle cages and petri dishes. Label each specimen with a marker pen. Also display any available pictures.

Activity Procedure
1. Observe the specimens.
2. Identify features common to all specimens.
3. Identify the distinctive features of each specimen.
4. Group the specimens into the five classes of Phylum Arthropoda.
5. List the general features of Phylum Arthropoda.
6. Draw and label a representative specimen from each class.

Results and Conclusions
The organisms can be easily differentiated into the five classes by observing the number of legs and antennae.
Clean Up Procedure

1. Collect and clean all the used materials, storing items that will be used later. No special waste disposal required.

Discussion Questions

1. What are the general features of Phylum Arthropoda?
2. Describe the habitat and feeding habits of each specimen.
3. Mention the classes of Phylum Arthropoda and the features of each.
4. What is the economic importance of Phylum Arthropoda?

Investigation of Phylum Chordata

Chordates are organisms in Kingdom Animalia with a vertebral column. There are six classes in this phylum; Reptiles, Amphibia, Mammalia, Aves, Chondrichthyes, and Osteichthyes. Such organisms differ in mode of reproduction, respiration, habitat and structure.

Learning Objectives

- To explain distinctive features of each class of Phylum Chordata.
Materials
Live and preserved chordates, hand drawn pictures of chordates such as reptiles, mammals, aves, amphibians and fish, cardboard boxes, petri dishes*, bottle cages*, and traps.

Specimens
*Instructions for collecting and preserving these specimens are described in the previous chapter*

Hazards and Safety
- When collecting specimens, take precautions with dangerous animals.
- Preservatives like formalin maybe be poisonous and should only be handled by the teacher in a well-ventilated room.

Preparation Procedure
1. Collect at least one specimen from each class of Phylum Chordata, for example a rat, fish, and worm. If you cannot find a specimen, photocopy the pictures from the previous chapter.
2. Collect live specimens by using traps and cut bottles from the field. Purchase preserved fish from the market.
3. Find or draw pictures showing chordates that can not be found in your area.
4. Put the specimens in bottles and petri dishes. Then label them using masking tape and a marker pen.

Activity Procedure
1. Display specimens for observation.
2. Identify the general and distinctive features of each specimen.
3. Group the specimens into their respective classes according to similarities and differences.
4. Draw and label a specimen from each class.
Results and Conclusions

The tail of each organism should be easily observed, showing one of the main features of Phylum Chordata. Additionally, each organism will exhibit characteristics specific to their class. For more information about classification features, refer to the previous chapter.

Clean Up Procedure

1. Collect and clean all the used materials, storing items that will be used later. No special waste disposal required.

2. Return the specimens into their respective bottles/containers for preservation and future use.

Discussion Questions

1. What are the general features of Chordates?

2. Mention the classes of Kingdom Chordata and distinct features of each.

3. Draw and label a specimen from each class.

4. Discuss the economic importance of Class Osteichthyes and Aves.

Notes

Some features may not be seen unless the organism is dissected. Refer to the next activity for instructions on dissection.

Dissection of a Rat

A mammal body contains different systems which are vital to its daily life. They perform different important functions. One of the important system is the digestive system. Digestive systems break down large food particles into pieces that are small enough to pass through the gut wall and dissolve into the blood. In order to see the digestive system inside a mammal body and how it works we need to dissect it. Dissections may work well as a demonstration first by the teacher and then later performed by the students on their own in small groups.
Learning Objectives

- To identify parts of the mammalian digestive system and their adaptive features.

Materials

Rat, dissection tray*, knife, needles or office pins, clothes pin, razor blade, a bucket full of water, trap, bleach, tomato, charts/diagrams of human digestive system.

Specimens

Instructions for collecting and preserving these specimens are described in the previous chapter

- Rat

Hazards and Safety

- Always cut away from yourself to avoid injury.

Preparation Procedure

1. Buy a rat trap from the market.
2. Cut a piece of tomato and put it inside the trap.
3. Put the trap in a place where there are rats overnight.
4. Prepare a dissecting tray.
5. Prepare a dissecting kit with a knife, razor blade, pins (from injection needles from pharmacy and thorns from acacia tree), and forceps from cloth pegs/wood.
6. After catching a rat in the trap, kill it by dipping the trap together with the rat in a bucket full of water for 5-10 minutes.
7. When the rat is dead, add 3 spoons of bleach to the bucket full of water and wait for 10 minutes so that the bleach kills the micro organisms.
Activity Procedure

1. Remove the rat from the bucket.

2. Lay the freshly killed rat on the dissecting board ventral side (abdomen) facing upward and pin it using needles or thorns from acacia plant.

3. Using a clothes pin, lift the skin of the abdomen and using a knife or a razor blade, make a longitudinal cut/slit at the centre of the abdomen.

4. Extend the cut with a knife up to the thoracic cavity and make an incision towards the limbs.

5. Using a piece of wood or clothes pin, separate and stretch the skin from the lower body wall.

6. Pin the folds of skin on the dissection tray using acacia thorns or needles.

7. Cut the body wall on either side of the mid line in order to observe different internal organs. Do not cut too deep otherwise you will damage the underlying organs.

8. Open the thoracic cavity by cutting through intercostal muscles and rib cage.

9. Observe the internal digestive system clearly and use the provided chart/diagram of a human digestive system to compare the structures.

Results and Conclusions

The digestive system of a rat is very similar to that of humans. You will be able to observe the organs of the digestive system as well as other main organs like the lungs and heart.

Clean Up Procedure

1. Discard the dissected rat together with used pin and all unwanted materials into a pit latrine.

2. Clean the dissection tray with disinfectant.
Discussion Questions

1. Mention 5 different organs found in the digestive system and their function.

2. How is the digestive system of a rat similar to that of a human being?

Notes

Rats may carry disease causing microorganisms. This is why it is important to place bleach into the water when drowning the rat.
Chapter 6

Biology Activities

The following activities are demonstrations and practicals that can be performed by both the teachers and the students. They are arranged by topic in order of the syllabus.

Introduction to Biology

Measuring and Recording Mass, Temperature, Pulse Rate, and Volume

Measurement is the use of a set unit to describe a factor of the thing that we are studying. There are 6 things that we measure: mass, length, time, temperature, rate, and volume.

Mass is how heavy something is. It is measured in grams (g) or kilograms (kg). Length is how long, wide or deep something is. It is measured in centimetres (cm), metres (m) and kilometres (km). Time is measured in seconds, minutes, and hours. Temperature is how hot or cold something is. Temperature is measured in degrees. Rate is how quickly something changes. It is usually measured in another unit per unit of time, for example kilometers per hour or grams per minute. Volume is the amount of space something takes up. It is usually measured in litres.

Learning Objectives

- To take measurements of mass, temperature, pulse rate, and volume.
Materials
Spring balance*, thermometer (if available), plastic bottles, droppers*, digital wrist watch or wall clock, cold water, warm water, beaker*, volumetric flask*, twine or rope, marker pen, a ruler, and sand.

Preparation Procedure
1. Pour a known amount of water into the plastic bottles and write the volume in millilitres on the bottle.

Activity Procedure
1. Mark the rope at 10 cm intervals.
2. Record all of the following measurements.
3. Measure the temperature of the cold and warm water by using the thermometer, if available.
4. Measure the weight of sand using the spring balance.
5. Determine your pulse rate by placing your first two fingers on your neck. This should be measured for one minute and recorded as beats per minute.
6. Measure your height by using the rope with marked intervals.
7. Measure the volume of the water in the bottle using the volumetric flask.

Results and Conclusions
The data collected should reflect realistic values for the specimens.

Clean Up Procedure
1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.
Discussion Questions

1. Write down the metric units used to measure mass, length, and temperature.

2. Which one is heavier, a 1000 grams of water or 1000 mL of water? Why?

Notes

There are several units used to measure length, weight and volume. It can be very difficult to convert units if you do not first identify the unit measured in the question. Therefore, knowledge of measurements and their corresponding units will minimize the problems.

Cell Structure and Organization

Examining Animal and Plant Cells

Plant and animal cells have similarities and differences. Plant cells have a cell wall which gives it a definite shape. Animal cells only have a cell membrane and thus a less rigid structure. Both types of cells have a nucleus which controls the function of the cell. Cells have different types of structures depending on their function in the organism.

Learning Objectives

• To differentiate various types of cells.

Materials


Hazards and Safety

• Gentian Violet can stain the skin and clothes.
**Preparation Procedure**

1. Collect a few cheek cells from the inside of your cheek using a toothpick. Run a few drops of water over the toothpick onto a slide. Cover with a cover slip.

**Activity Procedure**

1. Collect all materials

2. Peel a thin layer of epidermal cells from the onion and stain them using a few drops of iodine solution.

3. Cut a few thin cross sections from the stem and root using a sharp razor blade and place the specimens into a petri dish with water and a few drops of Gentian Violet.

4. Select the thinnest section of a stem and root and place the specimens on a slide.

5. Observe each specimen with the water drop microscope and draw what you see.

![Cheek cells as viewed through the water drop microscope](image1)

Figure 6.1: Cheek cells as viewed through the water drop microscope

![Plant cells as viewed through the water drop microscope](image2)

Figure 6.2: Plant cells as viewed through the water drop microscope
Results and Conclusion

The activity is intended to enable you to observe the structure of different plant cells.

Clean Up Procedure

1. Collect all the used materials, cleaning and storing items that will be used later.

2. Gentian Violet should be reused if possible; waste Gentian Violet should be disposed of in the pit latrine.

Discussion Questions

1. What is the function of epidermal cells of plants?

2. What differences did you observe between the plant and animal cells?

Notes

While observing the animal and plant cells under a water drop microscope, you will only see the layout of the cells but not the details of different organelles as with a light microscope.

Nutrition

Nutrition is the way organisms obtain materials they need to live. There are two types of nutrition, autotrophic nutrition and heterotrophic nutrition. Autotrophic nutrition is how plants get their food. Plants use energy from sunlight to convert raw materials into food. This process is called photosynthesis.

Heterotrophic nutrition is how animals get food. Animal food may be plants or other animals, alive or dead. Food is anything that provides the body with a source of energy, material for growth and repair, or other factors for good health. Nutrients are food substances necessary for healthy growth. Humans eat foods containing the following nutrients: carbohydrates, fats, proteins, vitamins, and mineral elements. Nutrition is important because it allows us to move, grow, keep our bodies warm, repair damaged tissue and fight diseases.

The activities in this section often appear on the NECTA examination because of their relevance to students’ daily life. Therefore, it is important
that these nutrition activities are practiced by the students, at first in small
groups and then individually.

Food Test for Lipids

Lipids are an organic food substance made of carbon, oxygen, and hydrogen. Lipids occur in two forms: fats and oils. Oils are liquid at room temperature whereas fats are solid. Lipids provide the body with energy and create a layer of insulation to help keep the body warm. The main sources of lipids are milk, animal fats, groundnuts, coconuts, and avocado.

Learning Objectives

- To carry out a test for lipids in a given food sample.

Materials

Iodine solution*, water, empty plastic bottles, test tubes*, droppers*, and a cooking oil that is liquid at room temperature, e.g. sunflower oil.

Hazards and Safety

- Iodine solution is harmful to swallow.
- Iodine solution can stain clothing. Remove stains promptly with a solution of crushed vitamin C (ascorbic acid). Iodine will also migrate into wood stain, permanently discolouring tables - prevent spills.

Preparation Procedure

1. Mix about 10 mL (one cap full) of cooking oil and about 100 ml of water in a plastic bottle.

2. Close the bottle and shake vigorously.

Activity Procedure

1. Pour 2 mL of the food sample solution into a test tube. You should shake the bottle of sample solution each time before pouring it to prevent the oil from separating.

2. Add 3 drops of iodine solution to the test tube.

3. Shake the test tube and let the mixture settle.
4. Record results.

**Results and Conclusions**

You should see the formation of a red ring at the top of the sample solution. This indicates the presence of lipids.

**Clean Up Procedure**

1. Unused iodine solution should be stored in a labeled bottles for future use.

2. None of the waste from this experiment requires special disposal.

**Discussion Questions**

1. In which part of the digestive system is the identified food substance digested?

2. Name the enzyme responsible for its digestion.

3. When the identified food substance is digested, what is the end product?

**Notes**

Many biology books call for a chemical called Sudan III to test for lipids. Sudan III is a bright red pigment that is much more soluble in oil than in water. For this reason, Sudan III solution is usually prepared using ethanol to bring the Sudan III pigment into the solution. In mixtures of oil and water, the oil separates and moves to the top. When shaken with Sudan III, this oil absorbs the Sudan III, turns red, and produces a "red ring" at the top of the test tube. However, the ethanol used to make Sudan III causes the water and oil to form an emulsion. In an emulsion, the oil is broken into very small particles and it takes a long time for this emulsion to break down and form an oil layer on the top. Hence testing with Sudan III takes a long time to show a clear result.

Iodine is another coloured molecule that is more soluble in oil than in water. When a mixture of oil and water is shaken with iodine solution, the iodine moves to the oil layer, colouring it orange or red. This also gives the result of a "red ring" at the top of the test tube. To prevent an emulsion forming - as happens with Sudan III - it is very important to make iodine solution from pharmacy tincture that is without ethanol. Another benefit of
using iodine is that while Sudan III is always red, iodine is uniquely yellow in water and red in oil, making the difference between positive and negative results easier to see. Because there is no ethanol in iodine solution, the result also comes much faster, usually within 10-20 seconds.

Note that if the oil and water mixture settles before you transfer it to the test tube, there may be too little or too much oil in the test tube. Shake the food sample solution before taking each sample.

**Food Test for Proteins**

Proteins are organic food substances consisting of carbon, hydrogen, oxygen, and nitrogen. Proteins create growth and repairs damaged tissue. The main source of protein are beans and nuts, meat, fish, milk, cheese, and eggs.

**Learning Objectives**

- To carry out test for proteins in a given food sample.

**Materials**

Copper sulphate solution*, sodium hydroxide solution*, water, food sample containing protein such as egg, beaker*, empty plastic bottles, plastic spoon, test tube*, and citric acid*

**Hazards and Safety**

- Copper sulphate solution is poisonous and should not be swallowed.
- Use a plastic spoon for measuring caustic soda - the hydroxide will corrode a metal one.
- Sodium hydroxide is corrosive - concentrated solutions can burn skin and wood. Even dilute solutions can blind if they get into eyes.
- If sodium hydroxide solution spills, neutralize spills with citric acid solution or vinegar.
- Close the container of sodium hydroxide solution after use to prevent reaction with atmospheric carbon dioxide.
Preparation Procedure

1. Make a small hole at the tip of an egg.
2. Pour some of the egg white into a beaker.
3. Dilute the egg white with 150 mL water.
4. Stir until the solution is clear.

Activity Procedure

1. Put 2 mL of sample solution into a test tube.
2. Add 1 mL of sodium hydroxide solution to the test tube, then 1 mL of copper sulphate solution to the test tube.
3. Record results.

Results and Conclusions

The colour of the food sample will change from a clear colour to a violet or purple colour. This indicates the presence of protein in the food sample.

Clean Up Procedure

1. Unused reagents should be stored in plastic bottles for further use. Do not store sodium hydroxide in glass bottles.
2. Dispose chemical waste in a pit latrine.

Discussion Questions

1. List down any three examples of food that contain the nutrient identified in this experiment.
2. What is the function of this nutrient in the human body?
3. What is the deficiency disease caused by a lack of this nutrient?
Notes
Some textbooks may recommend using Millon’s reagent to test for protein. This reagent contains mercury, which is extremely poisonous and should never be handled by students.

The purple colour from a positive test is the result of a complex between four nitrogen atoms and the copper (II) ion. Specifically, these nitrogen atoms are all part of peptide bonds. These peptide bonds are adjacent on a protein, either two from one protein and two from another, or two from one part of a protein and two from another part of the same protein.

Food Test for Starch
Starch is a carbohydrate, specifically a polymer of glucose. Carbohydrates provide the body with energy. Starch is found in food like potatoes, cassava, maize, and wheat.

Learning Objectives
- To carry out test for starch in a given food sample.

Materials
Iodine solution*, water, empty plastic bottle, droppers*, heat source, test tubes*, and a food sample containing starch such as maize flour.

Hazards and Safety
- Iodine solution is harmful to swallow.

Preparation Procedure
1. Prepare a food sample solution by either saving the water that remains from boiling pasta or potatoes, or by mixing 2 teaspoons of maize flour into about a litre of water, then heat up to dissolve and reduce the white appearance of the liquid, which may give students the answer without having to perform the experiment.

Activity Procedure
1. Place 2 mL of sample solution into a test tube.
2. Add 3 drops of iodine solution to the test tube and record what happens.

Results and Conclusions
When iodine is added, the food sample will change to a blue-black colour. This indicates that the food sample contains starch.

Clean Up Procedure
1. Unused iodine solution should be stored in a labeled reagent bottle.
2. No special disposal is required for waste from this activity.

Discussion Questions
1. What have you perceived after adding iodine solution to the food sample?
2. List down three foods which contain the nutrient identified in the experiment.
3. What is the importance of this food nutrient to the human body?

Food Test for Reducing Sugars
Reducing sugars are simple sugars with the ability to reduce copper (II) ions to copper (I). All monosaccharides (fructose, glucose, galactose) are reducing sugars as are some disaccharides, such as lactose and maltose. Simple sugars are all carbohydrates, and are used by the body as a source of energy.

Learning Objectives
- To carry out food tests for reducing sugar in a given food sample.

Materials
Benedict’s solution*, cooking pot, kerosene stove or charcoal burner, plastic spoon, droppers*, empty plastic bottles, test tube*, test tube holders*, and food sample containing a reducing sugar like glucose or onions.
Preparation Procedure

1. Make a solution of a food sample containing a reducing sugar. This can be done by adding a spoonful of glucose to a litre of water or cutting an onion into quarters, grinding them in a mortar and pestle, and collecting and diluting the juice. Let the juice settle and decant the solution for use.

Activity Procedure

1. Put 2 mL of the food sample solution into a test tube.
2. Add 1 mL of Benedict’s solution to the test tube.
3. Hold the test tube upright in the water bath and heat the solution to boiling.

Clean Up Procedure

1. Unused Benedict’s solution should be stored in a labeled plastic bottle for future use.
2. Dispose of chemical waste in a pit latrine.

Hazards and Safety

- Copper is harmful to swallow and in large quantities is harmful to the environment.

Discussion Questions

1. What changes did you observe in the food sample during the experiment?
2. Name any two sources of the food nutrient identified in the experiment above.
3. What is the importance of the identified food nutrient in the human body?

Results and Conclusion

The colour of the food sample will change to green, yellow, orange, and finally form a brick red precipitate. This indicates the presence of a reducing sugar.
Notes

Benedict’s solution contains aqueous copper (II) sulphate, sodium carbonate, and sodium citrate. The citrate ions in Benedict’s solution complex the copper (II) ions to prevent the formation of insoluble copper (II) carbonate. In the presence of a reducing sugar, however, the copper (II) ions are reduced to copper (I) ions which form a brick red precipitate of copper (I) oxide. The oxygen in the copper (I) oxide comes from hydroxide; the purpose of the sodium carbonate is to provide this hydroxide by creating an alkaline environment.

Normally, sugar molecules form five or six member rings and have no reducing properties. In water, however, the rings of some sugar molecules can open to form a linear structure, often with an aldehyde group at one end. These aldehyde groups react with copper (II) to reduce it to copper (I). Sugars that do not have an aldehyde group in the linear structure or that are not able to open are not able to reduce copper (II) ions and are thus called non-reducing sugars. Students do not need to understand this chemistry for their exam, but they may ask about what is happening in the reaction.

Food Test for Non-Reducing Sugars

Disaccharides are compound sugars formed when two monosaccharide molecules combine. Disaccharides are found in sugar cane (sucrose), malt (maltose), and milk (lactose). Some disaccharides are reducing sugars (lactose and maltose), while others are non-reducing sugars (sucrose).

Learning Objectives

• To carry out food test for non-reducing sugar in a given food sample.

Materials

Benedict’s solution*, cooking pot, kerosene stove or charcoal burner, plastic spoon, droppers*, empty plastic bottles, test tube*, test tube holders*, citric acid solution*, sodium hydroxide solution*, food sample containing non-reducing sugar like table sugar or fresh sugar cane.

Preparation Procedure

1. Make a solution of a food sample containing a non-reducing sugar.
Activity Procedure

1. Put 2 mL of the sample solution in a test tube.
2. Add 2 drops of citric acid solution to the food sample.
3. Heat the mixture to boiling in a hot water bath.
4. Remove the solution as soon as it boils and let the solution cool.
5. Add 2 drops of sodium hydroxide solution to the food sample.
6. Add 2 drops of Benedict’s solution to the food sample.
7. Heat the mixture in the water bath again and record your observations.

Clean Up Procedure

1. Unused reagents should be stored in plastic bottles for further use. Do not store sodium hydroxide in glass bottles.
2. Dispose of chemical waste in a pit latrine.

Hazards and Safety

• Sodium hydroxide is corrosive - concentrated solutions can burn skin and wood and even dilute solutions can blind if they get into eyes.
• Citric acid is irritating - keep out of eyes.
• If sodium hydroxide solution spills, neutralize spills with citric acid solution or vinegar.
• Close the container of sodium hydroxide solution after use to prevent reaction with atmospheric carbon dioxide.

Discussion Questions

1. What have you observed during the experiment?
2. Name two examples that contain the identified food nutrient in the experiment above.
3. What is the importance of the identified food nutrient in the human body?
4. What is the purpose of adding acid to the sample and heating it?

5. What is the importance of adding sodium hydroxide to the sample?

Results and Conclusions

The colour of the food sample will change from green to yellow and finally to a brick red precipitate. This indicates the presence of a non-reducing sugar.

Notes

This experiment will also test positive for all reducing sugars. Therefore it is important to first perform the test for reducing sugars before considering this test. If the test for reducing sugars is positive, there is no reason to perform the test for non-reducing sugars - the conclusion will be invalid.

Non-reducing sugars are a misnomer, that is, their name is incorrect. This test does not test for any sugar that is not reducing. Rather, this is a test for any molecule made of multiple reducing sugars bound together, such as sucrose or starch. When these polysaccharides are heated in the presence of acid, they hydrolyse and release monosaccharides. The presence of these monosaccharides is then identified with Benedict’s solution.

The purpose of the sodium hydroxide is to neutralize the citric acid added for hydrolysis. If the citric acid is not hydrolysed, it will react with the sodium carbonate in Benedict’s solution, possibly making the solution ineffective.

For information about Benedict’s solution and reducing sugars, see the explanation in the previous experiment: Food Tests - Reducing Sugars.

Investigating the Structures of a Leaf

Photosynthesis is the process by which green plants make their own food using water, carbon dioxide, and energy from the sun. Photosynthesis takes place in the leaves. The green colour, which is caused by the presence of chlorophyll, absorbs the sunlight and uses that energy to convert CO$_2$ and H$_2$O into glucose.

A leaf consists of a broad, flat part called the lamina that is joined to the rest of the plant by a leaf stock or petiole. Running through the petiole are vascular bundles which then form the veins in the leaf. These contain tubes that carry substances to and from the leaf. Each vein contains large, thick walled xylem vessels for carrying water and smaller, thin walled phloem tubes for carrying away food that the leaf has made.
Learning Objectives

- To describe the different structures in a leaf and their roles in photosynthesis.

Materials

Variety of leaves, razor blades, GV stain*, water drop microscope*, plastic slides*, plastic cover slips*, and water.

Hazards and Safety

- Use caution when cutting with razor blades. Make sure to cut away from your fingers. Have available soap and water for cleaning cuts. Do not use dull razor blades where you have to apply more pressure, increasing the risk of cuts.

Preparation Procedure

1. Put collected leaves into a beaker with water and a few drops of GV.

Activity Procedure


2. Cut a leaf in half, vertically. Next, cut a very thin transverse section from the centre of the leaf, so that the mid rib is included. The result will be in a thin diamond-like cross section of the leaf.

3. Mount the cross section on a slide with a drop of water and cover it with a cover slip.

4. Observe the specimen under the water drop microscope. You should be able to see the vascular bundles in the mid rib and differentiate between the upper and lower surface.

5. Draw what you see in the microscope.

Results and Conclusions

The upper and lower epidermis will be seen in the water drop microscope. You should also be able to view the palisade cells.
Clean Up Procedure

1. Collect all the used materials, cleaning and storing items that will be used later.

2. Dispose of waste containing GV in a pit latrine.

Discussion Questions

1. Why do you think there is a close package of palisade cells at the upper surface of the leaf?

2. What would happen if the stomata were at the upper surface of the leaf?

3. What is the function of the cuticle on the upper surface of the leaf?

4. Mention the functions of stomata in relation to photosynthesis.

Notes

The water drop microscope can only show the outlines of cells. The stomata and conducting tissues cannot be seen clearly. The best result can be obtained through the use of succulent leaves like a comelina plant.

Test for Starch in Leaves

Photosynthesis is the process by which green plants and some other organisms use sunlight to synthesize food from carbon dioxide and water. One product of photosynthesis in green plants is starch. The presence of starch can be confirmed by the addition of iodine solution.

Learning Objectives

• To show that starch is a product of photosynthesis.

Materials

Young green leaves, ethanol*, iodine solution*, heat source, cooking pots, water, test tube*, white tile, dropper*, and cotton wool*.
Hazards and Safety

- Ethanol is very flammable! Make sure that student cover their test tubes with cotton wool to avoid excess release of ethanol vapour. If a test tube catches on fire, instruct student to cover the tube with a non-flammable object to extinguish the flame.

Preparation Procedure

1. Collect green leaves from the environment. Try to find leaves that do not have a very waxy outer coat.

2. Heat water to boiling using the heat source.

Activity Procedure

1. Choose one leaf and submerge a piece of it in the boiling water for about 3 minutes. (Note: the piece of leaf used should be no larger than a bottle cap.)

2. Remove the leaf from the water and insert it into a test tube containing methylated spirit and plug the test tube with a piece of cotton wool. The test tube should be less than half full of ethanol.

3. Submerge the test tube in the boiling water and leave it to boil until the leaf loses all of its colour.

4. Once the leaf has lost its colour, remove it from the ethanol solution and dip it briefly into the boiling water to remove the ethanol and soften it.

5. Spread the decolourized leaf on a white tile and add iodine solution until the whole leaf is covered. Record your observations.

Results and Conclusions

The leaf is dipped in hot water to kill the cells. The leaf is then submerged in boiling ethanol to extract the colour from the leaf. The ethanol will change to a green colour while the leaf should lose all of its colour to become white. When iodine solution is added, it should turn dark blue/black colour which indicates the presence of starch in the leaf.
Clean Up Procedure
Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions
1. What was the reason for boiling the leaf?
2. What was the importance of boiling the leaf in ethanol? What did you observe during this step?
3. Why was the test tube containing methylated spirit plugged with cotton wool?
4. Why was the leaf dipped in boiling water after it was removed from the ethanol?
5. Why was a water bath used to heat the ethanol?
6. What did you observe when the iodine was added to the leaf? What does this indicate is present in the leaf?

Notes
It is important that the leaf does not contain a thick waxy coating. Before doing this experiment with students, test some leaves from the local environment to ensure that they respond well to the experiment. Leaves such as amaranthus, beans and commilina respond fast. Make sure that the leaf has been in sunlight for at least 6 hours prior to the experiment or there may
not be enough starch present to detect. This practical should not be done in the morning.

Ethanol boils at a lower temperature than water, thus it can be boiled in a water bath. Ethanol is very flammable and it is possible that the top of test tube catches fire. If this happens a non-flammable material such as glass or metal can be used to cover the flame and deprive it of oxygen.

The Importance of Carbon Dioxide in Photosynthesis

Photosynthesis is the process by which green plants and some other organisms use sunlight to synthesize food from carbon dioxide and water. Carbon dioxide is needed for photosynthesis.

Learning Objectives

• To show that carbon dioxide is necessary for photosynthesis.

Materials

Potted plant, sodium hydroxide*, ethanol*, iodine solution*, heat source, cooking pot, water, test tube*, white tile*, dropper*, cotton wool, empty water bottle or clear plastic bag, and rubber bands.

Hazards and Safety

• Sodium hydroxide is corrosive to skin and wood. Even when dilute it can blind if it gets into the eyes. Neutralise spills with a weak acid.

• Ethanol is very flammable! Make sure that student cover their test tubes to avoid excess release of ethanol vapour. If a test tube catches fire, instruct student to cover the tube with a non-flammable object to extinguish the flame.

Preparation Procedure

1. Put a potted plant in a dark place for 24 hours to de-starch its leaves.

2. Enclose one leaf in a clear plastic bag or empty plastic water bottle containing approximately one teaspoon of sodium hydroxide.

3. Seal the plastic container so that no air can enter. The aim of this is to prevent the leaf from coming into contact with carbon dioxide.
4. Allow the plant to sit in direct sunlight for at least 6 hours.

Figure 6.4: Experiment to show the importance of CO$_2$ in photosynthesis

**Activity Procedure**

1. Choose one of the leaves that has been deprived of carbon dioxide.
2. Submerge this leaf in boiling water for about 3 minutes.
3. Remove the leaf from the water and insert it into a test tube containing ethanol and plug the test tube with a piece of cotton wool. Note: the test tube should be less than half full of ethanol.
4. Submerge the test tube in the boiling water and leave it to boil until the leaf loses all of its colour.
5. Once the leaf has lost its colour, remove it from the ethanol solution and dip it briefly into the boiling water to remove the ethanol and soften it.
6. Spread the decolourized leaf on a white tile and add iodine solution drop wise until the whole leaf is covered.
7. Record your observations and draw a picture showing the colour pattern of the leaf. The leaves should test negative for starch.

**Results and Conclusions**

After adding iodine solution to the leaf, it retains the colour of iodine; it should not form the blue-black colour of an iodine-starch complex. The
iodine colour implies that the leaf has no starch, which means that photosynthesis did not occur. This proves that carbon dioxide is necessary for photosynthesis.

Clean Up Procedure
Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions
1. What was the aim of keeping the plant in darkness before the experiment?
2. What was the purpose of attaching the bag with sodium hydroxide to the leaf?
3. What did you observe after adding iodine solution to the leaf? Did photosynthesis occur in this leaf? Explain why or why not.
4. Explain why carbon dioxide is necessary for photosynthesis.

Notes
It is important that the leaf does not contain a thick waxy coating or else the iodine will not penetrate the leaf. Ethanol boils at a lower temperature than water, thus it can be boiled in a water bath. Sodium hydroxide is used in the bag with the leaf to absorb any CO\(_2\) that might be present. The plant must be kept in darkness prior to this experiment to ensure that all starch from prior photosynthesis is consumed.

The Importance of Chlorophyll in Photosynthesis
Photosynthesis is the process by which green plants and some other organisms use sunlight to synthesize food from carbon dioxide and water. Chlorophyll is a green pigment present in all green plants. It is responsible for the absorption of light which provides energy for photosynthesis to occur. A variegated leaf is a leaf that has two different colours (i.e. green and white or green and red). Only the parts of the leaves which are green contain chlorophyll.

Learning Objectives
- To demonstrate the importance of chlorophyll in photosynthesis.
Materials
Variegated leaf, ethanol*, iodine solution*, heat source, cooking pot, water, test tube*, white tile*, dropper*, and cotton wool*.

Hazards and Safety
- Ethanol is very flammable! Make sure that student cover their test tubes to avoid excess release of ethanol vapour. If a test tube catches fire, instruct student to cover the tube with a non-flammable object to extinguish the flame.

Preparation Procedure
1. Collect variegated leaves from the environment. Try to find leaves that do not have a waxy outer coat.
2. Heat water to boiling using a heat source.

Activity Procedure
1. Choose a small piece of one leaf (the piece should not be bigger than the lid of a soda bottle) and draw a picture to show the colour pattern. Label which parts of the plants are green and which parts are not.
2. Submerge this leaf in boiling water for about 3 minutes.
3. Remove the leaf from the water and insert it into a test tube containing ethanol and to plug the test tube with a piece of cotton wool. Note: the test tube should be less than half full of ethanol.
4. Submerge the test tube in the boiling water and leave it to boil until the leaf loses all of its colour.
5. Once the leaf has lost its colour, remove it from the ethanol solution and dip it briefly into the boiling water to remove the ethanol and soften it.
6. Spread the decolourized leaf on a white tile and add iodine solution drop wise until the whole leaf is covered. Record your observations and draw a diagram showing the colour pattern of the leaf.
Results and Conclusions

The leaf is dipped in boiling water to kill the cells. The leaf is then submerged in boiling ethanol to extract the colour from the leaf. The ethanol will change to a green colour while the leaf should lose all of its colour, becoming white. When iodine solution is added, the leaf will turn a dark blue/black colour in all the places that the leaf was green. The non-green parts of the leaf should not turn dark, but should remain the colour of iodine solution. This indicates that chlorophyll is necessary for photosynthesis because only the parts of the leaf containing chlorophyll were able to photosynthesise and produce starch.

Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. Why is it important to draw the leaf before starting this experiment?

2. What was the reason for boiling the leaf?

3. What was the importance of boiling the leaf in ethanol?

4. Why was the test tube containing methylated spirit plugged with cotton wool?

5. Why was the leaf dipped in boiling water after it was removed from the ethanol?

6. Why was a water bath used to heat the ethanol rather than an open flame?

7. What did you observe when the iodine was added to the leaf? Which part of the leaf showed the presence of starch?
8. Why is chlorophyll necessary for photosynthesis?

9. Why would it be a bad idea to do this experiment early in the morning or on a rainy day?

Notes
It is important that the leaf does not contain a thick waxy coating. Variegated leaves can be found in areas that contain decorative plants, such as in front of houses and buildings. Before doing this experiment with students, test some variegated leaves from the local environment to ensure that they respond well to the experiment. Make sure that the leaf has been in sunlight for at least 6 hours prior to the experiment or there may not be enough starch to detect. This practical should NOT be done in the morning.

Ethanol boils at a lower temperature than water, thus it can be boiled in a water bath. Ethanol is very flammable and it is possible that the top of test tube catches fire. If this happens a non-flammable material such as glass or metal can be used to cover the flame and deprive it of oxygen.

The Importance of Light in Photosynthesis
Photosynthesis is the process through which green plants and some other organisms use sunlight to synthesize food from carbon dioxide and water. Light energy is required for photosynthesis to occur.

Learning Objectives
- To show that light is needed for photosynthesis.

Materials
Aluminium foil or black carbon paper, clips, a green leaf, ethanol*, iodine solution*, heat source, cooking pot, water, test tube*, white tile*, dropper*, and cotton wool.

Hazards and Safety
- Ethanol is very flammable! Make sure you cover the test tubes with cotton wool to avoid excess release of ethanol vapour. If the test tube catches on fire, cover the tube with a non-flammable object to extinguish the flame.
Preparation Procedure

1. Put a potted plant in a dark place for 24 hours to de-starch it.

2. Use aluminium foil or carbon paper to cover a portion of the upper and lower epidermis of a leaf (see diagram).

3. Allow the plant to sit in sunlight for at least 6 hours.

Activity Procedure

1. Submerge the leaf in boiling water for about 3 minutes.

2. Remove the leaf from the water and insert it into a test tube containing ethanol and plug the test tube with a piece of cotton wool. Note: the test tube should be less than half full of ethanol.

3. Submerge the test tube in the boiling water and leave it to boil until the leaf loses all of its colour.

4. Once the leaf has lost its colour, remove it from the ethanol solution and dip it briefly into the boiling water to remove the ethanol and soften it.

5. Spread the decolourized leaf on a white tile and add iodine solution drop wise until the whole leaf is covered.

6. Record your observations and draw a diagram showing the colour pattern of the leaf after the addition of iodine solution.

Results and Conclusion

The aluminium foil blocks sunlight from reaching the leaf, thus preventing photosynthesis from taking place. Any part of the leaf that was covered with foil will test negative for starch while the parts exposed to sun will test positive for starch. This proves that sunlight is necessary for photosynthesis.

Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.
Discussion Questions

1. What was the purpose of covering the leaf and allowing it to sit in the sun?

2. Which parts of the leaf tested positive for starch?

3. What did you observe when the iodine was added to the leaf? Which part of the leaf showed the presence of starch?

4. Why is sunlight light necessary for photosynthesis?

Notes

It is important that the leaf does not contain a thick waxy coating. Do the procedure for testing a plant for starch on other leaves from this plant before setting the aluminium foil to ensure it works.

Because ethanol boils at a lower temperature than water, the ethanol solution can be boiled in a water bath. Ethanol is very flammable and it is possible that the top of the test tube will catch fire. If this happens, cover the top of the test tube with a non-flammable material such as glass or metal to cover the flame and deprive it of oxygen.

Oxygen as a By-product of Photosynthesis

Photosynthesis is the process by which green plants and some other organisms use sunlight to synthesize food from carbon dioxide and water. Photosynthesis produces oxygen. This helps to replace the oxygen that is used during burning, respiration, rusting and other processes.

Learning Objectives

- To demonstrate that oxygen is a by-product of photosynthesis.

Materials

2 empty plastic bottles (350 mL), straw, potted plant, super glue, sodium hydroxide*, sodium hydrogen carbonate*, dilute weak acid (citric or acetic acid)*
Hazards and Safety

- Sodium hydroxide is corrosive to skin and wood and even when dilute can blind if it gets into the eyes. Neutralise spills with a weak acid.

Figure 6.6: An activity showing the production of oxygen.

Activity Procedure

1. Take two bottles and make a hole in one side of each bottle and connect them using a straw. Make sure there is an airtight seal by sealing leaks with superglue or cello tape.

2. Label the bottles A and B.

3. In bottle A put potted plant.

4. In bottle B put about one teaspoon of sodium hydroxide crystals. This is to absorb any excess carbon dioxide later in the experiment.

5. Tie or bend the connecting straw to prevent movement of air between the two bottles.

6. Squeeze extra air out of bottle B and cap it tightly.

7. In a separate beaker, combine acid and sodium hydrogen carbonate in order to form carbon dioxide gas. Slowly pour the gas (not the liquid) into bottle A. Repeat this until a glowing splint is extinguished in the mouth of test tube A. The aim of this is to fill the bottle with carbon dioxide, thus ensuring that any oxygen found later was produced by the plant.
8. Seal bottle A and allow the set up to sit in sunlight for 6 hours.

9. After 6 hours, open the straw and squeeze bottle A to force any gas into bottle B.

10. Shake bottle B so that any carbon dioxide gas is absorbed by the sodium hydroxide crystals.

11. Open bottle B and use a glowing splint to test for oxygen gas in bottle B.

Results and Conclusions
When a glowing splint is inserted into bottle B, it relights. This shows the presence of oxygen gas from the potted plant in bottle A.

Clean Up Procedure
Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions
1. What is the aim of putting sodium hydroxide in bottle B?

2. Why was bottle B compressed at the beginning of the experiment?

Notes
There should be enough CO2 in Bottle A and no loss of air between the two bottles during this experiment.

Essential Minerals in Plants
Plants need mineral elements in addition to the food they manufacture. Mineral elements are found in the soil or dissolved in water and they are absorbed by plants in the form of ions. Mineral elements required for normal healthy plant growth include nitrogen, phosphorus, potassium, magnesium, calcium, sulphur and iron. Each mineral element has a specific function in the plant body some are used in the production of building materials while others play an important role in the metabolic activities of the plant.
Learning Objectives

- To investigate the roles of essential mineral elements in plant nutrition.
- To identify different mineral deficiencies in plants.

Materials

Inorganic fertilizers: CAN, DAP, NPK and SA; magnesium sulphate*, iron pills*, sodium chloride*, beakers*, cotton wool*, maize plants, and rain water.

Preparation Procedure

1. Sow maize seeds and wait for about 5-7 days for the seedling to develop.
2. Label six beakers A, B, C, D, E and F and put a bundle of cotton wool into each beaker.
3. Grind CAN, DAP, NPK, SA, MgSO₄, Fe and NaCl so they are in fine powder form.

Activity Procedure

1. Make seven solutions of salts by dissolving the specified amounts in approximately 1 L of rainwater
   
   (a) **Solution 1**: one slightly heaped teaspoon of sodium chloride
   (b) **Solution 2**: one flat teaspoon of sodium chloride + a pinch of CAN (a few crystals)
   (c) **Solution 3**: one flat teaspoon of sodium chloride + a pinch of DAP (a few crystals)
   (d) **Solution 4**: one flat teaspoon of sodium chloride + a pinch of NPK (a few crystals)
   (e) **Solution 5**: one flat teaspoon of sodium chloride + a pinch of SA (a few crystals)
   (f) **Solution 6**: one flat teaspoon of sodium chloride + a pinch of MgSO₄ (a few crystals)
   (g) **Solution 7**: one flat teaspoon of sodium chloride + a pinch of iron (a few crystals)
2. Combine these solutions in beakers as follows. Put 2 mL of each mentioned solution in the beaker:

(a) **Beaker A (all nutrient)** solutions 2, 4, 6 and 7
(b) **Beaker B (calcium deficient)** solutions 4, 6 and 7
(c) **Beaker C (iron deficient)** solutions 2, 4, and 6
(d) **Beaker D (magnesium deficient)** solutions 2, 4, 5, and 7
(e) **Beaker E (potassium deficient)** solutions 2, 3, 6, and 7
(f) **Beaker E (no nutrients)** 6 mL of solution 1

3. Place 3 seedlings in each beaker and place beakers near a window.

4. Measure and record the height of each of each seeding every day

5. Observe and record the colour of the leaves of the seedlings in each bottle every three days.

6. Make sure that plants do not dry out – if the water level gets low, increase by adding 1 mL of each solution added initially.

**Results and Conclusions**

When plants lack one of the mineral elements, their growth will be disturbed. The plants will have slow growth and leaves may drop or change colour.
<table>
<thead>
<tr>
<th>Essential Plant Element</th>
<th>Role of Element in Plant Growth</th>
<th>Deficiency Symptoms</th>
</tr>
</thead>
<tbody>
<tr>
<td>Nitrogen (N)</td>
<td>Makes proteins, manufactures chlorophyll, and promotes normal plant growth</td>
<td>Leaves become pale green or yellow, the plant has small leaves, thin, weak stem, stunned growth</td>
</tr>
<tr>
<td>Phosphorus (P)</td>
<td>Root and Branch growth, makes proteins, releases energy during respiration</td>
<td>Short or small roots, leaves, and branches; leaves become a reddish purple</td>
</tr>
<tr>
<td>Potassium (K)</td>
<td>Potassium is used during photosynthesis and for protein metabolism in young leaves</td>
<td>Yellow leaves with dead spots especially at the margins and tips</td>
</tr>
<tr>
<td>Magnesium (Mg)</td>
<td>Creates chlorophyll and helps in enzyme activity</td>
<td>Leave become yellow</td>
</tr>
<tr>
<td>Calcium (Ca)</td>
<td>Promotes normal plant growth and the creation of cell walls</td>
<td>Poor root growth and dead growing regions</td>
</tr>
<tr>
<td>Sulphur (S)</td>
<td>Synthesizes or creates proteins</td>
<td>Small growth and yellow patches on leaves</td>
</tr>
<tr>
<td>Iron (I)</td>
<td>Creation of Chlorophyll</td>
<td>Thin and weak stems; leaves become white or pale</td>
</tr>
</tbody>
</table>

**Clean Up Procedure**

Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

**Discussion Questions**

1. What minerals are required by plants in large amount?
2. What observations did you make about the plant that was
   (a) calcium deficient
   (b) iron deficient
(c) magnesium deficient
(d) potassium deficient

3. Look in a book to identify the qualities of a plant that is nitrogen deficient.

Notes
Minerals are required by plants in small quantities. Solutions that are too concentrated may kill the plant because of water loss through osmosis. The purpose of the sodium chloride is to set the proper osmotic pressure.

Interaction of Living Organisms

Our environment is made up of two components. First are the biotic (living) components like plants, animals, and other groups of living organisms. There are also abiotic (non-living) components like water, air, soil, rocks, climate, and weather. Biotic components depend on abiotic components for their survival. The type of abiotic components found in different areas determine the types of biotic components found there.

Investigation of Abiotic and Biotic Components in the Environment

Learning Objectives
- To describe biotic and abiotic components in the environment.

Materials
Ants, termites, tadpoles, soil, stones, plants, dried fish, beaker*, water, and plastic bags

Preparation Procedure
1. Collect live tadpoles from a lake in a plastic bottle with water.

Activity Procedure
1. Bring soil, plants, ants, termites, stones and uprooted plant seedlings inside.
2. Blow into a plastic bag and tie it to hold air in.

3. Fill one beaker with only water, a second beaker with a tadpole in water, and a third beaker with a dry fish.

4. Arrange all of the components into 2 groups: biotic and abiotic.

Results and Conclusion
Non-living components are very important to the survival of biotic components. Water, air, and soil are all abiotic components. Light, water, and carbon dioxide are also abiotic but plants cannot manufacture their foods without them. It is important to preserve our environment to maintain the biotic and abiotic components for our survival.

Clean Up Procedure
1. Return the biotic and abiotic components to their environment. Clean and store items that will be used later. No special waste disposal is required.

Discussion Questions
1. What will happen to the biotic components if there is no water?

2. Suppose the level of oxygen goes down drastically in the environment. What kind of biotic components will survive?

3. Is soil biotic or abiotic?

Notes
This activity will enable the students to realise the importance of abiotic components normally thought to be freely available. The activity will raise the students consciousness in avoiding the activities causing water, air and soil pollution. Vegetation plays a big role in purifying air by increasing the level of oxygen in the atmosphere but plants depend on water and soil for their survival.

Construction of Food Webs and Food Chains
Feeding relationships can be shown in a simple way where organisms feed on the next organisms in a liner sequence. This is called a food chain. However,
in reality most organisms have several food sources that interact with one another. These interactions can be represented in a food web.

Learning Objectives

- To mention the components of a food chain and food web.

Materials

Manila sheet or flat boxes, maker pens, specimens or pictures of maize seedlings, termite, toad, caterpillar (butter fly/beetle larva), and a small bird

Preparation Procedure

1. Germinate maize grains to get seedlings.

2. Ask students to collect and bring in termites, toad, a small bird, and a caterpillar in a cage or plastic bottle.

Activity Procedure

1. Arrange the 3 organisms on the manilla paper or flat box in such a way that one organism is the food source for another organism. This feeding relationship should make a line, for example maize, caterpillar, small bird.

2. Write names of each organism and their tropic level.

3. Draw arrows on the manilla paper, pointing away from the organism being eaten.

4. Arrange all the organisms randomly on the other manilla sheet.

5. Draw arrows away from each organism being eaten towards the organisms that is eating it.

6. Write the names of each organism and their tropic level.
Results and Conclusion

The first diagram indicates a food chain while the second one indicates a food web. Food chain shows a sequence of living things in which each organism is the food of the next one in the sequence. Arrows are used to show the direction of flow of energy. A food chain starts with the producer and ends with the top consumer.

Clean Up Procedure

1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. Write the names of the food relation in the first and second drawings.

2. What is the importance of food web in real life?

Notes

Primary producers occupy the lowest level in trophic levels. In most cases they are plants. The top consumers occupy the top levels. In this activity birds were the top consumer but in most cases decomposers like bacteria or fungi would be at the top.

Transport of Materials in Living Things

Living things need transport systems to supply all their cells with food, oxygen, and other materials in order to carry out life processes such as growth, respiration, and reproduction. Lungs take in oxygen for the combustion of food and they eliminate the carbon dioxide produced. The urinary system disposes of dissolved waste molecules (urea), the intestinal tract removes solid wastes, and the skin and lungs rid the body of heat energy. The circulatory system moves all these substances to and from cells where they are needed or produced, responding to changing demands. The methods of transport are diffusion, osmosis and mass flow.

These activities can be prepared by the teacher and performed easily by students to show the importance of diffusion, osmosis, and mass flow in living organisms.
Demonstration of Diffusion

Diffusion is the movement of particles from an area of high concentration to an area of low concentration. Diffusion continues until the particles are evenly distributed.

Learning Objectives

- To carry out experiment to demonstration the process of diffusion.

Materials

Beakers*, water, soda or water bottle caps, GV stain*, droppers*.

Activity Procedure

1. Put a very small amount of GV in the bottle cap.
2. Fill the beaker about half way with water.
3. Draw a drop of GV from their cap using the dropper.
4. Put one drop of GV into the beaker.
5. Observe what is happening in the container for the first 5 minutes.
6. After 20 minutes, observe their beaker again and record their observations.

Clean Up Procedure

Collect all used materials, storing items that will be used later. The chemicals used in this experiment require no special disposal.

Hazards and Safety

- GV stains skin and clothes.

Discussion Question

Apart from this experiment, where else have you seen diffusion taking place?
Results and Conclusions

Immediately after putting the drop of GV in water, GV molecules start moving towards areas with lower concentration of GV molecules. The movement continues until the whole solution will have the same concentration of GV molecules.

Notes

Diffusion can take place through any substance. Other examples of diffusion include colour of tea spreading in hot water, the smell of perfume molecules spreading through the air, and the sight of heavy smoke thinning into the air. Molecules are always moving. Solid particle remain in the same location, however liquid, gas, and solute particles move randomly through space. Because there are more molecules in an area of high concentration than in an area of low concentration, more molecules are available to move from the area of high concentration to the area of low concentration than are available to move from the area of low concentration to the area of high concentration. While particles are always moving in all directions, over time there is a net flow of particles from the area of high concentration to low concentration. Eventually, the concentration in all parts is the same. In this state the molecules continue to move from one place to another, but no net change is observed. This is called equilibrium.

Osmosis

Osmosis is the movement of water molecules through a semi-permeable membrane from an area of low solute concentration to an area of high solute concentration.

Learning Objectives

- To demonstrate osmosis.

Materials

Irish potatoes, 4 beakers* or petri dishes*, sugar, water, knife, kerosene stove, and a cooking pot

Preparation Procedure

1. Dissolve 10 table spoons of sugar in about 100 mL of water. This solution should be very concentrated and thick.
2. Fill a cooking pot half way with water and heat it to boiling on a stove.

**Activity Procedure**

1. Boil one potato and leave the other uncooked.

2. Peel the potatoes and cut them into two halves.

3. Make a shallow hole in the four halves of the potatoes. Each cut potato should look like a bowl.

4. Put a small amount of water in each beaker.

5. Put one carved potato in each beaker. The water should not spill into the inside of the potato bowl.

6. Put sugar solution in the centre of 1 raw potato and 1 boiled potatoes. The other two potatoes will act as controls.

7. Set the experiment aside for an hour.

8. After one hour examine the potatoes and write down what you observe.

**Results and Conclusion**

After an hour the level of water in the raw potato with sugar will rise while in the boiled potato with sugar there will be no change. Boiling kills the cells, therefore the cell membrane loses its permeability. The potatoes without sugar should show no change.

**Clean Up Procedure**

1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required. The used potatoes should not be eaten.

**Discussion Questions**

1. What is the function of the controls in this experiment?

2. If you put chemical fertilizers on plant seedlings in the dry season, the plants dries up. Why does this happen?
Notes
Osmosis is a special case of diffusion - the movement of a substance from an area of high concentration to an area of low concentration. The area of low solute concentration has relatively high water concentration whereas the area of high solute concentration has relatively low water concentration. Therefore water moves from the area of high water concentration to the area of low water concentration, or from the area of low solute concentration to the area of high solute concentration. The solute cannot pass through the semi-permeable membrane.

Demonstration of Capillarity
Capillarity is the action that causes water to rise in narrow tubes. Capillarity is made possible by cohesion and adhesion forces. Cohesion is the attraction between molecules of the same substance and adhesion is the attraction between molecules of different substances. Water molecules in a plant are attracted to each other (cohesion) as well as to the walls of the xylem vessel (adhesion). Xylem vessels have a narrow tube which makes it possible for water to rise in them by capillarity.

Learning Objectives

- To conduct an experiment to demonstrate capillarity.

Materials
Plastic tubes of different diameters (the empty ink tube of a pen or a straw can be used), water, GV stain*, clothes pin, and 2 beakers*.

Hazards and Safety

- GV will stain clothes and skin.

Preparation Procedure

1. Fill a beaker half way with water and add a few drops of GV to make a coloured solution.

Activity Procedure

1. Dip the different straws in the coloured solution.
2. Attach 1 clothes pin to the edge of the beaker and tie the other clothes pin to it. In the clothes pin there will be 2 holes. Place 2 straws in the 2 holes.

3. Observe the changes as time goes by.

Results and Conclusions

The coloured solution climbed to a higher level in the thinner tube than the wider one. Xylem vessels in a plant works the same way as a capillary tube.

Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later. GV stain should be disposed of in the pit latrine.

Discussion Questions

1. What changes did you notice in the experiment?

2. Which part of the vascular system of a plant functions like the capillary tube?

Notes

The narrower the tubes used in this experiment, the more you will be able to see the capillary effect.

Demonstration of Mass Flow

Learning Objectives

- To carry out experiments to demonstrate the process of mass flow.

Mass flow is the movement of fluids within a cell or along a vessel that does not pass through a membrane. This mode of transport is important in large complex organisms where substances are required in large amounts and also have to be transported over large distances to reach the required area at the right time. Diffusion and osmosis cannot perform such large functions. In many animals mass flow is demonstrated in their lymphatic and circulatory systems. In plants, mass flow is responsible for the transport of water and mineral salts. These travel from roots, through the stem and branches to the leaves in xylem vessels. Sugars are also transported from different parts of a plant through phloem vessels by the same process.
Materials
Beaker*, water, GV stain*, water drop microscope*, razor blade, dropper*, plastic slide, plastic cover slip, and an uprooted plant (e.g. commelina plant.)

Hazards and Safety
• GV stains clothes and skin.

Preparation Procedure
1. Put some water into a beaker and add two drops of GV to colour the water.
2. Place the uprooted plant upright in a plastic beaker containing coloured water.
3. Leave the plant in the sun for one hour.
4. After an hour remove the plant from the sun and put it in a special area to be used by students for observation.

Activity Procedure
1. Cut a leaf, stem, and root from the plant in half. Make 3 transverse cross sections by cutting a thin slice from the centre of the root, stem, and leaf.
2. Mount the circular cross sections on a slide with a drop of water and cover it with a plastic cover slip.
3. Observe the colour of the specimens carefully using the water drop microscope.
4. Draw the cross section of the root, stem, and leaf you have just observed, showing the distribution of colour.

Results and Conclusions
The presence of colour in the leaf, stem, and root cross section indicates the presence of coloured water that was present in the container. This suggests that there was a movement of coloured water molecules from the container to the rest of the plant parts via the xylem tissue. This proves that there is a mass flow of water from the low plant parts like roots to the high plant parts like the stems and leaves.
Clean Up Procedure
Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions
1. What does the presence of colour in the tissue of leaves, stems and roots indicate?
2. What can you conclude from the experiment?

Notes
The commelina plant species is best to use in this experiment because it is clearly seen by the water drop microscope and brings better results as compared to other plants.

Demonstration of Transpiration Pull
There are three mechanisms which facilitate movement of water from the ground through the stem to the leaves: root pressure, transpiration pull and capillarity. Transpiration pull occurs when water evaporates through the stomata. As water evaporate through the stomata, mesophyll cells draws water from the xylem of the leaves, which in turn draws water from xylem in the stem. This create a tension called transpiration pull.

Learning Objectives
• To conduct experiments to demonstrate transpiration pull.

Materials
Beaker*, narrow tubes from a used ink pen, cover from syringe needle, GV stain*, super glue, and the stem from a plant with leaves attached.

Hazards and Safety
• GV stain skin and clothes.
Preparation Procedure

1. Cut the closed end of the syringe cover to fit the ink pen tube. Fit the ink pen tube into the hole in the syringe cover.

2. Seal the junction between the syringe cover and the tube with super glue so that air or water cannot pass through.

3. Cut a plant to get leafy shoots without roots.

4. Prepare coloured water using few drops of GV.

Activity Procedure

1. Fill the beaker with coloured water.

2. Fill the tube with clean water, making sure that one air bubble is created in the tube. Mark the location of the air bubble using pen.

3. Fix the stem into the open part of the syringe cover.

4. Transfer the ink pen tube-syringe cover-plant set up into the coloured water in the plastic container. Hold the set-up so that the tube does not touch the bottom of the container. Place near a window.

5. Observe the set up every 15 minutes and note the upward movement of air bubble through the tube.

Results and Conclusions

The leaves and stem will draw up water, causing the air bubble to move up. The higher the rate of transpiration, the higher the speed of the moving air bubble.

Clean Up Procedure

Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. How can you define transpiration pull?

2. What can you conclude from the experiment?
Notes

Capillarity and root pressure are not enough to push water to the leaves. Root pressure facilitate movement of water to the leaves. However, the transpiration pull is associated with water loss. Therefore, transpiration pull facilitates drawing of water upwards, but results in a loss of water. The comelina plant has been tested and works very well for this experiment. The stem of the plant should tightly into the syringe cap.

Examination of the Vascular System in Plants

The vascular system in plants is composed of xylem, which carries water up from the roots to the leaves, and phloem, which transports nutrients down from the leaves to the roots. The arrangement of vascular bundles in dicot stems is a ring shape, while in the monocot stems the bundles are scattered. In monocot roots the vascular bundles are also scattered and have a pith, while in dicot roots the xylem resembles a star.

Learning Objectives

- To describe the components of the vascular system in plants.

Materials

Water drop microscope*, plastic slides*, plastic cover slips*, 4 plastic cups, maize grains, bean seeds, water, cotton wool, GV stain*, razor blades, and 2 droppers*.

Hazards and Safety

- GV can stain the skin and clothes.

Preparation Procedure

1. Soak maize and bean seeds in water overnight.

2. Wet cotton wool and place it into 2 plastic cups.

3. Remove the seeds from the water and put them into the two separate cups with cotton wool.

4. Cover the seeds with wet cotton wool and leave the seeds for four days.
5. Transfer the seedlings to a plastic cup that has water and a few drops of GV.

**Activity Procedure**

1. Cut a stem in half vertically, then cut a very thin transverse section from centre of the stem, resulting in a thin circular cross section of the stem.

2. Cut a root in half vertically, then cut a very thin transverse section from centre of the root, resulting in a thin circular cross section of the root.

3. Cut a leaf in half vertically, then cut a very thin transverse section from centre of the leaf, so that the mid rib is included. The result will be in a thin diamond-like cross section of the leaf.

4. Mount the cross sections on slides with a drop of water and cover with a cover slip.

5. Observe the specimens using the water drop microscope.

6. Draw what is seen in the microscope.

7. Classify the specimens as monocots or dicots.

**Results and Conclusion**

The purple colour will be seen in the xylem tissue, which should be similar to the description mentioned in the introduction to this activity.

**Clean Up Procedure**

Collect all the used materials, storing items that will be used later. Waste containing GV should be disposed of in the pit latrine.

**Discussion Questions**

1. Describe the difference between the arrangement of the vascular bundles in monocot stems and dicot stems.

2. Describe the difference between the arrangement of the vascular bundles in monocot stems and dicot roots.

3. What are names of the cells coloured by GV?
Notes
In this experiment, you will not be able to see the phloem because it is not coloured.

Examination of Root Hair in Germinated Seeds
Roots of plants are responsible for absorption of water and mineral salts from the soil. The roots have root hairs which are responsible in the absorption process. These are extensions of epidermal cells of roots. They are long and slender to provide large surface area for absorption.

Learning Objectives
- To explain the functions of root hairs in absorption in the movement of water and mineral salts.

Materials
Bean seeds, maize grains, plastic bottles, water, and soil.

Preparation Procedure
1. Cut plastic bottles to get six inch containers.
2. Soak the maize grains and bean seeds in two separate clear plastic containers overnight.
3. Remove the bean seeds and maize grains from the water and place them into two separate plastic containers with wet cotton wool.
4. Leave the seeds for two days to allow them to germinate.
5. Shift the seeds into another plastic container with soil.
6. Make sure that the seeds are grown near the wall of the container to make sure that the roots will be seen from outside.
7. Leave the experiment for three days to allow growth of the roots.

Activity Procedure
1. Observe the root hairs of the germinating seeds through the containers.
2. Draw what you have seen.
Results and Conclusion

You will see the root hairs through the plastic containers. The root hairs look like small white threads on the root tips.

Clean Up Procedure

1. Remove the germinating seeds from the classroom and place them where there is enough light to be used for other experiments which require seedlings.

Discussion Questions

1. What would happen if the plants did not have root hairs?
2. When plants are transplanted they wilt for sometimes and flourish again after a day or so. Why?
3. Root hairs are not found at the tip of the roots. Why this is the case?

Notes

There are no root hairs at the tips of the roots. The root hairs develop after differentiation. There are a large number of root hairs to increase surface areas for absorption of water and mineral salts. The root hairs need to be observed without uprooting the seedling because they can be destroyed in the process of uprooting.

Determination of Pulse Rate

Learning Objectives

- To measure human pulse rate.

Pulse is the result of contraction and relaxation of arteries. Pulse rate is the number of pulses per minute. Pulse rate reflects the heart beat. An adult human’s heart beats at an average of 72 times a minute. This can increase or decrease depending on the physical activity, emotional state or health factors.

Materials

Wrist watch, notebook and a pen or a pencil.
Activity Procedure

1. Use the first two fingers on the right side of your left wrist to feel for pulse. Pulse can also be measured by placing the first two fingers on one side of the neck under the lower jaw.

2. Count the number of pulses in one minute. Record your answer.

3. Repeat this measurement 3 times and calculate the average.

4. Run around outside for a minute, then return and repeat steps number 2 and 3. Record the pulse rate.

![Figure 6.7: Pulse can be taken at the neck.](image)

Figure 6.7: Pulse can be taken at the neck.

![Figure 6.8: Pulse can also be measured at the wrist.](image)

Figure 6.8: Pulse can also be measured at the wrist.

Results and Conclusion

There should be an increase in the pulse rate after exercise.
Discussion Questions

1. What is pulse rate?
2. What was the average pulse rate before exercise?
3. What was the average pulse rate after exercise?
4. Why are these pulse rates different?

Notes

When counting the pulse rate, there should be no distractions on the students.

Gaseous Exchange and Respiration

Identification of Carbon Dioxide in Exhaled Air

During respiration, living cells oxidize food substance to produce carbon dioxide. Carbon dioxide is a waste product and must be removed from the body. The blood carries carbon dioxide to the lungs where it is released in exhalation.

Learning Objectives

- To identify the presence of carbon dioxide in exhaled air.

Materials

Clear plastic container, plastic straw, lime water*.

Activity Procedure

1. Put approximately 10 mL of lime water into a clear container.
2. Blow exhaled air through the straw and into the limewater until a change is observed.

Results and Conclusion

The addition of carbon dioxide turns limewater milky (white). This shows that carbon dioxide is present in exhaled air.
Clean Up Procedure

1. Unused lime water should be stored in an airtight labeled bottle for future use.

2. Used lime water contains suspended solids and should be disposed outside, not down the drain.

Discussion Questions

1. What change did you observe in the lime water at the end of the experiment?

2. What caused the change in limewater?

Notes

Lime water reacts with carbon dioxide to form white calcium carbonate precipitate. \( \text{CO}_2(g) + \text{Ca(OH)}_2(aq) \rightarrow \text{CaCO}_3(s) + \text{H}_2\text{O}(l) \)

Anaerobic Respiration

Respiration is the production of energy through the breakdown of complex organic structures. Anaerobic respiration is respiration without oxygen. The products of anaerobic respiration are alcohol and carbon dioxide.

Learning Objectives

- To identify the products of anaerobic respiration.
Materials

Plastic bottle with lid, plastic syringe, delivery tube*, cotton wool, test tube*, beaker*, yeast, glucose*, water, and lime water*.

Preparation Procedure

1. Make a hole on one side of plastic water bottle and connect the delivery tube, making sure there is an airtight seal.

2. Boil some water to remove dissolved oxygen and let it cool.

3. Prepare a water bath by mixing hot and cold water. The ideal temperature is the same as human body temperature - the water should feel warm but not hot.

Activity Procedure

1. In the plastic bottle mix 1/4 spoon of glucose, 1/2 spoon of yeast, and approximately 30 mL of cool boiled water. Mix thoroughly.

2. Add about 2 mL of lime water in the test tube, insert the free end of the delivery tube into the test tube, making sure that it is immersed in the lime water. Cover the test tube with cotton wool.

3. Dip the bottle containing the mixture of yeast and sugar in a warm water bath, make sure that the opening of the delivery tube remains submerged in the lime water.

4. Check periodically for bubbles passing through the lime water and note any changes that occur in the limewater.

5. After a change in the lime water has been noted, smell the yeast solution.

Results and Conclusion

The lime water will turn milky showing the presence of carbon dioxide gas. The students should detect a slight smell of alcohol from the mixture of glucose and yeast showing that anaerobic respiration produces alcohol.
Clean Up Procedure

1. Unused lime water should be stored in a well labeled reagent bottle for further use.

2. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. Why is it important to boil the water used to make the yeast solution prior to this experiment?

2. Name the gas produced during this reaction.

3. Why was glucose added to the solution of yeast?

4. Why was the solution submerged in a warm water bath?

5. What smell do you detect from the mixture of glucose and yeast after the experiment?

6. Where is the principal of anaerobic respiration applied in a Tanzanian village? How are the products used?

Notes

This principle is applied in the manufacture of alcoholic beverages, both in industry and by local brewers. If you find that the gas is taking a long time to form, you can gently squeeze the bottle containing the yeast solution. This will force any gas formed through the delivery tube and will speed up the change in lime water. If this is done, be sure not to release the bottle before removing the cap when the straw is still submerged in limewater - otherwise air pressure will force the limewater back into the yeast solution, ending the experiment. The smell of alcohol may be faint and hard to detect; if this is the case leave the solution for 3-4 days and smell again.

Movement

Movement is the change in the position of an organism or a part of an organism. There are two types of movement: locomotion and growth curvature. Animals, protoctista, and some bacteria use locomotion to move their whole
body from place to place. Plants use growth curvature to respond to stimuli such as light, gravity and important chemicals needed for growth and survival.

These activities are conducted well in small groups over a week.

Investigate the Effects of Phototropism

Tropic movement is the directional movement of a plant in response to an external stimulus. Phototropism is the growth of plant shoots towards light.

Learning Objectives

- To carry out experiments to investigate the effect of phototropism on plants.

Materials

Maize grain, 2 pots or containers, cotton wool, and 2 boxes.

Preparation Procedure

1. Make a hole in one of the boxes on the side.

2. Germinate maize grains by placing them into a container with wet soil.

Activity Procedure

1. Cover the maize seedlings with the two boxes, one with a hole and one without a hole.

2. Leave the covered plants for about 2-3 days.

3. Uncover the boxes and observe the direction of the shoot in the two separate plants.

Results and Conclusion

The plant covered by the box with no light source will grow upwards. The plant covered by the box with the hole will grow towards the light.
Clean Up Procedure

1. Collect all used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. Define phototropism.
2. What is the importance of light in plant growth?

Notes

The investigation shows that plant stems grow towards a light source. This shows that they are positively phototrophic. This tropism enables plant leaves to receive the maximum amount of light for photosynthesis.

Investigation of the Effects of Hydrotropism

Plants need water to grow and survive. Because of this, plant roots tend to grow towards a source of water. This process is termed hydrotropism.

Learning Objectives

- To carry out an experiment to investigate the effect of hydrotropism in plants.
**Materials**

Maize and bean seedlings, water bottle, knife, take-away food container, dry saw dust, and water.

**Preparation Procedure**

1. Prepare a perforated container by cutting a water bottle in half and then punch small holes into left half of the container.

![Image of perforated container and saw dust](image.png)

**Activity Procedure**

1. Put saw dust in the take-away food container.

2. Place the perforated container in the centre of the tray with saw dust.

3. Fill the container in the centre with water, so one side of the saw dust tray is wet while saw dust on the other side is dry.

4. Sow the seedlings in the saw dust on both sides.

5. Leave for 4-5 days.

**Results and Conclusion**

After a few days all the roots of the plants growing towards the left or perforated side of the water container.
Clean Up Procedure

1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

Discussion Questions

1. What is hydrotropism?

2. What are the effects of hydrotropism to a plant?

Notes

In a carefully set up experiment, you will observe that radicals did grow towards the water. Thus, water has a greater influence on root growth than gravity.

Investigation of Effects of Geotropism

Geotropism is the growth of shoot away from gravity and of roots towards gravity. When the plant stem grows away from gravity it is termed negative geotropism and when plant roots grow towards gravity it is termed positive geotropism. This enables the plant to anchor its roots securely in the ground, reaching water and minerals to ensure their survival and to ensure that the stem grows upright towards the light.

Learning Objectives

• To carry out experiments to investigate the effect of geotropism in plants.

Materials

Germinating bean seeds, moist cotton wool, petri dish, covering lids, and cellotape

Preparation Procedure

1. Prepare a petri dishes from bottle caps or from bottoms of empty plastic bottles.

2. Soak bean seeds/maize grains/cow peas in water.
Activity Procedure

1. Make two layers of moist cotton wool.

2. Place the germinating seeds between the two layers of moist cotton wool.

3. Place the seeds in a petri dishes with their radicals; one facing horizontally, one pointing vertically upwards and one pointing vertically downwards.

4. Cover the petri dish with a lid made from a box or bottle caps.

5. Place the petri dish on its edge by using cellotape in the dark cardboard.

6. Leave it for two days and observe the changes.

Results and Conclusion

Plant roots will grow towards gravity, showing a positive response to gravity. The stems will grow away from gravity, thus showing negative geotropism.

Clean Up Procedure

1. Remove all the unwanted materials from the bench.

Discussion Questions

1. Define geotropism.

2. Why is it important to moisten the cotton wool?

3. Which force causes the response shown by the seedlings?

4. How is this response important to plant life?
Notes

Plant stems grow away from gravity a process termed negative geotropism while roots towards gravity is a process termed positive geotropism. Positive geotropism enables plants to anchor its roots in the ground, reaching water and minerals necessary for their survival.

Coordination

Coordination is the process of different organs working together to perform a particular function. All living organisms use coordination to respond to changes in their environment. Sense organs allow organisms to perceive changes in their environment.

The following activity is described as an example of an activity the teacher may use in the classroom to help students explore their sense organs.

Using Sense Organs to Make Observations

There are five sense organs in the human body that we use to make observations. We use our tongue to taste, our nose to smell, our skin to feel, our ears to hear, and our eyes to see.

Learning Objective

- To make observations with sense organs.

Materials

A sharp stick, a colourful flower like hibiscus or bougainvillea, salt, sugar, orange or lemon leaves, soap and water, and 2 pieces of metal.

Hazards and Safety

- This activity should not be conducted in a laboratory as nothing should ever enter the mouth in a school laboratory.

Activity Procedure

1. Instruct all students to wash their hands with soap.

2. Provide each group with a sharp stick, flower, small amount of sugar and salt, and a lemon or orange leaf.
3. Instruct one partner to close their eyes and open their mouth.

4. Instruct the other partner to put a very small amount of sugar and then salt on their partner’s tongue. Tell the student to describe the taste of each unknown substance.

5. Instruct the student to keep their eyes closed and smell one of the crushed lemon/orange leaves. Guide students to describe the smell of each unknown substance.

6. Instruct students to touch each other with a sharp stick and describe the feeling.

7. Instruct students to describe the colour and shape of the flower.

8. Instruct all students to close their eyes. Strike the metal rods together.

9. Guide students to describe what they have heard.

**Results and Conclusion**

By using our sense organs, we should be able to make hypotheses about what we are tasting, smelling, hearing, feeling, and seeing.

**Clean Up Procedure**

1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

**Discussion Questions**

1. Mention the five sense organs and their functions.

2. Is there any relationship between the sense of smell and that of taste? Give an explanation.

**Growth**

Growth is a characteristic of living things. Growth is defined as the permanent increase in size. Growth happens through cell division or cells getting larger. In most flowering plants, growth starts when the seed begins to germinate.
Investigating Conditions Necessary for Seed Germination

Seed germination is the development of a seed into a seedling. The changes that occur during seed germination include absorption of water through micropyle, bursting of testa, and emerging and elongation of the radical. Then seed coat is discarded and cotyledons open out and begin to photosynthesize. Between the cotyledons, the plumule emerges and produces leaves. At this point, the young plant is called a seedling. The conditions necessary for seed germination include water, oxygen and optimum temperature.

Learning Objectives

- To investigate conditions necessary for seed germination.

Materials

Bean seeds, water, cotton wool, rubber stopper*, 4 test tubes*, cooking oil, boiling water, ice water (if available)

Preparation Procedure

1. Prepare 4 test tubes from syringes and label them 1, 2, 3, and 4.
2. Buy ice for ice water.
3. Boil water and let it cool to room temperature.

Activity Procedure

1. Place cotton wool at the bottom of each test tube.
2. Add a few seeds in each of the test tubes.
3. In test tube 1, add enough water to soak the cotton wool.
4. In test tube 2, add cool boiled water to flood the seeds; add small amount of oil to form a layer above the water.
5. In test tube 3, add ice water.
6. In test tube 4, do not add any water.
7. Keep the test tubes under these conditions for four days.
8. Record your observations every day and add water as needed to each tube, being sure to add only ice water to test tube 3.

**Results and Conclusion**

Only test tube 1 will show proper germination. The other test tubes will show little or no growth because they do not have the conditions necessary for germination.

**Clean Up Procedure**

1. Collect all the used materials, cleaning and storing items that will be used later. No special waste disposal is required.

**Discussion Questions**

1. Why do you think was the reason for using boiled water in test tube 2?

2. What germination conditions are missing from test tubes 3 and 4?

3. Describe the changes that occur during germination of a bean seed.

**Notes**

When planting seeds we must make sure that they receive oxygen, water, and proper temperature for germination. Boiling removes the oxygen dissolved in water and the layer of oil in test tube 2 prevents oxygen from re-entering the water.

**Demonstration of Epigeal and Hypogeal Germination**

Seed germination is the development of seed into a seedling. There are two types of germination: epigeal and hypogeal. Different seeds germinate differently depending on their classification group. Monocotyledons leave their cotyledons underground; this is called hypogeal germination. In dicotyledons the cotyledon emerges above the soil; this is called epigeal germination.

**Learning Objectives**

- To demonstrate epigeal and hypogeal germination.
Materials
Bean seeds, maize seeds, pots for sowing*, soil, and water

Preparation Procedure
1. Prepare 2 pots with soil for sowing seeds.
2. Collect maize and beans seeds.
3. Direct students to sow a few maize and bean seeds in two separate pots.

Activity Procedure
1. Observe the seedlings as they emerge from the soil.
2. Draw and label diagrams of maize and bean seedlings and classify as epigeal or hypogeal.

![Diagram of seedling with labels](image-url)

Figure 6.13: Hypogeal germination

Results and Conclusion
In epigeal germination cotyledons are carried above the soil, as in the germination of bean seeds (dicotyledonous seeds). In hypogeal germination cotyledons remains underground, as in the germination of maize seeds (monocotyledonous seed).
Discussion Questions

1. Define hypogeal and epigeal germination.

2. Distinguish between the germination of maize and bean seeds.

3. Draw and label maize seedling and bean seedling, identify the roots, shoots, and cotyledons.