BIOLOGY EXPERIMENTS USER GUIDE

ADVANCED SECONDARY LEVEL

Senior 4

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FOREWORD

Dear teacher,

Rwanda Basic Education Board (REB) is honoured to present the user guide for Biology experiments and practical activities for advanced Level (S4). This booklet will serve as a guide to competence-based teaching and learning to ensure consistency and coherence in the learning of Biology.

In this booklet, special attention was paid to practical activities that facilitate the learning process in which students can manipulate concrete materials, develop ideas, and make new discoveries during activities carried out individually or in pairs/ small groups.

In competence-based curriculum, practical activities open students' minds and provide them with the opportunities to interact with the world, use available tools, collect data, and effectively model real life problems.

For efficient use of this user guidebook, your role as a teacher is to:

- Plan your lessons and prepare appropriate teaching materials. \
- Engage students through active learning methods.
- Organize groups for students considering the importance of social constructivism.
- Provide supervised opportunities for students to develop different competences by giving tasks which enhance critical thinking, problem solving, research, creativity and innovation, communication, and cooperation.
- Support and facilitate the learning process by valuing students' contributions in the practical activities.
- Guide students towards the conclusion on the results of the experiments.
- Encourage individual, peer, and group evaluation of the work done and use appropriate competence-based assessment approaches and methods.

To facilitate you in your teaching activities, the content of this guide is self-explanatory so that you can easily use it. It is divided in 3 parts:

The part I explains the structure of this guide and gives you the general introduction on the role of practical activities and lab experiments in the implementation of CBC.

The part II gives the list of materials (apparatuses and chemicals)

The part III explains selected practical activities and how you can facilitate them in lessons.

Even though this guide contains practical activities, they are not enough, as expert and experienced teacher, you can guide students to carry out more practical activities using improvised teaching resources.

I wish to sincerely extend my appreciation to the people who contributed towards the development of this guide, The African Institute for Mathematics Sciences, Teacher Training Program (AIMS-TTP) in partneship with Mastercard Foundation who provided technical and financial support and REB staff particularly those from the Mathematics and Science Subjects Unit in the Curriculum Teaching and Learning Resources Department.

Special appreciation goes also to teachers and independent experts in education who supported the exercise throughout the progress. Any comment or contribution would be welcome for the improvement of this booklet for next versions.

Dr. MBARUSHIMANA Nelson
Director General, REB

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MURUNGI Joan
Head of CTLR Department

LIST OF ACRONYMS

REB: Rwanda Basic Education Board

CBC: Competence-based curriculum

ICT: Information Communication Technology

Lab: Laboratory

STEM: Science Technology Engineering and Mathematics

KBC: Knowledge Based Curriculum

SET: Science and Elementary Technology

IEE: Inspire, Educate and Empower Rwanda

AIMS: African Institute for Mathematical and Sciences

UR-CE: University of Rwanda - College of Education

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PART 1: GENERAL INTRODUCTION

1. Structure of the user guide

The Biology Experiments User Guide is divided in 3 parts:

The part I explains the structure of this book and gives you the general introduction on the role of practical activities and lab experiments in the implementation of CBC.

The part II gives the list of materials in schools.

The part III details the practical activities and how you can facilitate them in lessons.

2. Laboratory experiments in the Competence Based Curriculum

A competence-based curriculum (CBC) focuses on what learners can do and apply in different situations by developing skills, attitudes, and values in addition to knowledge and understanding. This learning process is learner-focused, where a learner is engaged in active and participatory learning activities, and learners finally build new knowledge from prior knowledge. Since 2015, the Rwanda Education system has changed from KBC to CBC for preparing students that meet the national and international job market requirements and job creation. Therefore, implementing the CBC education system necessitates qualitative laboratory practical works for mathematics and science as more highlighted aspects.

In addressing this necessity, laboratory experiments play a major role. A learner is motivated to learn sciences by getting involved in handling various concrete manipulative in various activities. In addition to activities, games in sciences also help the child's involvement in learning by strategizing and reasoning.

For learning biology concepts through the above-mentioned approach, a learner-centred science kits have been developed for the learners of lower and advanced Secondary schools. The kits include various kit items along with a manual for performing activities.

The kit broadly covers the activities in the areas of biology, chemistry and physics.

The kit has the following advantages:

- Availability of necessary and common materials at one place
- Multipurpose use of items

- Economy of time in doing the activities
- Portability from one place to another
- Provision for teacher's innovation
- Low-cost material and use of indigenous resources.

Apart from the kit, the user guide for laboratory and practical activities to be used by teachers was developed. This biology lab experiment user guide is designed to help biology teachers to perform high-quality lab experiments for biology subject. This user guide structure induces learner's interest, achievement, and motivation through the qualitative science lab experiments offered by their teachers and will finally lead to the targeted goals of the CBC education system, particularly in the field of Biology.

In CBC, learners hand on the materials and reveal the theory behind the experiment done. Here, experiments are done inductively, where experiments serve as an insight towards revealing the theory. Thus, the experiment starts, and theory is produced from the results of the experiment.

3. Type of lab experiments

The goal of the practical work defines the type of practical work and how it is organized. Therefore, before doing practical work, it is important to have a clear idea of the objective.

The three types of practical work that correspond with its three main goals are:

1. Equipment-based practical work: the goal is for students to learn to handle scientific equipment like using a microscope, doing titrations, making an electric circuit, etc.
2. Concept-based practical work: learning new concepts.
3. Inquiry-based practical work: learning process skills. Examples of process skills are defining the problem and good research question (s), installing an experimental setup, observing, measuring, processing data in tables and graphs, identifying conclusions, defining limitations of the experiment etc.

Note

- To learn the new concept by practical work, the lesson should start with the practical work, and the theory can be explained by the teacher afterward (explore – explain).

Starting by teaching the theory and then doing the practical work to prove what they have learned is demotivating and offers little added value for student learning.

- Try to avoid complex arrangements or procedures. Use simple equipment or handling skills to make it not too complicated and keep the focus on learning of the new concept.
- If this is not possible and is necessary to use new equipment or handling skills, then first exercise these skills before starting the concept-based practical work experiments.
- The experiments should be useful for all learners and not only for aspiring scientists. Try to link the practical work as much as possible with their daily life and preconceptions.

4. Organization, analysis, and interpretation of data

Once collected, data must be ordered in a form that can reveal patterns and relationships and allows results to be communicated to others. We list goals about analysing and interpreting data. By the end of secondary education, students should be able to:

- Analyze data systematically, either look for relevant patterns or test whether data are consistent with the initial hypothesis.
- Recognize when data conflict with expectations and consider what revisions in the initial model are needed.
- Use spreadsheets, databases, tables, charts, graphs, statistics, mathematics, and ICT to compare, analyze, summarize, and display data and explore relationships between variables, especially those representing input and output.
- Evaluate the strength of a conclusion that can be inferred from any data set, using appropriate grade-level mathematical and statistical techniques.
- Recognize patterns in data that suggest relationships worth investigating further. Distinguish between causal and correlational relationships.
- Collect data from physical models and analyze the performance of a design under a range of conditions.

5. Organising lab experiments

a) Methods of organizing a practical work

There are 3 methods of organizing practical work:

- **Each group does the same experiments at the same time**

All learners can follow the logical sequence of the experiments, but this implies that a lot of material is needed. The best group size is 3, as all learners will be involved. With bigger groups, you can ask to do the experiment twice, where learners change roles.

– **Experiments are divided among groups with group rotation**

Each group does the assigned experiment and moves to the next experiment upon a signal by the teacher. At the end of the lesson, each group has done every experiment. This method saves material but is not perfect when experiments are ordered in a logical way. In some cases, the conclusion of an experiment provides the research question for the next experiment. In that case, this method is not very suitable.

The organization is also more complex. Before starting the lesson, the materials for each experiment should be placed in the different places where the groups will work. Also, the required time for each experiment should be about the same. Use a timer to show learners the time left for each experiment. Provide an extra exercise for fast groups.

– **All experiments are divided among groups without group rotation**

Each group does only one or two experiments. The other experiments are done by other groups. Afterward, the results are brought together and discussed with the whole class. This saves time and materials, but it means that each learner does only one experiment and 'listens' to the other experiments' description. The method is suitable for experiments that are optional or like each other. It is not a good method for experiments that all learners need to master.

b) Preparation of a practical work

When preparing a practical work, do the following:

Have a look at the available material at school and make a list of what you can use and what you need to improvise.

- Determine the required quantities by determining the method (see above).
- Collect all materials for the experiments in one place. If learners' group is small, they can come to get the materials on that spot, but with more than 15 learners, this will create disorder. In that case, prepare for each group a set of materials and place it on their desk.
- Test all experiments and measure the required time for each experiment.
- Prepare a nice but educational extra task for learners who are ready before the end of the lesson.
- Write on the blackboard how groups of learners are formed.

c) Preparation of a lesson for practical work

In the lesson plan of a lesson with practical work, there should be the following phases:

1. **The introduction of the practical work** or the 'excite' phase consists of formulation of a key question, discrepant event, or a small conversation to motivate learners and make connections with daily life and learners' prior knowledge.
2. **The discussion of safety rules for the practical work**
   - Only work at the assigned place; do not walk around in the class if this is not asked.
   - Long hairs should be tied together, and safety eyeglasses should be worn for chemical experiments.
   - Only the material needed for the experiment should be on the table.
   - The practical work instructions: how groups are formed, where they get the materials, special treatment of materials (if relevant), what they must write down...
   - When the practical work materials aren't yet at the correct location, then distribute them now. Once learners have the materials, it is more difficult to get their attention.
3. **How to conduct a practical work**
   - Learners do the experiments, while the teacher coaches by asking questions (Explore phase).
   - The practical work should preferably be processed immediately with an explain phase. If not, this should happen in the next lesson.
4. **How to conclude the lesson of a practical work**
   - Learners refer to instructions and conduct the experiment,
5. **Learners record and interpret recorded data**
   - Cleaning the workspace after the practical work (by the learners as much as possible).
6. **Role and responsibilities of teacher and learners in lab experiment**

Roles and responsibilities of teacher during a lab experiment

Before conducting an experiment, the teacher will do the following:

- Decide how to incorporate experiments into class content best,
- Prepare in advance materials needed in the experiment,
- Prepare protocol for the experiment,
- Perform in advance the experiment to ensure that everything works as expected,
- Designate an appropriate amount of time for the experiment - some experiments might be adapted to take more than one class period, while others may be adapted to take only a few minutes.

- Match the experiment to the class level, course atmosphere, and your students' personalities and learning styles.
- Verify lab equipment before lab practices.
- Provide the working sheet and give instructions to learners during lab session.

During practical work, the teacher's role is to coach instead of helping with advice or questions. It is better to answer a learner's question with another question than to immediately give the answer or advice. The additional question should help learners to find the answer themselves.

- Prepare some pre-lab questions for each practical work, no matter what the type is.
- Try and start the practical work: start with a discrepant event or questions that help define the problem or questions that link the practical work with students' daily life or their initial conceptions about the topic.
- Use coaching questions during the practical work: 'Why do you do this?', 'What is a control tube?', ''What is the purpose of the experiment?', 'How do you call this product?', 'What are your results?' etc.
- Use some questions to end the practical work: 'What was the meaning of the experiment?', 'What did we learn?', 'What do we know now that we didn't know at the start?', 'What surprised you?'etc.
- Announce the end of the practical work 10 minutes before giving learners enough time to finish their work and clean their space.

Role of a lab technician during a laboratory-based lesson

In schools having laboratory technicians, they assist the science teachers in the following tasks:

- Maintaining, calibrating, cleaning, and testing the sterility of the equipment,
- Collecting, preparing and/or testing samples,
- Demonstrating procedures.

Learners' responsibilities in the lab work

During the lab experiment, both learners have different activities to do; the table barrow summarizes them. General learner's activities are:

- Experiment and obtain data themselves,
- Record data using the equipment provided by the teacher,
- Analyze the data often this involves graphing it to produce the related graph,

– Interpret the obtained results and deduct the theory behind the concept under the experimentation,
– Discuss the error in the experiment and suggest improvements,
– Cleaning and arranging material after a lab experiment.

7. Safety rules and precautions during lab experiments

Regardless of the type of lab you are in, there are general rules enforced as safety precautions. Each lab member must learn and adhere to the rules and guidelines set, to minimize the risks of harm that may happen to them within the working environment. These encompass dress' code, use of personal protection equipment, and general behaviour in the lab. It is important to know that some laboratories contain certain inherent dangers and hazards.

Therefore, when working in a laboratory, you must learn how to work safely with these hazards to prevent injury to yourself and other lab mates around you. You must make a constant effort to think about the potential hazards associated with what you are doing and think about how to work safely to prevent or minimize these hazards as much as possible.

Before doing any scientific experiment, you should make sure that you know where the fire extinguishers are in your laboratory, and there should also be a bucket of sand to extinguish fires. You must ensure that you are appropriately dressed whenever you are near chemicals or performing experiments. Please make sure you are familiar with the safety precautions, hazard warnings, and procedures of the experiment you perform on a given day before you start any work. Experiments should not be performed without an instructor in attendance and must not be left unattended while in progress.

A. Hygiene plan

A laboratory is a shared workspace, and everyone has the responsibility to ensure that it is organized, clean, well-maintained, and free of contamination that might interfere with the lab members' work or safety.

For waste disposal, all chemicals and used materials must be discarded in designated containers. Keep the container closed when not in use. When in doubt, check with your instructor.

B. Hazard warning symbols

To maintain a safe workplace and avoid accidents, lab safety symbols and signs need to be posted throughout the workplace.

Chemicals pose health and safety hazards to personnel due to innate chemical, physical, and toxicological properties. Chemicals can be grouped into several

different hazard classes. The hazard class will determine how similar materials should be stored and handled and what special equipment and procedures are needed to use them safely.

Each of these hazards has a different set of safety precautions associated with them.

The annex 1 shows hazard symbols found in laboratories and the corresponding explanations.

C. Safety rules

Safety is the number one priority in any laboratory. All students are required to know and comply with good laboratory practices and safety norms; otherwise, they will be asked to leave the laboratory. Make sure you understand all the safety precautions before starting your experiments, and you are requested to help your learners to understand too.

The following are some general guidelines that should always be followed:

Lab coat

While working in the lab, everyone must always wear a lab coat (Figure 1) to prevent incidental and unexpected exposures to the skin and clothing. The primary purpose of a lab coat is to protect against splashes and spills. The lab coat must be wrist-fitted and must always keep buttoned. A lab coat should be non-flammable and should be easily removed.

Safety glasses

For eyes protection, goggles must always be worn over by all persons in the laboratory while students are working with chemicals. Safety glasses, with or without side-shields, are not acceptable. The eyes protection safety indicates the possibility of chemical, environmental, radiological, or mechanical irritants and hazards in the laboratory.

Breathing Masks

Respirators are designed to prevent contamination from volatile compounds that may enter in your body through the respiratory system. “Half mask” respirators (Figure3) cover just the nose and mouth; “full face” respirators cover the entire face, and “hood” or “helmet” style respirators cover the entire head. The breathing mask safety sign lets you know that you are working in an area with potentially contaminated air.

Eye Wash Station

Eyes wash stations consist of a mirror and a set of bottles containing saline solution that can be used to wash the injured eye with water. The eye wash station is intended to flood the eye with a continuous stream of water.

Eyes wash stations provide a continuous, low-pressure stream of aerated water in laboratories where chemical or biological agents are used or stored and in facilities where non-human primates are handled. The eyewash stations should easily be accessed from any part of the laboratory, and if possible, located near the safety shower so that, if necessary, the eyes can be washed while the body is showered.

Footwear

Shoes that cover entirely the toes, heel, and top of the foot provide the best general protection (Figure 1.5). Closed shoes must always be worn while in the laboratory, regardless of the experiment or curricular activity. Shoes must fully cover your feet up to the ankles, and no skin should be shown. Socks do not constitute a cover replacement for shoes. Sandals, backless and open shoes are unacceptable.

Gloves

When handling chemical, physical, or biological hazards that can enter the body through the skin, it is important to wear the proper protective gloves. Butyl, neoprene and nitrile gloves are resistant to most chemicals, e.g., alcohols, aldehydes, ketones, most inorganic acids, and caustics.

Hair dressing

If hair is long, it must be tied back. It is good to report all accidents including minor incidents to your instructor immediately.

Eat and drink

Never drink, eat, taste, or smell anything in the laboratory unless you are allowed by the lab instructor.

Hot objects

Never hold very hot objects with your bare hands. Always hold them with a test tube holder, tongs, or a piece of cloth or paper.

8. Guidance on the Management of lab materials (Storage Management, Repairing and Disposal of Lab equipment and chemicals)

Keeping and cleaning up

Working spaces must always be kept neat and cleaned up before leaving. Equipment must be returned to its proper place. Keep backpacks or bags off the floor as they represent a tripping hazard. Open flames of any kind are prohibited in the laboratory unless specific permission is granted to use them during an experiment.

Management of lab materials

A science laboratory is a place where basic experimental skills are learned only by performing a set of prescribed experiments. Safety procedures usually involve chemical hygiene plans and waste disposal procedures. When providing chemicals, you must read the label carefully before starting the experiment. To avoid contamination and possibly violent reaction, do never return unwanted chemicals to their container. In the laboratory, chemicals should be stored in their original containers, and cabinets should be suitably ventilated. It is important to notify students that chemicals cannot be stored in containers on the floor. Sharp and pointed tools should be stored properly.

Students should always behave maturely and responsibly in the laboratory or wherever chemicals are stored or handled.

Hot equipment and glassware handling

Hazard symbols should be used as a guide for the handling of chemical reagents. Chemicals should be labeled as explosives, flammable, oxidizers, toxic and infectious substances, radioactive materials, corrosives etc. All glassware should be inspected before use, and any broken, cracked, or chipped glassware should be disposed of in an appropriate container. All hot equipment should be allowed to cool before storing it.

All glassware must be handled carefully and stored in its appropriate place after use. All chemical glass containers should be transported in rubber or polyethylene bottle carriers when leaving one lab area to enter another. When working in a lab, do never leave a hot plate unattended while it is turned on. It is recommended to handle hot equipment with safety gloves and other appropriate aids but never with bare hands. You must ensure that hands, hair, and clothing are kept away from the flame or heating area and turn heating devices off when they are not in use in the laboratories.

Waste disposal considerations

Waste disposal is a normal part of any science laboratory. As teachers or students perform demonstrations or laboratory experiments, chemical waste is generated.

These wastes should be collected in appropriate containers and disposed of according to local, state, and federal regulations. All schools should have a person with the responsibility of being familiar with this waste disposal. In order to minimize the amount of waste generated and handle it safely, there are several steps to consider.

Sinks with water taps for washing purposes and liquid waste disposal are usually provided on the working table. It is essential to clean the sink regularly. Notice that you should never put broken glass or ceramics in a regular waste container. Use a dustpan, a brush, and heavy gloves to carefully pick-up broken pieces, and dispose of them in a container specifically provided for this purpose. Hazardous chemical waste, including solvents, acids, and reagents, should never be disposed of down sewer drains. All chemical waste must be identified properly before it can be disposed of. Bottles containing chemical waste must be labeled appropriately. Labeling should include the words "hazardous waste." Chemical waste should be disposed of in glass or polyethylene bottles. Plastic coated glass bottles are best for this purpose. Aluminum cans that are easily corroded should not be used for waste disposal and storage.

Equipment Maintenance

Maintenance consists of preventative care and corrective repair. Both approaches should be used to keep equipment in working order. Records of all maintenance, service, repairs, and histories of any damage, malfunction, or equipment modification must be maintained in the equipment logs. The record must describe hardware and software changes and/or updates and show the dates when these occurred. Each laboratory must maintain a chemical inventory that should be updated at least once a year.

9. Student Experiment Work Sheet

There should be a sheet to guide students about how they will conduct the experiment, materials to be used, procedures to be followed and the way of recording data. The following is a structure of the student experiment worksheet. It can be prepared by teacher or be availed from the other level.

a. Date
b. Name of student/group
c. The title of experiment
d. Type of experiment (concept, equipment and inquiry based)
e. Objective(s) of the experiment
f. Key question(s)
g. Materials (equipment/instrument, resources, etc...)
h. Procedures & Steps of experiment

i. Schematic reference if required.
j. Data recording and presentation

Number of tests	Types/Item/ Variables	Comments/Observations
1		
2		
3		
Etc		

a) Reflective questions and answers

Question1

Question 2

Question 3

b) Answer for the key question

10. Report Template for Learner

After conducting a laboratory experiment, students should write a report about their findings and the conclusion they took.

The report to be made depends on the level of students. The report done by primary school learners is not the same us the one to be made by secondary school learners.

The following is a structure of the report to be made by a group of secondary school learners.

1. Introduction (details related to the experiment: Students identification, date, year, topic area, unit title and lesson).
2. The title of experiment.
3. Type of experiment (concept, equipment and inquiry based)
4. Objective(s) of the experiment.
5. Key question(s)
6. Materials (equipment/instrument, resources, etc…)
7. Procedures & Steps of experiment
8. Schematic reference if required.
9. Data recording
10. Data analysis and presentation (Plots, tables, pictures, graphs)

11. Interpretation/discussion of the results, student alternative ideas form observation.

12. Theory or Main ideas concept, formulas, and application). Conclusion (answer reflective questions and the key question).

As a conclusion, there are safety rules and precautions to consider before, during and at the end of a lab experiment. We hope teachers are inspired to conduct lab experiments in a conducive Competence Based Curriculum way.

PART II: LIST OF MATERIALS FOR BIOLOGY LAB

II.1 List of main kit items and lab materials distributed in schools

#	Item	Picture	Description of uses
1	Beaker		Used to hold and heat liquids. Multipurpose and essential in the laboratory.
2	Brushes		Used to easily clean the inside of a test tubes and other glassware.
3	Buchner funnel		Used with vacuum flask for performing vacuum filtration.
4	Bunsen burner		First, make sure your workspace is free of potential fire hazards. Connect the gas line and ignite the burner. Adjust the metal collar and needle gas valve at the burner's base. When you're finished, close the air and gas ports, shut off the gas main line, and put the burner away once it's cool. Bunsen burner is used for heating and exposing items to flame.

5	Burette		Before delivering any solution, record the initial burette reading in your notebook. Open the stopcock by twisting it 90 degrees into the vertical position and allow the solution to drain. As you near the desired volume, slow the flow by turning the stopcock back toward the closed position. You should be able to control the burette to deliver one drop at a time. When the desired volume has been delivered, close the stopcock. Wait a couple of seconds, then record the final burette reading.
6	Burette clamp		Used to hold burette on a ring stand.
7	Clay triangle		Used to hold crucibles when they are being heated. They usually sit on a ring stand.
8	Crucible with lid		Used to heat small quantities to very high temperatures.
9	Crucible tong		Used to hold crucibles and evaporating dishes when they are hot.

10	Disposable pipette		Used for moving small amounts of liquid from place to place. They are usually made of plastic and are disposable.
11	Electronic balance		Used for weighing substances or objects, usually in grams. Place the electronic balance on a flat, stable surface indoors. Press the «ON» button and wait for the balance to show zeroes on the digital screen. Place the empty container you will use for the substance to be measured on the balance platform. Press the «Tare» or «Zero» button to cancel automatically the weight of the container. The digital display will show zero again. Carefully add the substance to the container. Ideally this is done with the container still on the platform, but it may be removed if necessary. Avoid placing the container on surfaces that may have substances which will add mass to the container such as powders or grease. Place the container with the substance back on the balance platform if necessary and record the mass as indicated by the digital display.

12	**Erlenmeyer flasks/Conical flask**		Used to heat, mix, and store liquids. The advantage to the Erlenmeyer Flask is that the bottom is wider than the top so it will heat quicker because of the greater surface area exposed to the heat.
13	**Evaporating dish**		Press the "Tare" or "Zero" button to cancel automatically the weight of the container. The digital display will show zero again.
14	**Forceps**		Carefully add the substance to the container. Ideally this is done with the container still on the platform, but it may be removed if necessary. Avoid placing the container on surfaces that may have substances which will add mass to the container such as powders or grease.
15	**Glass funnel & Polypropylene funnel**		Used to pour liquids into any container so they will not be lost or spilled. They are also used with folded filter paper for filtration.
16	**Glass stir rod**		Used to stir liquids. They are usually made of glass.
17	**Graduated cylinder/ measuring cylinder**		Used to measure the volumes of liquids.

18	**Micropipette**		Used for accurately measuring and delivering very small volumes of liquid-usually 1 mL or less. Steps to follow when using a micropipette. Select the volume. Set the tip. Press and hold the plunger at the first stop. Place the tip in the liquid. Slowly release the plunger. Pause for a second and then move the tip. Insert the tip into the delivery vessel. Press the plunger to the second stop.
19	**Mortar and pestle**		Used to crush solids into powders for experiments, usually to better dissolve the solids.
20	**Pipette filler**		How does a pipette filler work? Siphon liquid into the pipette to the desired level by squeezing valve "S" on the bottom of the pipette filler. This uses the vacuum created in the bulb to draw liquid into the pipette. Be careful not to draw liquid into the pipette filler. ... This allows you to release liquid at the desired rate and to the desired level.
21	**Pipette with pump**		Used for accurately measuring and delivering small volumes of liquid-usually 0.1-10 mL.

22	**Ring clamp**		Attached to a retort stand and with wire gauze used to hold beakers or flasks while they are heated by a gas burner.
23	Retort stand and accessories		Used to hold items being heated. Clamps or rings can be used so that items may be placed above the lab table for heating by Bunsen burners or other items. Used also to hold burette
24	**Rubber stopper**		Stoppers come in many different sizes. The sizes are from 0 to 8. Stoppers can have holes for thermometers and for other probes that may be used.
25	**Spatula**		Used for moving small amounts of solid from place to place.
26	**Test tube**		Used for storing, mixing, and heating small amounts of chemicals.
27	**Test tube holder**		Used to hold test tubes while heating.
28	**Test tube rack**		Used to hold test tubes while reactions happen in them or while they are not needed.
29	**Thermometer**		Used to take temperature of solids, liquids, and gases.
30	**Utility clamp**		Used to attach test tubes and other glassware to retort stand.

31	**Vacuum filter flask**		Used with vacuum line and Buchner funnel for vacuum filtration.
32	**Volumetric flask**		Used to prepare solutions with accurate concentration.
33	**Wash bottle**		Used to wash; rinse containers
34	**Watch glass**		Used to hold solids when being weighed or transported. They should never be heated. Can also be used to cover beakers or other containers.
35	**Wire gauze**		Used with a ring clamp to support glassware over a Bunsen burner.
36	**Borosilicate glass tube**		Used to connect to other items of glassware or equipment to deliver chemicals, solvents, liquids, gases and other products.
37	**Rubber tube**		Rubber tubing is often connected to a condenser, which is a laboratory tool used in the process of distillation. The rubber tubing helps cool water to flow in and out of the condenser and helps the heated water vapor in the condenser return to its liquid state.
38	**Borosilicate delivery tube**		The delivery tube is particularly useful for bubbling a gas from a gas cylinder or stoppered vessel through a liquid.

39	Rough		The rough is used for collecting gases, such as hydrogen, oxygen and nitrogen. Troughs require a liquid such as water.
40	**Beehive shelf**		A beehive shelf is usually used to support a receiving jar or tube while a gas is being collected over water with a pneumatic trough.
41	**Syringe**		They are often used for measuring and transferring solvents and reagents where a high precision is not required.
42	**Gas jar and cover**		A container used for collecting gas from experiments.
43	**Clinostat**		A clinostat is a device which uses rotation to negate the effects of gravitational pull on plant growth and development.
44	**Cork borers**		used in a biology laboratory, is a metal tool for cutting a hole in a cork or rubber stopper to insert glass tubing. Cork borers usually come in a set of nested sizes along with a solid pin for pushing the removed cork (or rubber) out of the borer.

45	Cover glasses		The cover glass serves two purposes: It protects the microscope's objective lens from contacting the specimen, and (2) It creates an even thickness (in wet mounts) for viewing.
46	**Dark blue plastic modelling clay pack of 500g**		used for sculpting and building by children, students, etc.
47	Visking (dialysis) tubing or suitable, size 2,normal diameter 14mm roll of 30 meters		Dialysis tubing, also known as Visking tubing, is an artificial semi-permeable membrane tubing used in separation techniques based on differential diffusion
48	**Dissecting kits**		used for dissection, includes scissors, pins, scalpel handle; dressing forceps, 16 cm; mayo hager needle holder, 16 cm; teaser needle; angled teaser needle straight; tissue Forceps, 1:2, 16 cm. ets
49	**First aid Education response**		In laboratory first aid kit includes:Triangle bandages;bandages;pins for bandages; sterile dressings;plasters; antiseptic wipes;eye pad dressings and gloves

50	Microbiological inoculating loop handles for inoculating wire		The inoculation handle can be used for a variety of applications in microbiology: inoculation, serial dilution, sterile sampling, transfer and spreading of microbiological samples. The inoculating loop is sterilised by passing it at an angle through the flame of a gas burner until the entire length of the wire becomes orange from the heat. In this way all contaminants on the wire are incinerated. Never lay the loop down once it is sterilised, or it may again become contaminated.
51	**Microscope slides**		A microscope slide is a thin flat piece of glass, typically 75 by 26 mm (3 by 1 inches) and about 1 mm thick, used to hold objects for examination under a microscope. Typically, the object is mounted (secured) on the slide, and then both are inserted together in the microscope for viewing.

52	**Microscope**		A light microscope is a biology laboratory instrument or tool, that uses visible light to detect and magnify very small objects and enlarge them. They use lenses to focus light on the specimen, magnifying it thus producing an image. The specimen is normally placed close to the microscopic lens. Steps on how to use a light microscope: Step 1: Connect the light microscope to a power source. Step 2: Turn the revolving nosepiece so the lowest objective lens is in position. Step 3: Mount your specimen onto the stage. Step 4: Use the metal clips to keep your slide in place. Step 5: Look into the eyepiece and slowly rotate the coarse adjustment knob to bring your specimen to focus. Step 6: Adjust the condenser for the maximum amount of light. Step 7: Now slowly rotate the fine adjustment knob until you obtain a clearer image of your specimen.

			Step 8: Examine your specimen. Step 9: After you're done viewing with the lowest power objective, switch to the medium power objective and re-adjust the focus with the fine adjustment knob. Step 10: Proceed to the high-power objective once you have it focused.
53	**Stirring rod, glass,** one end round, other flat, length 200 mm		A glass stirring rod is used to stir or mix solutions. One of their main uses is to "scratch" the side of glassware (such as an Erlenmeyer Flask) to start the crystallization process in many experiments.
54	**Stopwatch**. 2 buttons with laps and 1/100 second functions. 12 hour setting, lcd count/down/up		It is commonly used in laboratories; it can measure a time interval up to 0.01 second. It starts to indicate the time lapsed as the start/stop button is pressed. As soon as the start/stop button is pressed again, it stops and indicates the time interval recorded by it between the start and stop of an event.
55	**Sweeping** net (muslin)insect nets, a light weight, robust insect net with 800mm long handle		Sweep nets are used to sweep through vegetation to collect random insects not easily seen

56	**Spotting tile**		A spotting tile is a piece of observational equipment used to observe the colour changes of small quantities of a reacting mixture.
57	**Water bath**		It is made from a container filled with heated water and used to incubate samples in water at a constant temperature over a long period of time
58	**Autoclave**		A machine used to carry out and scientific processes requiring elevated temperature and pressure in relation to ambient pressure and/or temperature
59	**Tripod stands triangular top,** length of side arm 150 mm, height 200 mm, cast iron		A tripod is a portable three-legged frame or stand, used as a platform for supporting the weight and maintaining the stability of some other object. Ideal for the science laboratory or classroom to elevate Beakers or Flasks. They're perfect for use with Bunsen burners to support the object to be heated. Work best in conjunction with wire gauze mats.

60	**Sets of permanent slides** (Transverse section (ts) of bronchioles, permanent slides with cover slip;Transverse section (ts)of veins, permanent slide with cover slip;Transverse section (ts)of artery, permanent slides with cover slip;Transverse section(ts) of kidney- (adrenal gland t.s. cortex and medulla) permanent slides with cover slip; Slides of the sense organs, permanent slides for different sense organs; Penicillium microscope slide; Prepared slide of urinary system with slide cover; Prepared slide on mitosis, permanent slides with cover slip; Prepared slides of white blood cells, permanent slides with cover slip;		

	Slides of neurons, sensory, motor and rely neurons; Ts leaf of dicotyledonous mesophyte (such as ligustrum or prunus or local equivalent), maize;Ts lungs to show alveoli permanent slides with cover slip;Ts ovule permanent slides with cover slip;Ts spinal cord, permanent slides with cover slip; Ts trachea permanent slides with cover slip; Nerve muscle junction, permanent slides covered with cover slip).		A microscope slide is a thin flat piece of glass, typically 75 by 26 mm (3 by 1 inches) and about 1 mm thick, used to hold objects for examination under a microscope. Typically, the object is permanently mounted (secured) on the slide, and then both are inserted together in the microscope for viewing. When using a microscope, slides that are permanent can be examined and stored for a long time, (Permanent slides must be properly made for successful long-term storage)

II.2 List of biology chemicals

No	Name of chemical and quantities
1	Set of bottles as follows: Amylase enzyme - 1 lb (445g), trypsin/edta solution(100ml), protease (pack size: 500g), 1 for each sample: (Each set should contain 3 bottles, one for each type)
2	L -ascorbic acid (vitamin c) powder,100g
3	Benedict's solution,500ml
4	Sodium bicarbonate, 500g
5	Biuret reagent, laboratory grade, 100 ml
6	Bromothymol blue,500ml
7	2,6-dichloroindophenol is a dye used as a reagent in the determination of vitamin c. 1bottle
8	Eosin/red ink , dye content, ~99%,
9	Dextrose, monohydrate, powder, laboratory grade, 500 g
10	Iodine solution 2% in potassium iodide(aqueous), 30ml
11	Calcium hydroxide 500 g
12	Lugol's iodine solution 5% (1 oz.) Twin pack (2 bottles)
13	Methylated spirit (for extraction of chlorophyll),50ml
14	Methylene blue solution, 0.1% aqueous, laboratory grade, 500 ml
15	Millons' reagent ,500ml
16	Nutrient broth, 125ml
17	Agar powder , 100g
18	Potassium oxide, 250g
19	Starch 2%w/v solution 6.58, 500ml
20	Sucrose, molecular formula: c12h22o11, molecular weight: 342.30 (500g)
21	Toluidine blue stains for preparing slides to show mitosis,100g
22	Active dry yeast powder, 100g - lab grade chemical reagent
23	2,4-dinitrophenylhydrazine (brady's reagent),500g
24	Copper (II) carbonate, 250 g
25	Fehling's no1 copper solution,250 ml

26	Fehling's solution no 2, 250 ml
27	Distilled water, 25 l in high density, plastic container
28	Methyl orange sensitive,250ml
29	Sodium hydroxide pellets,250g
30	Hydrochloric acid, commercial, 500ml
31	Glucose,250g, pure solid cristals

PART III. EXPERIMENTS FOR S4

UNIT: 1 INTRODUCTION TO BIODIVERSITY

ACTIVITY 1.1: Use of frame quadrants, line and belt transects to assess the districtbution and abundance of organisms in a given area

This activity can be done when teaching the concept or topic related to biodiversity, specifically how biodiversity is threatened by climate variation, climate change and human activities.

Rationale

Each environment is inhabited by different types of microorganisms, animals, fungi and plants. Their distribution and abundance is different. There is a need to assess the distribution and abundance of microorganisms, plants, fungi and animals through sampling across quadrats, line and belt transects and determine the number of each plant, fungi and animal type to plan for environmental conservation.

Objective

To calculate the distribution and abundance of plants and animals across a quadrat, line and belt transects in a given area

Materials

- Decameter
- Marker flags
- Field notebook
- Pencil

Experiment setup

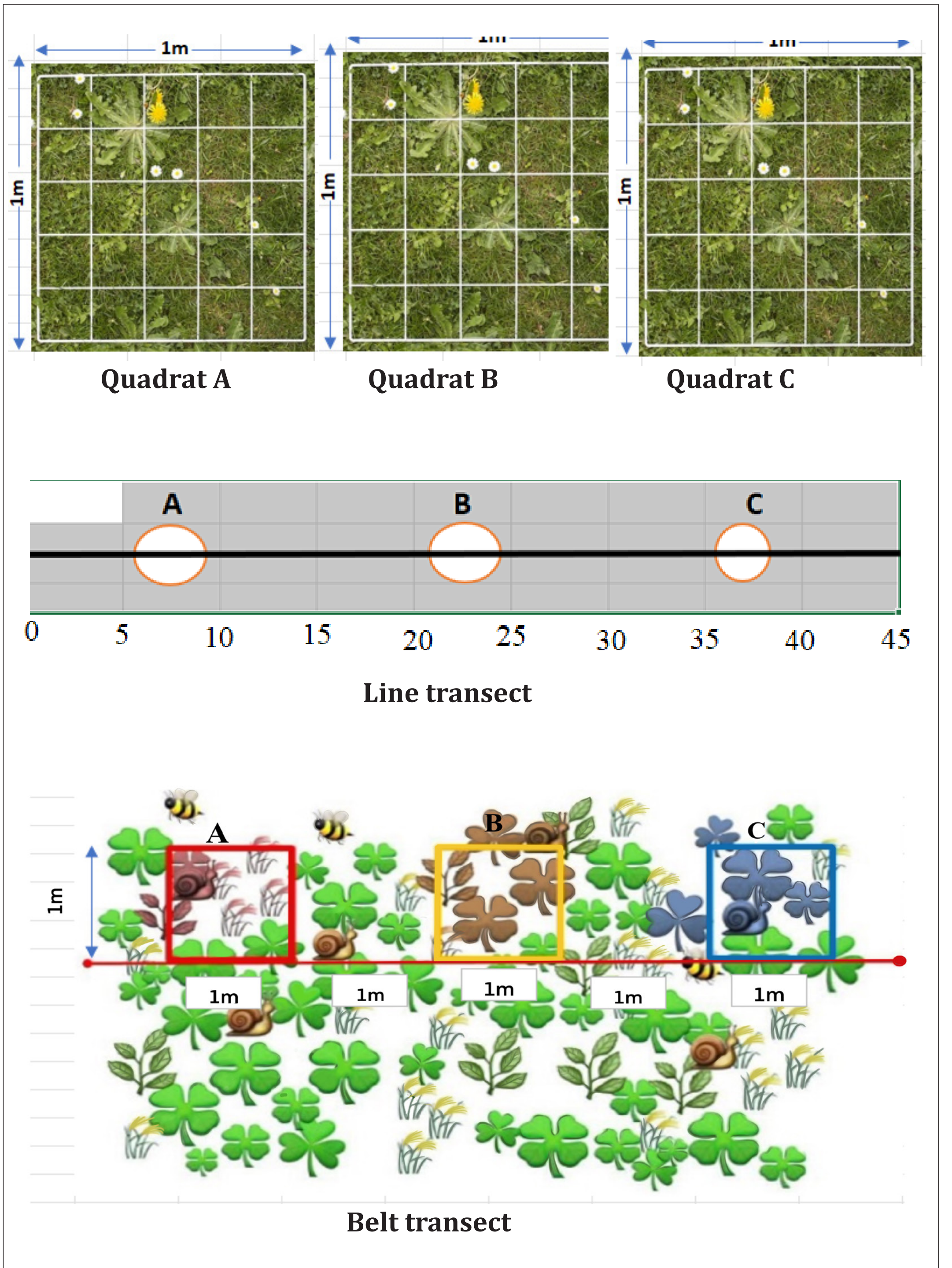


Fig.1.1: Calculation of population distribution and abundance in environment

Steps and procedure of the experiment

Step 1: Distribution and abundance of organisms across a quadrat

- In the garden, use a decametre and mark three quadrats (A, B, C) each having a one-meter square in size.
- Identify the types of plants in each quadrat and note down their names.
- Count the number of identified plants in each quadrat and note down the names and numbers for each plant.
- In each quadrat note down the names and numbers of invertebrates observed.

Step 2: Distribution and abundance across a transect

- By using a decameter, mark a transect of 45 meters in the field around the school.
- By leaving 5 meters at the edge, mark three circle sampling points (A,B,C) each of one-meter diameter separated by eight meters
- Identify the type of plant inside each circle and note down their names.
- Count the number of identified plants in each circle and note the numbers.
- In each circle note down the names and numbers of invertebrates observed.

Step 3: Distribution and abundance across a belt transect

- By using a decameter, mark a transect of 8 meters in the field around the school
- By leaving 1 meter at the edge, mark three quadrats each of one-meter square separated by one meter distance
- Identify the type of plants in each quadrat and note down their names
- Count the number of identified plants in each quadrat and note the numbers
- In each quadrat note down the names and numbers of invertebrates observed

Reflection question

Are all organisms equally distributed in quadrats, lines, and belts?

Data recording

Names of vegetation, trees, and invertebrates	Numbers in quadrats			Numbers in transect			Numbers in belts		
	A	**B**	**C**	**A**	**B**	**C**	**A**	**B**	**C**
Grevillea (*Greviallea robusta*)	1	0	1	2	1	1	0	0	0
Eucalyptus (*Eucalyptus maidenii*)	0	1	0	0	0	0	1	1	1
Blackjack (*Bidens pilosa*)	12	8	6	11	13	14	8	7	8
Honeybee (*Apis mellifera*)	3	2	5	3	4	6	2	2	1
Roman snail (*Helix pomatia*)	1	0	0	0	2	0	0	0	0
Driver ant (*Dorylus sp*)	20	15	17	8	6	7	11	15	9
Total abundance by each quadrat, line and belt transect	37	26	29	24	26	28	22	25	19
Total abundance	*92*			*78*			*66*		

Precaution: During sampling, you may find plants and invertebrates different from the ones in the above table. Also, the numbers might be different from the ones provided in the table above. However, data recording may follow the same process.

Interpretation of results and conclusion

Plants and invertebrates are not evenly distributed in the environment. For example, in the above provided table, Grevillea trees are highly distributed in line transect than in the quadrat and line belt. The driver ant is distributed in both quadrats, line and belt transects. In this case, considering the abundance (**N**), recorded data indicates higher abundance in quadrats (**N=92**) than in line (**N=78**) and belt transects (**66**). We conclude that the distribution and abundance vary from quadrats, line and belt transects which indicates that they also vary depending on the environment.

Guidance on the evaluation

Assess learners' understanding by providing photos on the distribution of different tree and animal species and data from the sampling. Ask them to identify the distribution and abundance of tree and animal species. The assessment will be done by asking questions such as:

1. Calculate the abundance for the plants and invertebrates in quadrat and line transects.
2. Which type of plants is highly distributed in the quadrats and line transect?
3. Which type of invertebrates is highly distributed in the quadrats and line transect?

UNIT: 2

INTRODUCTION TO CLASSIFICATION

Experiment 2.1: Classify living organisms based on external features

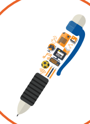
This experiment can be done when teaching the concept or topic related to classification of living organisms.

Rationale

Living organisms are diverse in nature and can be differentiated based on their external features. This experiment has a purpose of observing the external features of living organisms and coming up with distinctive features that allow their classification in specific groups.

Objective

To classify living organisms based on their external features



Materials

- Sweep nets
- Gloves
- Glass jars/ bottles
- Binocular
- Microscope
- Collected specimens
- Hand lenses
- Permanent slides of microorganisms

Experiment setup

Fig.2.1: Observing external features of living organisms

Steps and procedure of the experiment

- Collect a variety of specimens of organisms like grasshoppers, bean plant, maize plant, cockroach, bees, butterflies, millipede, blackjack, frog, gecko, moss, fern, and mushroom
- Avail the permanent slides of Amoeba, Paramecium, and Lacto bacillus
- Carefully observe every specimen of collected organism
- Use microscope and observe external features for specimens of permanent slides
- Identify external features of each specimen
- Put the specimens into main groups according to similarities and differences

Precautions

- Some organisms are poisonous, some have thorns and others can sting. The most care must be taken while handling them with learners.
- Collection of specimens should be done a day or few days before the experiment
- Use suitable methods for specimen collection and keep them for the future use

Reflection question

Do all living things have the same features?

Data recording

	Specimen groups				
	Group A	**Group B**	**Group C**	**Group D**	**Group E**
Features	Locomotory organs, distinct eyes, and mouth	They are green, some have distinct parts: roots, stem, and leaves	Not green, no roots, leaves, and stems.	They are microscopic, unicellular with defined nucleus	They are microscopic, unicellular without defined nucleus
Examples of organisms	Grasshopper Cockroach, Bees, Butterflies, Millipede, Frog, Gecko	Bean plant, Maize plant, Blackjack, Moss, Fern	Mushroom,	Amoeba, Paramecium, Plasmodium	Green algae, Lactobacillus, and other bacteria

Interpretation of results and conclusion

Living things have different features that can be observed using necked eyes or magnifying instruments. These characteristics are used to classify them into different groups. Fish, hen, and ant are grouped in kingdom **Animalia**. They belong to the same group as bees, butterflies, millipedes, frogs, and geckos. The strawberry belongs to the kingdom of **Plantae** together with bean and maize plants, blackjack, moss, and fern. The mushroom belongs to the kingdom of **Fungi**. Other living organisms are small and can only be observed using magnifying instruments such as microscope and binocular, and magnifying lenses. These include *Amoeba, Paramecium* and *Plasmodium* that belong to the kingdom **Protoctista**. Microscopic organisms also include the *Lactobacillus, Escherichia coli, streptococcus, Nostoc, Anabaena* and *Cynobacteria* that belongs to **Monera Kingdon**, single-celled organisms that lack a nucleus.

Guidance on the evaluation

Asses the understanding of the learnt concept by asking questions such as:

1. Link the groups A, B, C, D, E with the specific kingdom
2. State at least two examples of organisms from each kingdom
3. State one unique feature for organisms in each of the groups

Teachers can also provide a list of organisms to students by using printed papers or a projector and computer, ask them to give one or more characteristics, and put those having the same characteristics in the same group.

Experiment 2.2: Construct the dichotomous keys

This experiment can be done when teaching the concept or topic related to the classification of living organisms.

Rationale

The purpose of constructing dichotomous keys is the classification of living organisms in different groups based on the facts that living things vary and their differences and similarities can be used to place them into the same or different groups. This is

Objective

To construct a dichotomous key for the classification of collected organisms

Materials

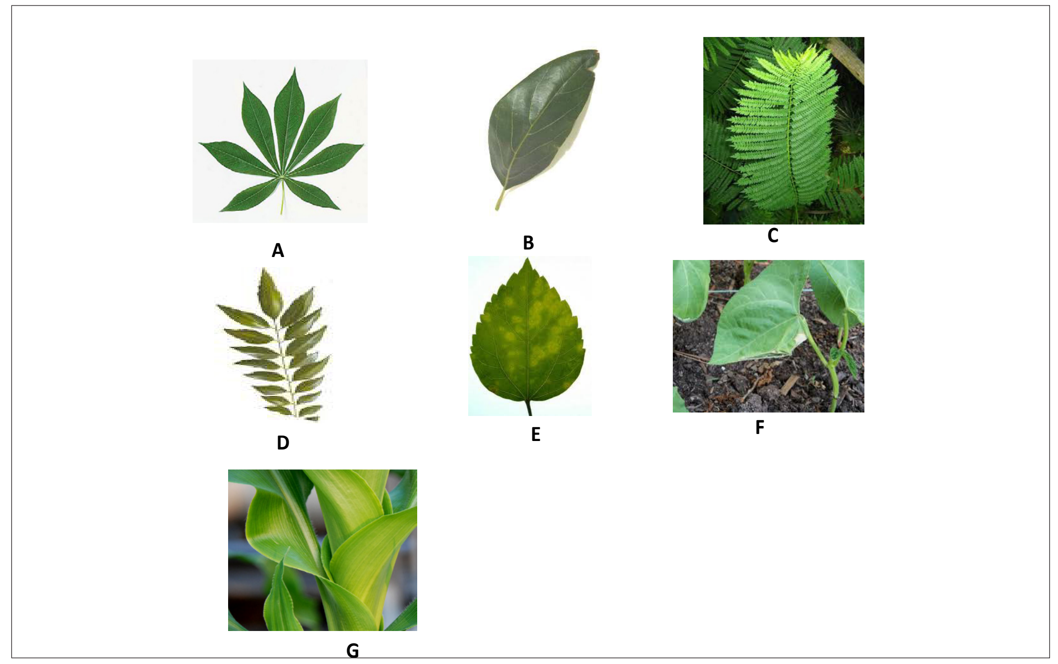
- Collect plants with different types of leaves, stems, roots, inflorescences, fruits, etc
- Arthropods including honeybee, spider, millipede, butterfly, sugar, ant, centipede, and mosquito.

Precaution

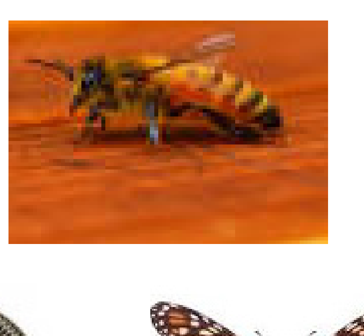
Some organisms are poisonous, some have thorns and others can sting. The most care must be taken while handling them with learners.

Experiment setup

A. Samples of plants



B. Samples of animals (invertebrates)



Procedure and Steps of the experiment

A)

- Collect leaves of different species for both simple and compound including *Cassava*, *avocado*, *Jacaranda*, *Cassia*, *Hibiscus*, bean, and maize plants
- Label different leaves collected as A, B, C, D, E, F and G respectively
- Observe and familiarize with the specimens before starting the experiment to minimize errors during the identification process
- Use sharply contrasting external features of collected leaves and start grouping them into two successive groups until each leaf is identified as illustrated by an example that follows: Preserve the specimen for future use

B)

- Label collected specimens of arthropods as A, B, C, D, E, F and G respectively, where the letters represent honeybee, spider, millipede, butterfly, sugar ant, centipede, and mosquito
- Observe and familiarize yourself with the specimens before starting the experiment to minimize errors during the identification process
- Observe external features to construct a dichotomous key
- Use sharply contrasting external features of collected specimens and start grouping them into two successive groups until each specimen is identified

Reflection question

Can all collected samples of plants or animals be grouped in the same group?

Data recording

A) Plants

1.a) Simple leaves (B, E and G).. go to 2

b) Compound leaves (A, C, D and F)... go to 4

2.a) Parallel venation.. G

b) Leaves with network venation... go to 3

3.a) Leaves with smooth margin.. B

b) Leaves without serrated margin.. E

4.a) Trifoliate leaves .... F

b) Non trifoliate leaves... go to 5

5.a) Digitate leaves.. A

b) Non digitate leaves.. go to 6

6.a) Pinnate leaves... D

b) Bipinnate leaves... C

B) Animals

1.a) 3 pairs of legs (A, D, E, G) -- go to 2

b) More than 3 pairs of legs (B, C, F) -- go to 5

2.a) With wings (A, D, G) --- go to 3

b) Without wings--- E

3.a) With pollen sacs---A

b) Without pollen sacs (D, G,) -- go to 4

4.a) With straight antennae--- D

b) With coiled antennae-- G

5.a) With four pairs of legs--- B

b) With more than four pairs of legs (C, F) -----------------------------------go to 6

6.a) Cylindrical body shape--- C

b) With flattened body shape--- F

Interpretation and conclusion

Based on the structure of leaves, not all plants can be grouped together. The grouping follows the characteristics of the leaves starting from the most shared characteristics to specific characteristics. In the above dichotomous key, collected leaves have been first grouped into simple and compound leaves following the steps 1a and 1b. Then, compound leaves can be separated

following specific characteristics of each plant leave (steps 4a to 6b) and simple leaves can also be classified based on specific characteristics of the specimens A, B and G (Steps 2a to 3b).

Based on the characteristic features, animals are classified apart from others based on specific characteristics. The steps followed to identify animal specimens A, B, C, D, E, F, and G are summarized in the following table:

Specimen	Steps followed	Identity/name
A	1a, 2a, and 3a	Honeybee
B	1b, and 5a	Spider
C	1b, 5b and 6a	Millipede
D	1a, 2a, 3b and 4a	Mosquito
E	1a and 2b	Sugar ant
F	1b, 5b and 6b	Centipede
G	1a, 2a, 3b and 4b	Butterfly

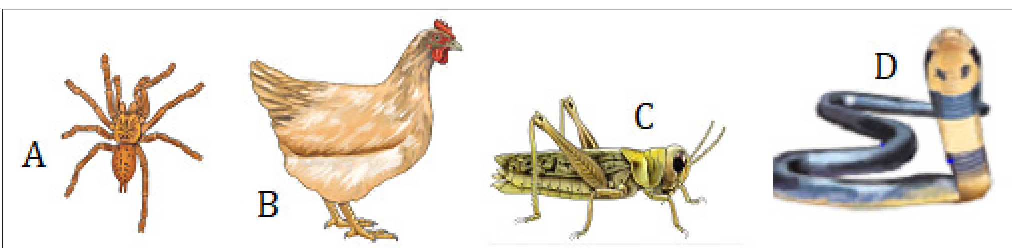
Keys are based on observable features of biological importance preferably structural features. By working through the series of statements, one can identify each of the organisms based on characteristics which is not found in another specimen. When constructing keys, the insistence is on features that are specific, which means permanent, observable, and distinct. Note that names, taxonomic categories, color, and size are the characteristics to base-on while doing the classification of the living things.

Source of errors

Identifying an organism that is missing some parts (broken leg, wing, leaflet…)

Guidance on the evaluation

Ask learners to construct dichotomous key using contrasting correct key statements for the following animals:



Hints for the exercise:

1. a) Has legs -- go to 2
   b) Has no legs---D
2. a) Has two legs--B
   b) Has more than two legs--go to 3
3. a) Has six legs---C
   b) Has eight legs--A

UNIT: 3 MICROSCOPY

Experiment 3.1 : Manipulation of light microscope using prepared slides

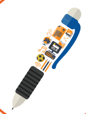
This activity can be done when teaching the concept or topic related to microscopes and their principal uses.

Rationale

Many features of interest in biological systems are too small to be seen by the naked eye and can only be observed by using the microscope. The light microscope consists of a coordinated system of lenses arranged so that a magnified image of a specimen is seen by the viewer. This activity aims at the manipulation of light microscope for its effective us.

Objective

To manipulate a light microscope to observe specimens from prepared slides.

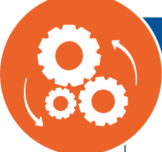


Materials

- Permanent slides of any organism
- Light Microscope

Experiment setup

Fig.3.1: Microscope manipulation



Procedures and steps of the experiment

- Connect the light microscope to a power source or find a place where natural light is easily accessible if the microscope uses a mirror.
- Turn the revolving nosepiece so the lowest objective lens is in position.
- Mount the prepared slide on the stage.
- Fix the slide using the metal clips and make sure the specimen is positioned in the center of the right.
- Look into the eyepiece and slowly rotate the coarse adjustment knob to bring your specimen to focus.
- Adjust the condenser for the maximum amount of light.
- Slowly rotate the fine adjustment knob until you obtain a clearer image of your specimen.
- After you're done viewing with the lowest power objective, switch to the medium power objective and re-adjust the focus with the fine adjustment knob.
- Proceed to the high-power objective once there is a need.

Precaution

Microscope is a delicate instrument and very expensive, therefore it should be handled with care.

Reflection question

Does the image of a prepared slide change with the change in the magnification and light intensity?

Data recording

Parts of microscope	Manipulation / Handling
Arm and Support base	To carry the microscope
Objective lenses	Ensure that the low power objective lens is in place and the stage is completely lowered before turning the microscope on.
Iris of diaphragm	Regulate the light intensity

Stage	Place the slide on the stage before observation
Stage clips	Make sure that the mounted slide is secured by stage clips

Interpretation of results and conclusion

While using a microscope, always carry the microscope using two hands if the microscope must be transported from one area to another, and one hand should support the bottom while the other hand is holding the arm. Set up the microscope on a flat surface, and once in place, remove the covers and plug the microscope to the electricity, and position the slide onto the stage, and clip it into or under the slide holders.

To observe the specimen, turn on the light from the illuminator under the stage, and center the slide in the best way possible without using any focusing knobs or the eyepiece. Then, look through the eyepiece, keeping both eyes open to avoid eye strain, while using the coarse focus knob to bring the stage and slide closer to the objective until the object can be seen through the eyepiece.

Further, use the fine focus knob to bring the image into sharper focus, center the object being viewed and change the iris diaphragm under the stage to open and close the iris. Change the amount of light entering through the specimen to observe more details. Always, start from lower power to higher magnifying objective.

Once you are done with the observation under the light microscope, clean the slide and objective with lens tissue after use, return the stage to the lowest level, change the objective back to the 4X lens, and unplug the microscope. Carefully return the microscope using both hands to where it is stored.

Source of errors

- Not starting from a lower objective.
- The objective not clicked into place over lens,
- Diaphragm closed too much or off center,
- Reflecting mirror not well positioned,
- Dirtiness of objectives, eyepiece lenses, slides, condenser lenses,
- The amount of light used to visualize specimens on the slide.

Guidance on the evaluation

Assess learners on manipulating a microscope for its effective use.

What are the appropriate techniques of using a microscope?

Experiment 3.2 : Making temporary preparations of slides of onion's epidermis, young stems and roots for light microscopy.

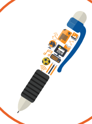
This experiment can be done when teaching the concept or topic related to microscopic observation of temporary slides.

Rationale

Temporary preparation of slides also called wet mounts has the advantage of improving the visibility of the parts of the specimens since water has reflective index greater than that of air and nearer that of a glass of which the lenses are made. This experiment aims at making slides of epidermis of onions, young stem, leaves, and roots for microscopy.

Objective

To prepare temporary slides for light microscopy.



Materials

- Onion
- Microscopic slides
- Microscopic cover slips
- Needles
- Dropper
- Iodine solution
- Blotting paper
- Water
- Knife
- Microscope

Experiment setup

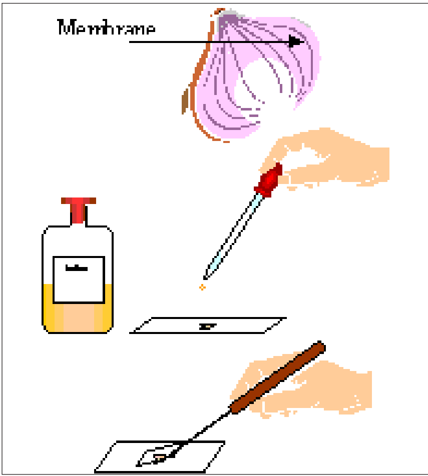


Fig.3.2: Making temporary slides

Procedures and steps of the experiment

- Cut red onion using a knife
- Remove an inner layer
- Peel a thin red outer layer with tweezer or fingernail
- Spread the peeled thin layer of onion on a slide
- Add a drop of iodine solution or methylene blue on the onion membrane
- Gently lay a microscopic cover slip on the membrane and press it down gently using a needle to remove air bubbles
- Touch a blotting paper on one side of the slide to drain excess iodine/water solution
- Place the slide on the microscope stage under low power to observe
- Adjust focus for clarity to observe
- Observe the prepared specimen using microscope
- Make another slide without adding drops of iodine solution or methylene blue
- Follow the same process and prepare slides of young stem, leaves, and roots
- Draw observation for each prepared slide

Reflection question

Is there any difference between the observed image of different prepared slides?

Precaution

Cut smoothly through the specimen to avoid distorting the cells and keep the cells moist. Transfer the cut sections immediately to a slide.

Data recording

Slides	Observation
Onion epidermis	Regular shape, large vacuole, nucleus, cell membrane, cell wall and cytoplasm
Young stem	Regular shape, large vacuole, nucleus, cell membrane, cell wall and cytoplasm
Young root	Regular shape, large vacuole, nucleus, cell membrane, cell wall and cytoplasm
Young leaf	Regular shape, large vacuole, nucleus, cell membrane, cell wall and cytoplasm

Interpretation of results and conclusion

All observed plant specimen shows regular shape, large vacuole, nucleus, cell membrane, cell wall and cytoplasm. We conclude that all plant cells show these parts when observed under light microscope.

Note on source of errors

Bigger layers of specimens lead to non-clear images. Further, using many stains and dirty slides implies unclear images.

Guidance on evaluation

Assess learners by asking the questions as follows:

1. What are the major steps in preparing a slide?
2. What is the importance of staining in microscope observation?

UNIT: 4 CELL STRUCTURE AND SPECIALIZATION

Experiment 4.1 : Preparation of temporary slides of cheek cells for microscopy

This experiment can be done when teaching the concept or topic related to the structure and function of cells in an organism.

Rationale

Animal cells are too small to be seen with the naked eye. Specifically, it is very hard to observe cheek cells that shed from the mouth lining. Yet it is essential to know their structure by using prepared slides. This experiment aims at preparing a temporary slide of cheek cells for microscopy through fixing, staining, and mounting steps.

Objective

To make a temporary slide of cheek cells and observe their structure under a microscope.

Materials

- Sterile cotton swab
- Clean sterile microscope slides
- Microscope cover slips,
- Methylene blue solution
- Dropper
- Tissue paper
- Microscope

Experiment setup

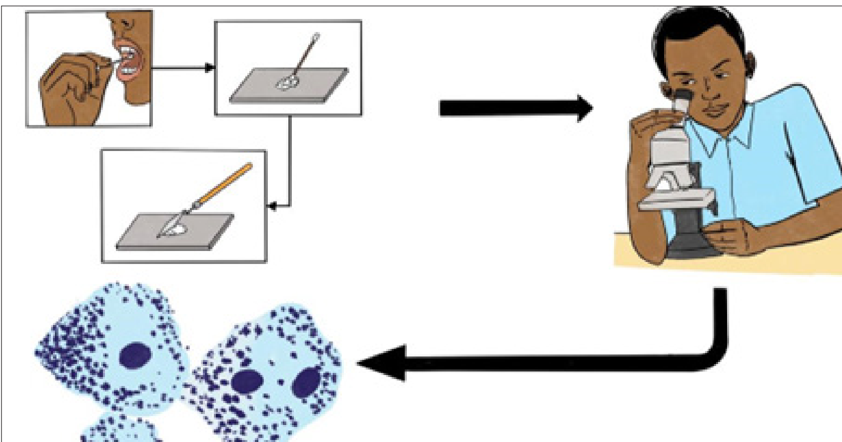
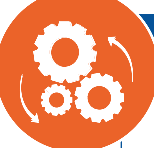


Fig.4.1: Observing animal cells



Procedures and steps of the experiment

- In advance, prepare all required materials: clean glass slide, cover slip, microscope
- Put a drop of blue methylene on the center of a clean glass slide
- Gently scrape the inside of your mouth to collect cheek cells using a sterile cotton swab
- Smear the cotton swab on the drop of blue methylene for about 4 seconds
- Gently cover the smear with a cover slip
- Mount your preparation of cheek cells on the stage of the microscope
- Observe under lower magnification, and then higher magnification

Reflection question

How is the structure of the cells under observation?

Data recording

Aspect to consider	Characteristics
Shape	Oval
Visible organelles	Smaller nuclei, cytoplasm, cell membrane

Interpretation and conclusion

The animal cell has different parts. Having absorbed the stain, these parts of the cell become more visible under the microscope and can therefore be easily distinguished from other parts of the same cell. Without stains, cells would appear to be almost transparent, making it difficult to visualize its parts. Observed under light microscope, cheek cells appear small, oval with few organelles. The visible parts are only the cell membrane, the cytoplasm, and the nucleus.

Note on source of errors

Using much stains and dirty slides implies unclear images

Guidance on evaluation

Assess learners by asking the following questions:

1. Why do we need to stain during this activity?
2. Why must we firmly cover the slide with clear cover slip?
3. What are the characteristics of observed cells?

UNIT: 5 DIVERSITY OF SPECIALIZED TISSUES

Experiment 5.1 : Observe and draw plant and animal tissues using permanent slides and microscopes

This experiment can be done when teaching the concept or topic related to specialized plant cells, animal cells, tissues, and their adaptation.

Rationale

A tissue is a group of associated, similarly structured cells that perform a specialized function for the survival of the organism. In biology it is essential to relate the tissues' structure to their respective biological functions. To determine the tissue's structure requires careful observations under the microscope, which is the purpose of this experiment.

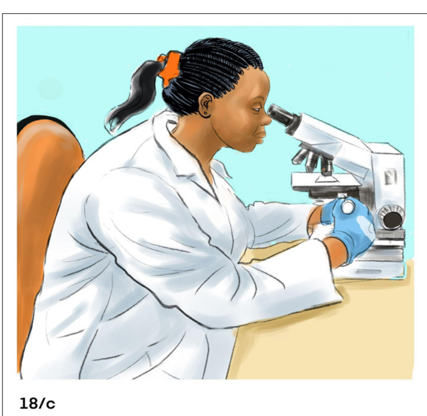
Objective

To draw animal and plant tissues as observed under microscope

Materials

- Compound microscope
- Prepared slides of the various animal and plant tissues
- Pencils
- Papers
- Rubbers

Experiment setup



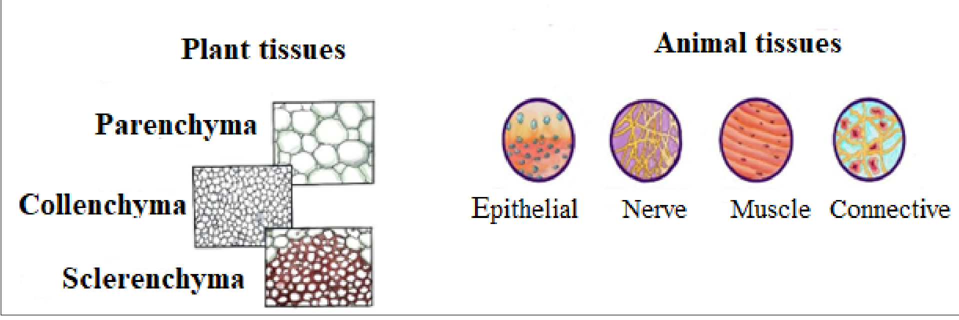


Fig.5.1: Observing plant and animal tissues

Procedures and steps of the experiment

- Put in place permanent slides of animal and plant tissues
- Mount slides of animal tissues on the microscope
- Draw label, and note your observation under the high magnification of Microscope
- Repeat the steps above using prepared slides of plant tissues
- Tabulate your observations showing specific characteristics of each tissue

Reflection questions

Do plant tissues look similar? Do animal tissues look similar?

Data recording

Slide tissue type	Characteristics
Animal tissues	
Epithelial tissue	• Consists of closely packed cells arranged in single or multilayered sheets
Nervous tissue	• Composed principally of densely packed cells called neurons • Neurons are well-organized fibers
Muscle tissue	• Consists of elongated cells held together
Connective tissue	• Made up of a variety of cells embedded in a large amount of intracellular substance
Plant tissues	
Parenchyma tissue	• The cells are generally oval or spherical in shape • The cells are large and are not packed closely • Intercellular spaces present • Each cell has a large vacuole, peripheral cytoplasm with a prominent nucleus
Chlorenchyma tissue	• These cells are isodiametric and elongated • Cell walls are unevenly thickened at the corners • Intercellular spaces are absent
Sclerenchyma tissue	• Cells are thick-walled, hard and contain little protoplasm • The cells are oval, polygonal and are of different shapes • The cells are dead and the nucleus is absent • The cells packed closely • Intercellular spaces are absent • The cell wall is evenly thickened with lignin and perforated pits

Interpretation and conclusion

Plants and animals are composed of tissues. These tissues are differentiated based on their shape, size, length, thickness, presence of different organelles in their cells, and the space between cells.

Note on source of errors

Dirtiness of objectives, eyepiece lenses, slides, condenser lenses; amount of light used to visualize specimens on the slide may lead to erroneous structure of tissues.

Guidance on evaluation

Assess learners by asking them questions related to the structures of plant and animal tissues.

1. How does collenchyma tissue differ from parenchyma?
2. Describe different animal tissues observed

UNIT: 6 TESTING FOR BIOLOGICAL MOLECULES

Experiment 6.1 : Carrying out the tests for reducing sugars and non-reducing sugars

This experiment can be done when teaching the concept or topic related to biological molecules, specifically reducing sugars and non-reducing sugars.

Rationale

All living things need food to survive. Plants make their own food while animals get food from plants or small animals through the food chain. Food contains different kinds of nutrients including reducing and non-reducing sugars. There is a need to know how to test the presence of some nutrients like reducing sugars and non-reducing sugars in different food stuffs.

Objective

To identify reducing and non-reducing sugars in food stuffs

Materials

- Beaker
- Test tube
- Benedict solution
- Bunsen burner
- Droppers
- HCl
- NaOH
- Glucose powder
- Sucrose powder

Experiment setup

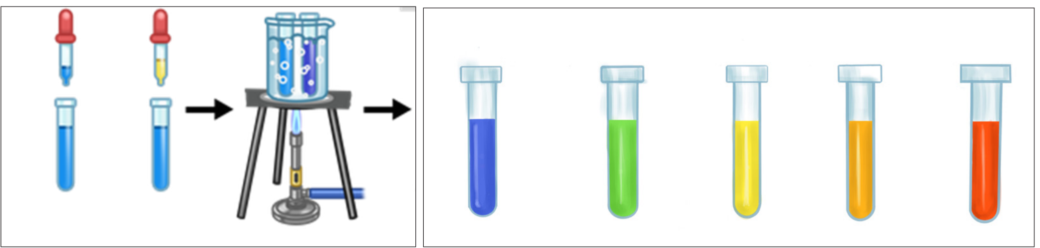


Fig.6.1.a: Test for reducing sugar

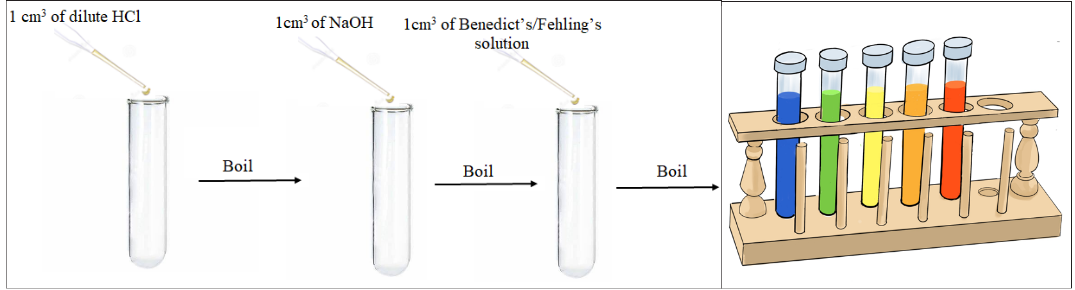


Fig.6.1.b: Test for non-reducing sugar

Procedures and steps of the experiment

a. For reducing sugar

- In the beaker mix $2cm^3$ of water and 1g of glucose powder to have a solution
- Pour the prepared solution of glucose in a test tube
- Add 1 ml of Benedict's solution and heat
- Note down your observations

b. For non- reducing sugar

- To $1cm^3$ of the food to test in test tube add 1 cm^3 of dilute HCl
- Boil the mixture, cool about 1 minute and add $1cm^3$ of NaOH
- Add $1cm^3$ of Benedict's/Fehling's solution and boil
- At every step, record the observations

Reflection question

Do you detect any difference between reducing and non-reducing sugars?

Data recording

Reagents	Food substance tested	Color changes	
		Presence of reducing sugar	Absence of reducing sugars
Benedict's solution or Fehling's solution	Reducing sugars	The color changes from blue to green, yellow, orange and brick red color	Blue
Benedict's solution or Fehling's solution HCl (any acid) NaOH (any alkali)	Non reducing sugars	The color changes from blue color to green, yellow, orange and brick red color	Blue

Interpretation and conclusion

The presence of reducing sugar can be tested by using benedict reagent. Benedict solution has copper ions that have a light blue color. When this solution is heated in the presence of simple reducing sugars such as glucose, the blue color of copper ions changes from a light green color to yellow-rusty orange-brick red color. If the color of Benedict reagent persists, the sugar tested is not a reducing sugar. Note that there is no special reagent to test for non-reducing sugar, but by adding HCl, non-reducing sugars can be hydrolyzed to reducing sugars. To test the presence of reducing sugars, a solution of sodium hydroxide is needed to neutralize the acidity because Benedict reagent works better in neutral solution.

Source of errors

The following can be source of errors: Forgetting to heat, inadequate heating, using too much solution, forgetting to observe while heating, forgetting to shake the test tube while heating, adding too little Benedict's solution, and heating continuously on the flame. While testing the presence of reducing sugar, forgetting to heat HCl, adding too little acid or little Benedict's solution, inadequate heating, and forgetting to add NaOH and shake the test tube while heating can lead to poor results or no results at all.

Guidance on evaluation

Provide learners with natural foods containing reducing sugar (lemon, orange, and banana) and non-reducing sugar (sugar cane, sugar beet) and ask them to identify which food has reducing sugar or non-reducing sugar.

Experiment 6.2: Test for starch

This experiment can be done when teaching the concept or topic related to the variety of carbohydrates.

Rationale

Starchy foods are our main source of carbohydrates and play an important role in a healthy diet. They are a good source of energy to the human body. We therefore need to test the presence of such highly important nutrient in our different daily food stuffs.

Objective

To test the presence of starch in the plant leaf

Materials

- A plant leaves
- Iodine solution
- Beakers
- Droppers
- Source of heat
- Test tubes

Experiment setup

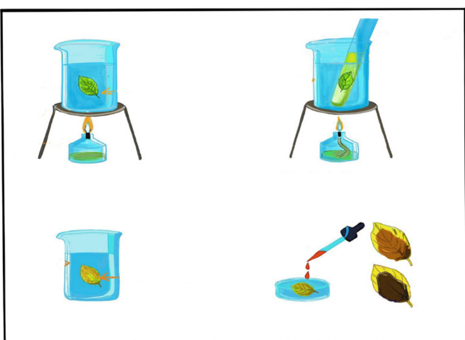


Fig.6.2: Test for starch

Procedures and steps of the experiment

- Collect leaves from a fresh plant
- Put water in a beaker and put it on Bunsen burner
- Heat a plant leaf in boiling water for 30 seconds
- Heat it in boiling ethanol for a few minutes
- Wash with water and spread onto a white tile
- Add iodine solution from a dropping pipette
- Note down your observation

Precaution

– Most care and attention must be observed once heating the test tube containing alcohol because it is flammable and can cause fire accidents in case of inattention.

– While heating the test tube containing alcohol, the test tube mouth must be pointed on the learner's opposite side.

Reflection question

Do you think the leaf contains starch?

Data recording

Sample	Condition	Reagent	Observation
Leaf	Fresh	Iodine	Brown color
	Heat	Iodine	Blue black

Interpretation and conclusion

The addition of Iodine solution (brown color) to the fresh leaf doesn't cause any change in color due to the presence of chlorophyll in a leaf that needs to be removed by boiling it in ethanol. The ethanol dissolves the chlorophyll and removes the green color from the leaf which turns white so it is easy to see the change in color. After removing the chlorophyll, washing it in water allows it to rehydrate and to be soft for easy iodine penetration. The addition of the Iodine solution to the boiled leaf causes the change of color from brown to blue black indicating the presence of starch in a leaf.

Source of errors

Addition of too little Iodine solution, inadequate heating, and the use of unclean test tubes. It may also result from the use of old leaves.

Guidance on evaluation

Provide learners with local foods like potatoes, maize grains, starch powder, prepared porridge and ask them to test the presence of starch. The teacher will be facilitating the distribution of Iodine to avoid wastage.

Experiment 6.3: Identification of lipids using the emulsion test

This experiment can be done when teaching the concept or topic related to nutrients' tests in different food samples.

Rationale

Lipids constitute a broad group of naturally occurring molecules which includes fats, waxes, and sterols. The functions of lipids include storing energy. Lipids also act as structural components of the cell membrane. They are found in food that we eat. It is essential to know and apply techniques used for investigating the presence of lipids in different food stuffs.

Objective

To identify lipids using the emulsion test

Materials

- Cooking oil
- Test tubes
- Ethanol
- Water

Experiment setup

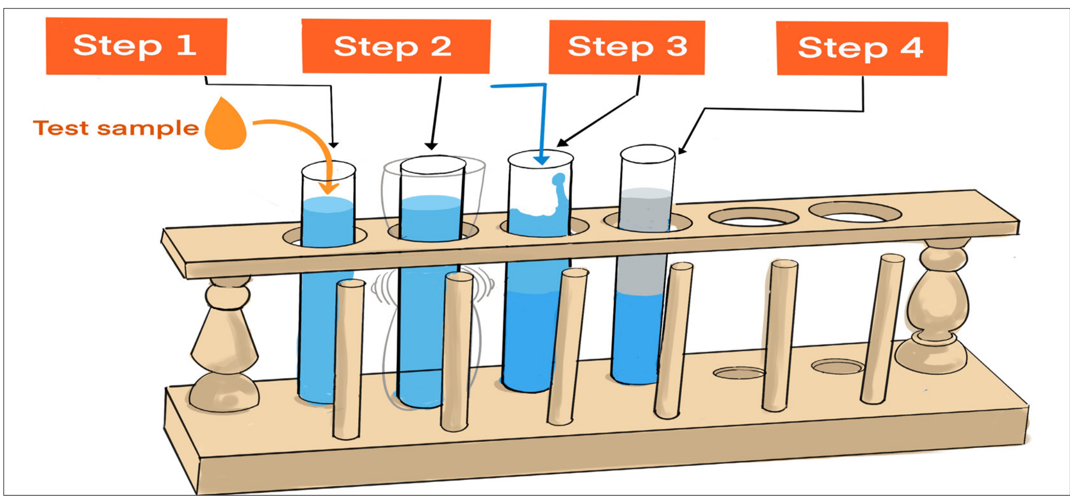


Fig.6.3: Test for lipids

Procedures and steps of the experiment

- Add 2 cm^3 of cooking oil in the test tube
- Add 5cm^3 of ethanol in the tube containing the sample
- Shake the test tube well and then allow the contents to settle
- Add 5$cm^3$of water to the test tube and shake it well
- Record the observation

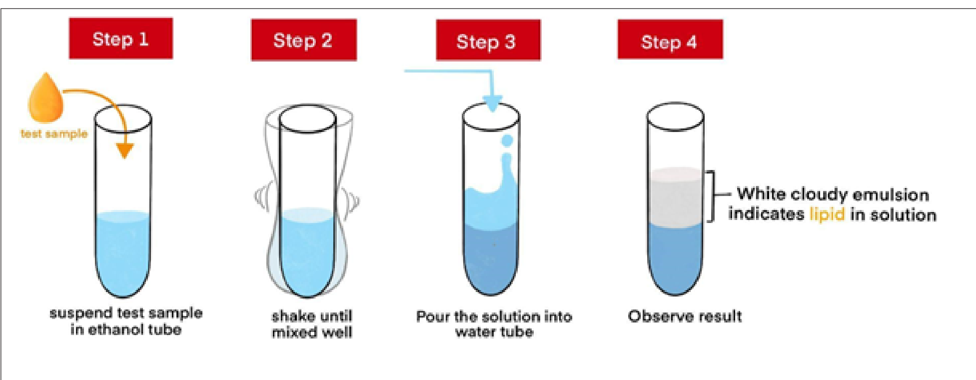
Reflection question

Do you think cooking oil contains lipids?

Data recording

Sample	Reagents	Observation
Cooking oil	Ethanol	Colorless
	Water	Milky

Interpretation and conclusion



When using ethanol for testing lipids, the positive results are indicated by the color change from colorless (ethanol color) to milky suspension after adding water and shaking.

Source of errors

Forgetting to shake, mixing reagents in the wrong way/order and using unclean test tubes.

Guidance on evaluation

Provide learners with two test tubes. One containing cooking oil labeled as solution X, another test tube containing water labeled as solution Y. Ask students to use the emulsion test to identify which solution contains lipids.

Experiment 6.4: Identification of proteins using Biuret and Millon's reagents

This experiment can be done when teaching the concept or topic related to the test for biological molecules, specifically the test for proteins.

Rationale

Every cell in the human body contains protein. The basic structure of protein is a chain of amino acids. You need proteins in your diet to help your body repair cells and make new ones. Protein is also important for growth and development in children, teens, and pregnant women. Therefore, this activity will help us to identify foods that contain proteins using appropriate techniques and reagents.

Objective

To identify proteins in foods using Biuret and Millon's reagent.

a. Using biuret test

Materials

- Food sample (egg albumen)
- Biuret reagent,
- Test tubes,
- Dropper

Experiment setup

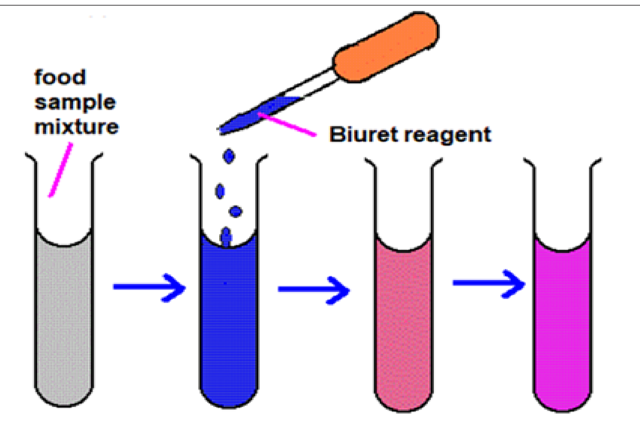


Fig.6.4: Test for proteins

Procedures and steps of the experiment

- Put 2 cm^3 of your prepared filtered food sample mixture into a test tube.
- Add 2 cm^3 of biuret reagent to the food sample
- Shake the mixture gently and allow to stand for 5 minutes
- Observe and record the color of the food sample and of the Biuret reagent, and not the color changes throughout the experiment

Data recording

Sample	Reagent	Color observed
Egg albumen solution	-	White like
-	Biuret reagent	Blue
Egg albumen	Biuret reagent	Blue-Red-Purple

Interpretation of results and conclusion

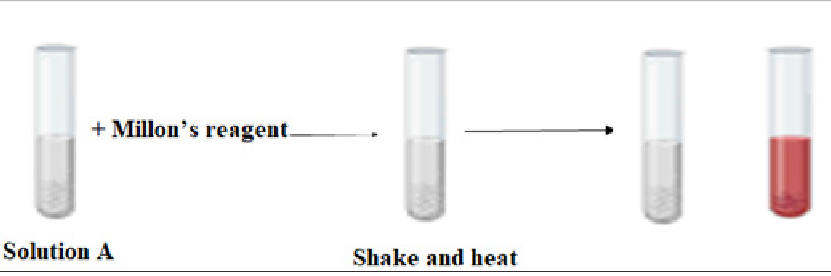
When using biuret reagent (blue) for testing proteins in food stuffs, the positive results are indicated by the presence of purple color after shaking the sample food mixed with Biuret reagent. When a purple color does not appear, this indicates the absence of proteins.

b. Using Millon's reagent

Materials

- Test tubes
- Test tube rack
- Test tube holder
- Pipettes
- Bunsen burner
- Water bath
- Food Sample (egg albumen)

Experiment setup



Procedures

- Put about 2 ml of the food sample solution in a test tube.
- Add to this about 2 ml of Millon's reagent and mix well.
- Heat gently for 1 minute.
- The test tubes are then kept in the water bath for about 2 minutes if red colored precipitate is not observed immediately.

Reflective questions

Does the food sample solution contain proteins?

Data recording

Sample	Condition	Reagent	Observation
Food	Heat	Millon's reagent	Colorless-Pink or Brick red

Source of errors

- Forgetting to heat
- Adding too little Millon's reagent

Interpretation of results and conclusion

When using a Millon reagent for testing proteins, the positive results are indicated by the presence of a pink or red color. When a pink or red color does not appear, it indicates absence of proteins.

Guidance on evaluation

You are provided with the sample of the substance A (soybeans) and M (Gkyceline). Carry out the experiments to test for proteins using both Biuret and Millon's reagent on each substance and write your conclusion on each case. Which substance between A and M contains proteins and how can proof your answer?

Experiment 6.5: Test for vitamin C (Ascorbic acid)

This experiment can be done when teaching the concept or topic related to testing for biological molecules, specifically vitamin C.

Rationale

The vitamins are natural and essential nutrients, required in small quantities and play a major role in growth and development, repair and healing wounds, maintaining healthy bones and tissues, for the proper functioning of an immune system, and other biological functions. Therefore, this activity will allow us to know techniques to identify foods that contain vitamin C such that we include them in daily diets accordingly.

Objective

To test for vitamin C (Ascorbic acid)

Materials

- Test tubes
- Citron juice
- Dichlorophenolindophenol (DCPIP)
- Pipettes
- Indophenol

Experiment setup

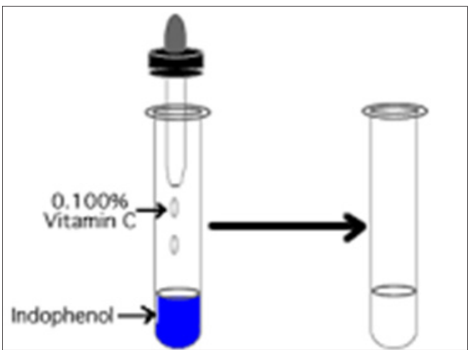


Fig.6.5: Test for Vitamin. C

Procedures and steps of the experiment

- Pour a small quantity of DCPIP in test tube
- Add drops of citron juice
- Observe colour change

Precaution: Do not shake

Data recording

Sample	Reagent	Observations
Citron juice	DCPIP	Colorless
Citron juice	DCPIP	Blue color disappears (decolorized).

Interpretation of results and conclusion

A reagent known as Dichlorophenolindophenol (DCPIP) is used to test for vitamin C. The DCPIP is a deep blue reagent in color. When the vitamin C is present in a food sample, the positive result observed is the disappearance of the blue color. When the blue colour of DCPIP remains, this shows the absence of vitamin C.

Source of errors

Errors may come from the addition of too little test solution and using unclean apparatuses

Guidance on evaluation

Provide learners with water labeled W and a tomato juice labeled X. Request learners to carry out the test for vitamin C and write the steps used, observations and conclusion.

UNIT: 7 CARBOHYDRATES AND LIPIDS

Experiment 7.1: Performing an activity for comparing bonding in maltose and sucrose

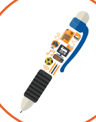
This activity can be conducted when teaching the concept or topic related to formation of glycosidic bonds.

Rationale

Carbohydrates play a vital role as they provide energy to the body cells. Dietary carbohydrates can be broadly classified into various categories based on the number of sugar units present in them. Monosaccharides may combine together in pairs to give a disaccharide (double sugar). The bond which combines them is called a glycosidic bond. The maltose is the sugar from the germinating seeds, sucrose or saccharose is the common table sugar obtained from sugarcane. This activity aims to explore and compare the bonds that link the monosaccharides in maltose and sucrose.

Objective

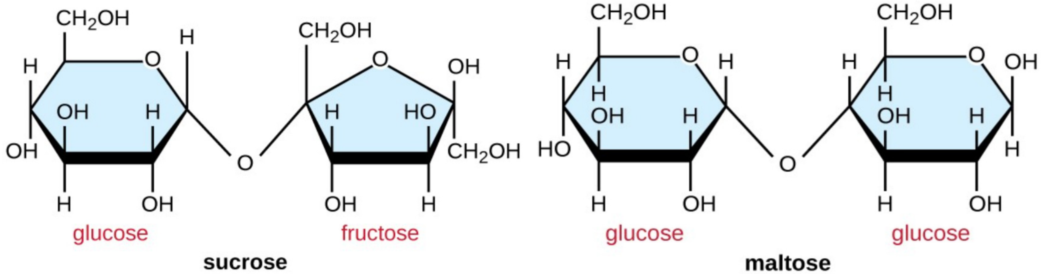
To compare the bonding in maltose and sucrose



Materials

- Figures showing the structure of maltose and sucrose
- Video explaining and showing the structure of maltose and sucrose: https://www.youtube.com/watch?v=3D17qaH9N28)
- You can also search for an animation showing the structure of maltose and sucrose: https://www.youtube.com/watch?v=3MSgxEp5IM4)

Experiment set up



Procedures and steps of the experiment

- Using chart/ figure or coloured printed papers in the class showing the structure of maltose and sucrose
- Distribute the printed papers /pictures in different groups of learners
- Request learners to identify the bonding structures.
- Request learners to reflect on questions and present their findings

Reflection questions

1. How does sucrose and maltose differ in structure?
2. What bond joins maltose and sucrose?

Data recording

Disaccharide name	Molecule's structure	Bonding
Maltose	Made up of two molecules of glucose	Alpha 1,4 glycosidic bond
Sucrose	Made up of glucose and fructose molecules	Glycosidic bonds (between C1 on the glucosyl subunit and C2 on the fructosyl unit).

Interpretation of results and conclusion

The key difference between maltose and sucrose is that maltose is a combination of two molecules of glucose while sucrose consists of one molecule of glucose connected to one molecule of fructose. In sucrose, the glycosidic bond is formed between the carbon 1 of glucose and the carbon 2 of fructose. It is formed between the functional groups of two molecules. It is non-reducing sugar because no free functional group is available to act as a reducing agent. In a maltose, both the glucose molecules are attached via a 1-4 glycosidic bond. This bond attaches the carbon 1 of one glucose molecule to carbon 4 of the second glucose molecule. It is a reducing sugar due to the free aldehydic group of glucose.

Guidance on evaluation

Assess the learners by letting them discuss in their respective group about the provided topics/questions, such as:

1. Differentiate the bonds in sucrose molecule and maltose molecule
2. Explain why sucrose is non reducing sugar while maltose is the reducing sugar?

Experiment 7.2: Carry out an experiment of using calorimeter to compare the enthalpy of combustion of 1g of glucose to that of lipid

This experiment can be done when teaching the concept or topics related to the combustion in sugars and lipids.

Rationale

Energy changes occur in chemical reactions as bonds are broken down and new bonds are formed. Enthalpy changes can be calculated from experimental data. This experiment serves as an example, and it consists of using a calorimeter to compare the enthalpy of combustion using one gramme of glucose and one gramme of lipids.

Objective

To compare the enthalpy of combustion of glucose and lipid

Materials

- Calorimeter
- 1g of glucose
- 1g of sunflower cooking oil
- Electronic balance
- Thermometer

Experiment set up

Fig.7.1: Comparing enthalopy of combustion

Procedures and steps of the experiment

- Using the electronic balance, measure 1 g of glucose and 1g of lipid separately
- Put the measured glucose and lipid in two different calorimeters
- Wait for the complete combustion in the calorimeter
- Read the change in temperature using the thermometer
- Calculate the enthalpy of both glucose and lipid.

Reflection questions

Is there differences in the enthalpy of 1gr of glucose and 1gr of lipid?

Data recording

The enthalpy can be calculated using the formula: Q = mc, where m is the mass, C is the specific heat capacity and is the temperature variation. Considering

the fact that the specific heat capacity of glucose and lipid is known, we have to calculate the mass in kilogram for both glucose and lipid, note down the observed changes in temperature (Kelvin degrees). Assuming that for glucose equals 5°K and for lipid equals 8°K , we can calculate the enthalpy Q = mc. Note that your data may vary depending on the variation of temperature you will get during your experiment.

Sample	Molar mass	Specific heat capacity (C)	Change in temperature ΔT (^0K)	Enthalpy ($mc\Delta T$)
Glucose	0.180 Kg	218.6 $J \cdot kg^{-1} \cdot K^{-1}$	5°K	196.74J
Lipid (cooking sunflower oil)	0.445 Kg	2250 $J \cdot kg^{-1} \cdot K^{-1}$	8°K	8,010J

Interpretation and conclusion

In the above example, when 1g of glucose undergoes combustion, the energy released is 196.74J. The enthalpy of combustion of glucose is -196.74J. The negative sign means that energy is given out during the combustion reaction, hence the reaction is called exothermic reaction. The enthalpy of lipids in general is higher (more negative) which means the fats and oils in general are higher energy producers. In our example this equals - 8,010J. Thus, lipids are the major sources of energy compared with glucose. However, the enthalpy values may vary depending on the type, source and viscosity of lipids/fat used.

Source of error

Errors may come from the poor settings of calorimeter and electronic balance.

Guidance on evaluation

The learners should repeat the experiment using different types of lipids (oils /fats) to compare different enthalpies of combustion. Set similar questions based on the experiment procedure.

UNIT: 8 PROTEINS AND WATER

Experiment 8.1: **Carry out an experiment to investigate the effect of temperature, pH and chemicals on the structure of proteins**

This experiment can be done when teaching the concept or topic related to structure and denaturation of proteins, specifically the causes of protein denaturation.

Rationale

Proteins are organic compounds of large molecular mass. They are polymers of amino acids, and their long chain can take different forms depending on the molecular weight and the types of bonds that hold together atoms and molecules. A protein may change its structure due to breakage of bonds holding the polypeptide chains and this is called protein denaturation. The changes in temperature, pH, and exposure to chemicals may alter the structure of protein.

Objective

To investigate the effect of chemicals on protein structure.

Materials

- Hair
- Cup of hair product
- Gloves

Experiment set up

Fig.8.1: Investigating effects of chemicals on proteins structure

Procedures and steps of the experiment

- Bring natural hairs and observe their structure
- Imbibe the observed hairs in the hair relaxer, and wait for 10 minutes
- Remove the hair from the hair relaxer (hair product) and observe their structure
- Compare the initial and the final hair structures
- Note down the observed changes

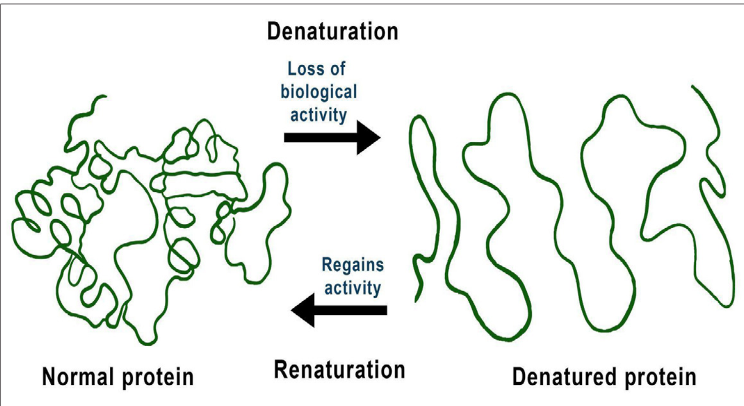
Reflection questions

1. What do you think are the causal agent of changes in the structure of hairs?

Data recording

Sample	Reagent (hair product)	Observations
Hair	-	Short hair
Hair	Hair product	Elongated hair

Interpretation and conclusion



With reference to the above figure, the natural hair gets elongated when exposed to hair products due to denaturation of hair proteins. Protein denaturation is a process by which protein changes shape due to breakage of bonds holding the polypeptide chains and getting elongated. Protein denaturation may be temporary or permanent. In this experiment, Proteins change their shape due to the denaturation caused by the exposure to chemical substances. *The same effect happens when proteins are exposed to changes in **temperature** and **pH**.*

Guidance on evaluation

Assess leaners by asking students to discuss on the effects of temperature and pH on the structure of proteins. The following is the example of the question:

1. Explain what happens on the structure of proteins when they are exposed to:
    a. Changing temperature
    b. Changing pH

Experiment 8.2: Carry out an experiment to investigate the effect that changes of temperature has on water

This experiment can be done when teaching the concept or topic related to water

Rationale

Water is an inorganic, transparent, tasteless, odorless, and nearly colorless chemical substance, which is the main constituent of Earth's hydrosphere and the fluids of all known living organisms. Temperature exerts a major influence water structure as well as on biological activity and growth of organisms. It is essential to assess the effect of changes in temperature on water and link these effects on biological functions and the state of water.

Objective

To investigate the effect of changing temperature on water

Materials

- Fresh water
- Three graduated beakers
- Source of heat
- Freezer
- Electronic balance

Experiment set up

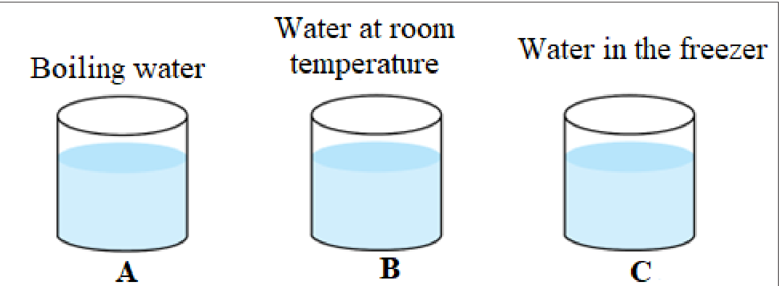


Fig.8.2: Investigating effects of temperature on water

Procedures and steps of the experiment

- Take three graduated beakers having the same volume of water, and label them A, B, and C, respectively
- Boil water in the beaker A
- Keep water of the beaker B at room temperature
- Cool the water in beaker C in the freezer
- Note down differences in water levels

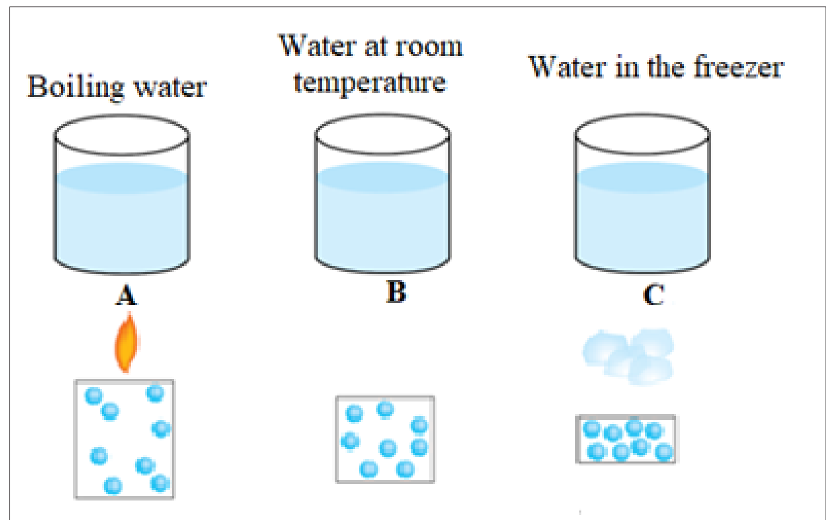
Reflection question

What is the causal agent of differences in water levels?

Data recording

Beaker of water	Level of water
Cup A	Water level increase
Cup B	Water level remain the same
Cup C	Water level decreases and water become solid at zero degree Celsius

Interpretation of results and conclusion



With reference to the figure above: as water was heated in cup A, an increase in temperature caused the water molecules to gain energy and move more rapidly, which resulted in water molecules that are farther apart, hence an increase in water volume and a decrease in density. The cup B was kept at room temperature and there is no change in volume and density. In the cup C water was kept in the freezer. A decrease in temperature causes water to stay closer which result in the decrease in volume and increase in density. As water occupies more than 70% in living organisms' bodies, changes in water temperature affects water status and the functioning of organisms.

Guidance on evaluation

Assess learners on the effect of lowering temperature on water by asking some questions like:

1. Explain how changes in water temperature affect functioning of living organisms?

Experiment 8.3: Using cooking oil and detergents to study hydrophilic and hydrophobic nature of substances

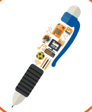
This experiment can be done when teaching the concept or topic related to the hydrophilic and hydrophobic nature of substances

Rationale

Substances are different in terms of their affinity towards water. Some are known as hydrophobic because they naturally repel water, causing water droplets or layers to form on their surface. Others are water-loving or hydrophilic and tend to dissolve well in water. Hydrophilic substances are polar in nature while hydrophobic substances are nonpolar, hence non-soluble or poorly soluble in water. As we always face hydrophilic and hydrophobic substances in our daily lives, this activity will help learners to investigate the behaviors of different substances when in contact with water and further apply this in the daily life activities.

Objective

To study the hydrophilic and hydrophobic nature of substances



Materials

- Water
- Oil
- Ethanol
- Beaker

Experiment set up

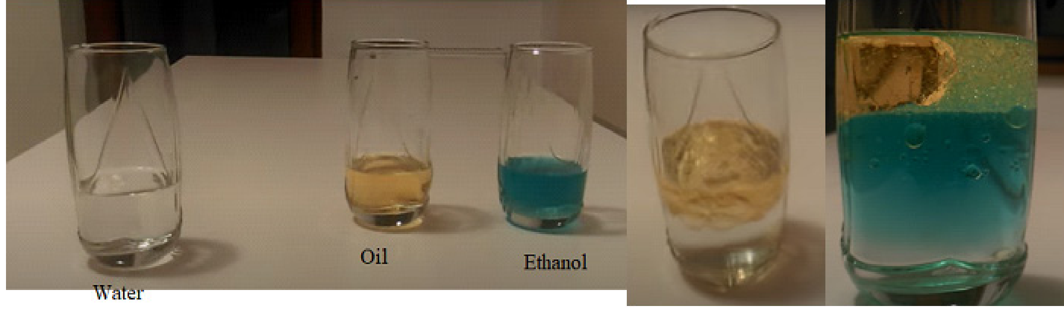


Fig.8.3: hydrophilic and hydrophobic nature of substances

Procedures and steps of the experiment

- Avail three beakers A, B and C
- Poor water in the beaker A, oil in the beaker B and ethanol in the beaker C
- Add oil in the beaker A, wait for 1 minute, and note down your observation
- In beaker A (water + oil) add the ethanol from the beaker C and wait about 1 minute
- Record your observation

Reflection questions

What is happening when water is mixed with oil and ethanol?

Data recording

Activity done	Observation
Oil added in water	Formation of two layers: oil comes on top and water at the bottom
Ethanol added to oil and water	Formation of two layers: water and ethanol at the bottom and oil on top

Interpretation of results and conclusion

Oils are hydrophobic, or water fearing as when oil is added to a beaker containing water the two don't mix with each other. Water molecules attract each other and pack closer so they sink to the bottom, leaving oil sitting on top of the water. On the other hand, when ethanol is added to water, molecules tend to break down the cohesive attractive forces of water molecules at the surface. As a result of the attractive forces between water molecules and ethanol, the surface tension is broken and viscosity increases. That is why ethanol is called hydrophobic substances.

Guidance on evaluation

Assess the learners in doing experiment by themselves and help them to interpret the results when water is mixed with oil and detergent. Ask them questions such as:

1. How detergent molecules interact with water?
2. Explain why oil doesn't mix with water.

UNIT: 10 ENZYMES

Experiment 10.1: Showing the effect of amylase on starch at different temperatures

This experiment can be done when teaching the concept or topic related to the effect of enzymes on biochemical reactions, specifically the effect of amylase on starch at different temperatures.

Rationale

Enzymes are biological catalysts produced by a living organism to control the rate of specific biochemical reactions. Enzymes speed up the rate of biochemical reactions in the cell but remain unchanged at the end of the reactions. Their activities can be limited by a number of factors such as the temperature, the pH, the concentration of the substrate or the enzyme itself and the presence of inhibitors. This experiment aims at investigating the effects of amylase on starch at different temperatures and will enhance the learners' understanding of the effect of temperature change on their body functioning.

Objective

To investigate the effect of amylase on starch at different temperatures

Materials

- Beaker
- Test tube
- Water bath
- Source of heat
- Thermometer
- Spotting tile
- Dropper

Experiment set up

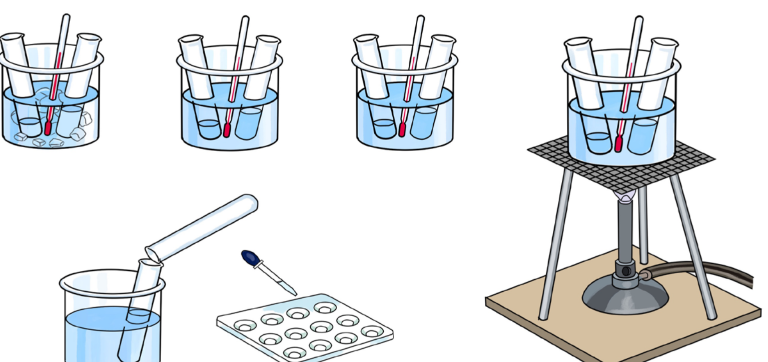


Fig.10.1: Effect of amylase on starch at different temperatures

Procedures and steps of the experiment

- Prepare solutions of starch in a test tube then label it A1 and the solution of amylase in a test tube A2 and put these solutions in ice bath at 2°C;
- Prepare solutions of starch in a test tube B1 and the solution of amylase in a test tube B2 and put these solutions in water bath at room temperature;
- Prepare solutions of starch in a test tube C1 and solution of amylase in a test tube C2 and put these solutions in water bath at 37°C;
- Prepare solutions of starch in a test tube D1 and the solution of amylase in a test tube D2 and heat these solutions in water bath at 100°C;
- At each step, mix test tube A1 with A2, then B1 with B2, then C1 with C2, then D1 with D2.
- Take drops from step 5, then by using a dropper, put drops in spotting tile for every mixture add drops of iodine solution and then observe the color change;
- Record the findings.

Reflection questions

1. Do you think that different temperatures will affect the action of amylase in the same way?

2. Why do we have to cool down or heat solutions at different temperatures?

Data recording

Solution	A1 +A2+Iodine	B1+B2+ Iodine	C1+C2+Iodine	D1+D2+Iodine
Temperature	2°C	24 °C	37 °C	100 °C
Observation	No observable change of colour	There is a slight change of colour towards purple	The colour is changed to blue-black	No observable change of colour

Interpretation of results and conclusion

At lower temperature (e.g 2°C), the enzyme amylase is deactivated and has no effect on starch. As the temperature increases (e.g 24 °C), the amylase starts to be progressively activated and converts starch, hence a slit change of colour towards purple. At 37° C, the enzyme is most active, hence, it takes less time to digest the starch. This is the optimum temperature for amylase activity, hence the colour is changed to blue-black. At higher temperature (e.g 80°C), the enzyme is denatured, hence no observable change of colour. Therefore, the amylase enzyme is most active at its optimum temperature and more time will be taken by the enzyme to digest the starch at lower and higher temperatures.

Guidance on evaluation

Teacher may assess learners on the effects of temperature on the action of amylase to starch by asking Ask them questions like:

1. What were the colour changes during the experiment?
2. What does the colour change mean in this experiment?
3. How can you relate your observations to activity of amylase in your body?

Experiment 10.2: Investigate the effect of temperature, pH and concentration of substrate on enzyme activities

This experiment can be done when teaching the concept or topic related to factors which affect the enzyme activity.

Rationale

Enzymes speed up the rate of biochemical reactions in the cell but remain unchanged at the end of the reactions. Its activities can be limited by a number of factors such as temperature, pH, concentration of the substrate or the enzyme itself. Enzymes work best at specific pH, temperature, and concentration of substrate. This experiment investigates the effects of pH, temperature and concentration of substrate on enzyme activity.

Objective

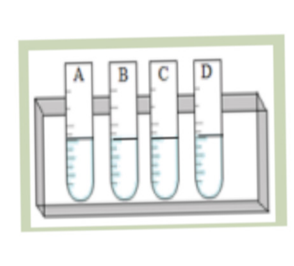
To investigate the effects of temperature, pH and concentration of substrate on enzyme activity.

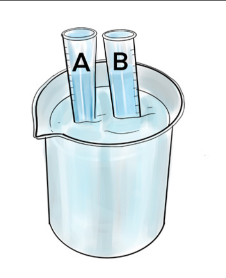
Materials

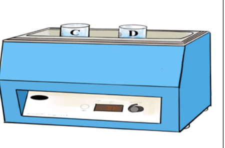
- Amylase solution
- Starch solutions
- Four test tubes
- Spotting tile
- Iodine
- Pipette
- Water bath

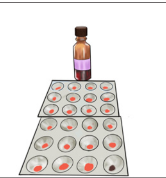
Experiment set up

A

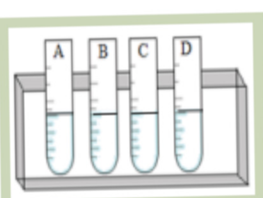








B



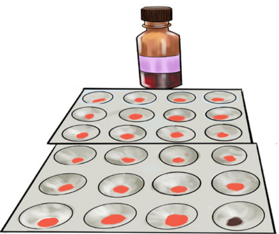


Fig.10.2: Effect of temperature on enzyme activity

Procedure and steps of the experiment

A

- Label your test tubes A-D
- Pour 1 cm3 of 1M starch solution to each test tube
- Keep tubes A and B in ice and tubes C and D in a water bath at 35o C for 5 minutes.
- Add 1 cm3 of 1M HCl on test tubes B and D, then shake the mixture to stir.
- Add 1 cm3 of 1M amylase solution on each test tube and shake.
- Keep A and B in the cold and C and D in a water bath for 10 minutes.
- Take a sample from each test tube and mix it with one drop of iodine.
- Use a different tile for each test tube and record the time taken before iodine change the colour

B.

- Label your test tubes A-D
- Pour 1 cm3 of 0.5 M starch solution in test tube A
- Pour 1 cm3 of 1 M starch solution in test tube B
- Pour 1 cm3 of 1.5 M starch solution in test tube C
- Pour 1 cm3 of 2 M starch solution in test tube D
- Add 1 cm3 of 1M amylase solution on each test tube and shake
- Keep the 4 test tubes at the temperature of 35o C for two minutes
- Take a sample from each test tube and mix it with one drop of iodine solution.
- Use a different tile for each test tube and record the time taken before iodine change the colour

Reflection question

What do you think will happen when iodine is added to the starch solution?

Data recording

A

Test tube	Sample (1 M)	reagent	Temperature condition	Observation
A	Starch solution	amylase + Iodine	Ice temperature	Blue black
B	Starch solution	HCl + amylase + Iodine	Ice temperature	Blue black
C	Starch solution	amylase + Iodine	35° C	No change of colour
D	Starch solution	HCl + amylase +Iodine	35° C	Blue black

B

Test tube	Sample	reagent	Temperature condition	Time taken before iodine change colour
A	0.5 M Starch solution	amylase + Iodine	35°C	12 min
B	1M Starch solution	amylase + Iodine	35°C	9 min
C	1.5 M Starch solution	amylase + Iodine	35° C	5 min
D	2 M Starch solution	amylase +Iodine	35° C	2 min

Precaution

The time taken before iodine changes colour is not experimental based, you may get more or less time during your experiment.

Interpretation of results and conclusion

A

In test tube A and B the amylase doesn't digest starch due to the low temperature of the Ice.

In the test tube C, the amylase digest enzyme and the solution doesn't change the colour, while in the test tube D the starch is not digested by amylase at 35°C due to the concentration of HCl (acidic pH). We conclude that then the solution of iodine in the spotting tile turns blue black due to the presence of starch, hence the enzyme activity doesn't take place.

B

The time taken for iodine to change colour depends on the substrate concentration. The rate of enzyme activity increases with the increase of the substrate concentration. However, there is an optimum substrate concentration above which the enzyme will become saturated since there are not enough enzyme molecules for breaking down the excess of substrate molecules.

Precautions

Iodine solution is irritant. If it touches the skin, it should be washed off. Goggles should be worn when performance this experiment.

Source of error

Measurement, preparation of solution, expired reagents and reactants

Guidance on evaluation

Assess learners on the effects of temperature, concentration of substrate and pH on the enzyme activity by asking questions such as:

1. How do the substrate concentration, pH, and temperature affect the enzyme activity?

Experiment 10.3: Investigating effect of immobilizing enzyme in alginate on its activity as compared with its activity when free in solution

This experiment can be done when teaching the concept or topic related to the effect of immobilizing enzymes in alginate as compared with its activity when free in solution.

Rationale

Enzymes have many applications in every daily life and different methods are used to get them. Enzyme immobilization methods include physical adsorption, ionic and covalent bonds, and various techniques such as binding, entrapment, encapsulation, and cross-linking. Enzyme immobilization allows one to re-use the enzyme for an extended period of time and enables easier separation of the catalyst from the product. Additionally, immobilization improves many properties of enzymes such as performance in organic solvents, pH tolerance, heat stability or the functional stability. This experiment will help us to understand how the process is carried out.

Objective

To investigate the effects of immobilized enzymes compared with its activity when free in solution.

Materials

- Sodium alginate
- Calcium chloride
- Beaker
- Stirrer
- Enzyme
- Separating funnel
- Erlenmeyer
- Dropper
- Tubes
- milk sample
- water bath
- glucose test trip

Experiment set up

Fig.10.3: Enzyme activity

Procedures

- Add the sodium alginate to calcium chloride in Erlenmeyer and mix using the stirrer
- Put the mixed solution to the beaker and leave it for few minutes
- Put the solution in separating tubes and wash it
- Prepare 2 different tubes (free enzyme's tube and immobilized enzyme's tube)
- Test the glucose in milk (you should find that there is glucose in milk sample)
- Add the milk sample to 2 prepared different tubes
- Leave the tubes in water bath for 5min
- Remove them and test each one for glucose
- Wash the beads again to remove excess calcium chloride
- Check for the enzyme immobilized calcium alginate beads
- Compare immobilizing enzyme in alginate with the free enzyme
- Record your observation

Refer to the links below for more information about preparation of enzyme immobilization:

- https://www.youtube.com/watch?v=36RXIjHMC6g
- https://www.youtube.com/watch?v=fq2CflK6wCk

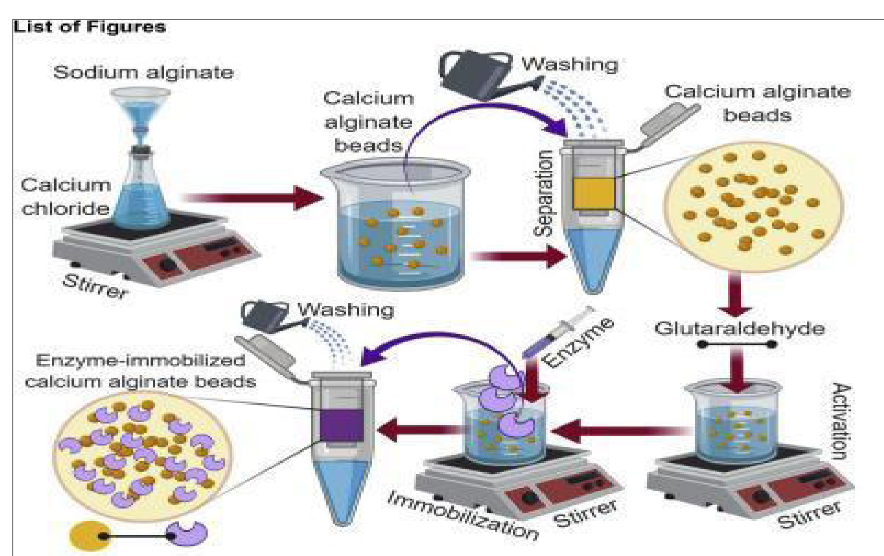
Reflection questions

1. What did you observe when sodium alginate was added to calcium chloride?
2. What does the presence of glucose in two tubes indicate?

Data recording

Activity	Free enzyme	Immobilized enzyme
Addition of sodium alginate to calcium chloride	• Absence of beads • Can only be used once	• Formation of insoluble calcium alginate (small beads) • Can be used again and again
Test of glucose	• Appearance of glucose	• Appearance of glucose
Effect on temperature	• Denature at the temperature above 60^0C	• Continue to work until 80^0C.
Separate from substrate	• Difficulty	• Easy
stability	• Less stable and more affected by temperature	• Stable and more resistant to temperature

Interpretation of results and conclusion



Immobilizing an enzyme allows an increased resistance to variables such as temperature or pH. It also allows the enzymes to be stationary throughout the process, which makes it much easier for them to be separated and reused. Nevertheless, the qualities of the enzymes produced, largely depend upon the carrier type and the process used to immobilize them.

The performance of physical binding is carried out under ambient conditions and results in high loading enzymes. The main demerit of adsorption immobilization process is very poor stability, due to the weak binding of enzyme and support may cause loss of enzyme molecules at the time of operation and washing. When sodium alginate comes to contact with calcium chloride (one drop at time) they form insoluble calcium alginate (small beads) that contain lactase enzymes that have not been immobilized. By adding the milk sample to 2 different tubes (free enzyme's tube and immobilized enzyme's tube) and test their glucose level, it shows the presence of glucose and galactose in both tubes, which indicate that the lactase enzymes have broken down the lactose in the milk into glucose and galactose. However, there is more glucose present in the milk with free enzymes compared to immobilized enzymes. During washing, the immobilized enzymes are easy to separate from the substrate and can be used again and again while it is difficult to separate the free enzyme with substrate and can only be used once.

Guidance on evaluation

Assess learners in doing experiment by themselves and interpreting their findings and ask them some questions such as:

1. What do you understand by enzyme immobilization?
2. How does immobilization affect enzyme performance?

UNIT: 11 PRINCIPLES OF GAS EXCHANGE SYSTEMS

Experiment 11.1: Carrying out an experiment to measure the diffusion rate into different sizes of gelatin tubes

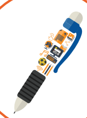
This experiment can be done when teaching the concept or topic related to diffusion.

Rationale

Diffusion allows movement of molecules, atoms, ions from high concentrations to low concentrations across the cell membrane. This allows cells to gain useful substances required to produce energy essential for growth. This experiment aims at measuring the rate of diffusion across the cell membrane represented by gelatin tubes.

Objective

To measure the rate of diffusion across gelatin tubes



Materials

- Hydrochloric acid
- Gelatine
- Tile
- Test tube
- Rubber
- Bung
- Scalpel
- Ruler
- Stopwatch
- Measuring cylinder.

Experiment set up

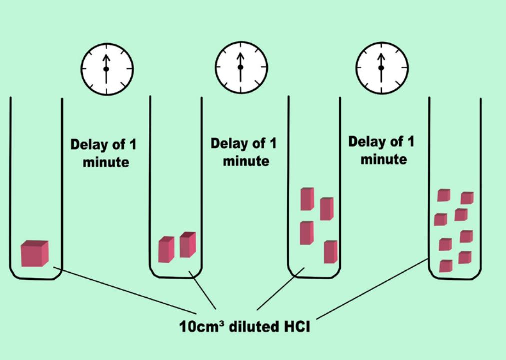


Fig.11.1: Diffusion across gelatin tube

Procedures and steps of the experiment

- Cut up the pieces of gelatins into the same size gelatin cubes using the scalpel, tile and ruler accurately
- Take one piece of the gelatin tube and cut it into two pieces of the same size
- Take another one and cut it into 4 pieces of the same size
- Take another one and cut it into 8 pieces of the same size
- Prepare 4 the test tubes
- Measure out 30 ml of hydrochloric acid using the measuring cylinder and pour it into each test tube
- In the test tube one, put the entire piece of gelatin
- In the test tube two, put 2 pieces of gelatin prepared previously
- In test tube three, put 4 pieces of gelatin previously prepared
- In the test tube four, put 8 pieces of the gelatin previously prepared
- Quickly put the bung on the top of each test tube and start the stopwatch
- Observe changes in each test tube for about 10 minutes

Reflection question

What is the time observed for Hydrochloric acid to diffuse across the gelatine tube (s)?

Data recording

Test tube	Observation time for diffusion
Test tube 1 with one gelatin cube	The diffusion delayed starting
Test tube 2 with two gelatin tubes	The diffusion was faster than in the test tube 1
Test tube 3 with four gelatin tubes	The diffusion was faster than in the test tube 2
Test tube 4 with eight gelatin tubes	The diffusion was faster than in the test tube 3

Interpretation of results and conclusion

The larger the surface per volume ratio of the gelatin the faster it is the acid to diffuse completely. This is because the more gelatin is exposed to the acid particles the more, they collide and more they diffuse. As conclusion, the diffusion depends on the surface per volume ratio.

Source of errors

The cubes stuck together and alter the surface to volume ratio; to prevent this from happening the cubes should be used separately. Further, remember to cover each test tube with the bung to avoid the evaporation of the HCl.

Guidance on evaluation

Assess learners for measuring the diffusion rate into different sizes of given materials and ask questions such as:

1. How does the diffusion change in terms of surface volume ratio?

Experiment 11.2: Observation of permanent slides of gaseous exchange surface of different organisms and identify common characteristics

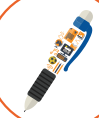
This experiment can be done when teaching the concept or topic related to gaseous exchange system

Rationale

Alveolus is the functional unit of gaseous exchange where the oxygen is taken into the blood and carbon dioxide gets out. This experiment investigates the prepared slides of gaseous exchange surfaces to identify common characteristics for fish, mammals, and insects.

Objective

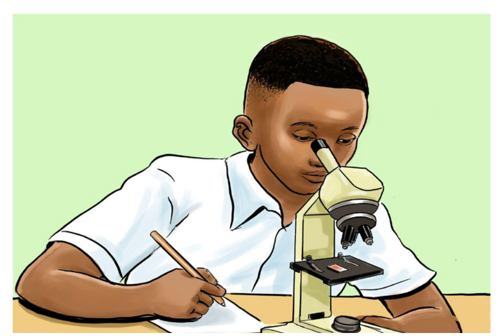
To identify the common characteristics of gaseous exchange surfaces for fish, mammals, and insects



Materials

- Microscope
- Permanent slides of fish, mammals, and insect respiratory surfaces
- Pencil
- Rubber
- Notebook

Experiment set up



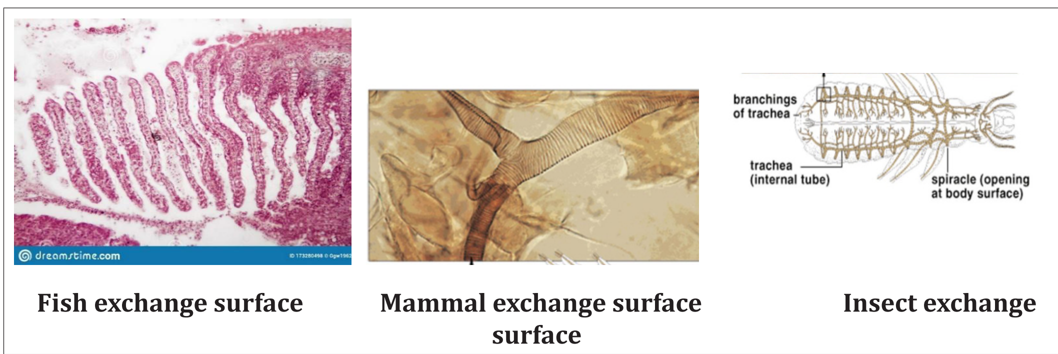


Fig.11.2: Investigating gaseous exchange surface

Procedures and steps of the experiment

- Put a permanent slide of fish showing gaseous exchange surface on the microscope
- Observe the prepared slide starting from lower to higher magnifying objective
- Draw your observation
- Repeat the same process with the permanent slides of gaz exchange surface for mammals and insects

Reflection question

Is there any difference in characteristics of the respiratory surface of fish, mammals, and insects?

Data recording

Organism	Observation	Common characteristics
Mammals	Alveoli	• Large surface area relative to the volume of organism • They are thin and so have a short diffusion pathway. • They have a moist surface where gazes can dissolve first before they diffuse in or out.
Fish	Gills	
Insect	Spiracles	

Interpretation of results and conclusion

The surface where gaseous exchange occurs in organisms are very different. The gas exchange in fish is very efficient because of the large surface area of the gills, large surface area of blood capillaries, the short distance required for diffusion, the outer layer of the gill filament and the capillary walls are just one cell thick. Gaseous exchange in insect occurs through the system of internal tubes, tracheal system, the finer branches which extend to all parts of the body and may become functionally intracellular muscle fibers. Gaseous exchange in mammals occurs only in alveoli. They are made of thin walled parenchyma cells, typically one- cell thick, that look like tiny bubbles within the sac. Alveoli are in direct contact with capillaries of the circulatory system. All gas exchange surfaces have the following characteristic in common: large surface area relative to the volume of the organism they are thin and so have a short diffusion pathway, they have a moist surface where gazes can dissolve first before they diffuse in or out.

Guidance on evaluation

Assess learners on the common characteristics of respiratory surface in different organisms and ask questions such as:

1. What are common characteristics of gaseous exchange surfaces in mammals, fish and insects?

Experiment 11.3: Dissect fish gills to observe the surface area for gaseous exchange

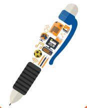
This experiment can be done when teaching the concept or topic related to gaseous exchange of fish

Rationale

Fish gills are organs that allow fish to breathe underwater. Most fish exchange gases like oxygen and carbon dioxide using gills that are protected and located under gills cover on both sides of the pharynx. Anatomically gills are tissues that look like short threads, protein structures called filament. They allow fish to get oxygen dissolved in water.

Objective

To dissect a fish for observing the structure of gills



Materials

- Head of a flesh fish (Tilapia)
- Scissor
- Scalpel
- Tweezers
- Gloves
- White tile
- Petri dish

Experiment set up

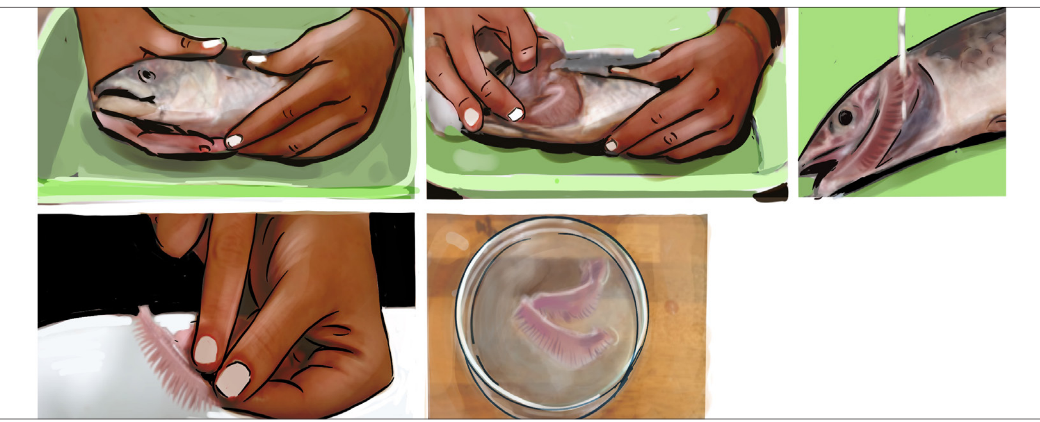


Fig.11.3: Observing structure of gills

Procedures and steps of the experiment

- Watch the video on the dissection of a fish for observing gills on this link: Fish Head Gills Gas Exchange System Dissection GCSE A Level Biology NEET Practical Skills - Bing video
- Use a scalpel, tweezers and scissors and place the fish on a tray
- Remove the operculum to reveal the gill filaments
- Remove one of the gill arches using a scalpel to take a closer look
- Place the removed gill in a petri dish containing water
- Observe carefully the removed gill

Reflection question

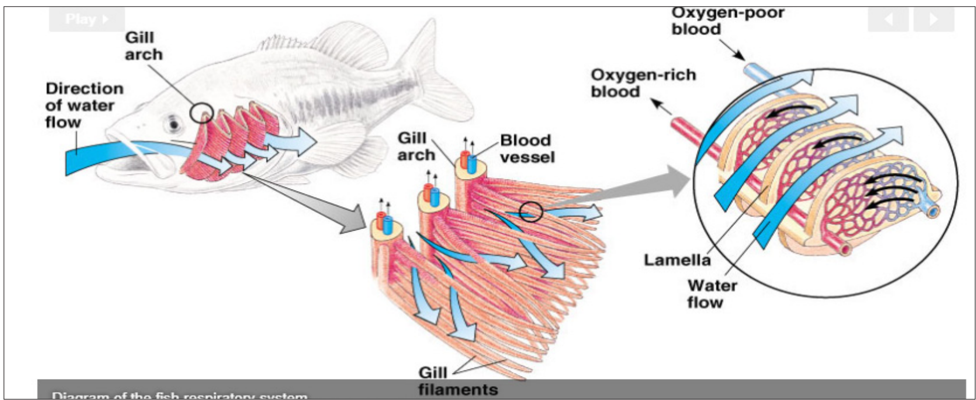
Do you think gills have characteristics that adapt them to gaseous exchange?

Table of data recording

Item	Observation
Gills color	• Reddish
Gills structure	• Numerous folds • Filaments covered by an array of lamellae
Effect of water	• Gills inflate

Interpretation of results and conclusion

Gills control gas exchange in fish. They are vital organs situated at either side of the fish's head and each gill consists of a row of filaments. Each filament is covered by an array of lamellae containing capillaries that supply blood to gills. This maintains concentration gradient so that diffusion of gases becomes efficient. Another adaptation of the fish would be the number of these gill filaments.



Guidance on evaluation

Assess learners on principles of gas exchange in fishes by asking questions such as:

What are the features that contribute to the efficiency of the gills during fish respiration?

Experiment 11.4: Dissect mammals to observe the lungs and identify their adaptations for gaseous exchange

This experiment can be done when teaching the concept or topic related to respiration of mammals.

Rationale

Respiration in mammals depends on the circulatory system. Oxygen is taken in and carbon dioxide is released outside of the cells. Lungs are the sites of oxygen and carbon dioxide exchange. It is essential to explore the structure of the lungs of mammals through dissection to understand their adaptations for gas exchange.

Objective

To dissect the rat for observing the adaptation of lungs to gas exchange

Materials

- Rat
- Ethanol
- Cotton wool
- Backet
- Scissors
- Prod
- Pins
- Tweezers
- Blade
- Gloves
- Dissecting board

Experiment set up

Fig.11.4: Observing rat lungs adaptation

Procedures and steps of the experiment

- Put the cotton wool and ethanol in bucket
- Put the rat in the bucket containing ethanol
- Set up your work bench and pin down the rat
- Place a pin through the paws and tail. If your pins can't penetrate the rats' limbs, tie a string to the rats' limbs and pin the string down
- Make an incision at the centre bottom of the rat and cut towards the top
- Make sure not to puncture the abdominal wall
- Peel back the skin and pin it to the board
- Make an incision at the bottom of the abdominal wall, cut up the abdominal wall till you feel some resistance. Cut the digestive track out
- Observe the respiratory movements
- Completely remove the lungs,
- Dissect the lungs to observe the internal structure
- Record your observations

Reflection question

Do the lungs in mammals have the same structure as gills observed in fish?

Data recording

Lungs' structure	
Items	**Observations**
Number of lungs	Two lungs: one left and one right
Colour	Pinkish white
Lobes	The right lung has 4 lobes and the left one has 1
Shape	Cone shaped
Effect of gas	Expand when full of air and relax when the air is released (inflate of lungs)
Lung tissue	Spongy

Interpretation of results and conclusion

The lungs of the rat are paired cone shaped organs like in other mammals. They lie on each side of the heart in the chest cavity. They have a spongy tissue and moist surface where gazes can dissolve first before they diffuse in or out.

Rat lungs differ from humans' in the division of lobes. The left lung of the rat contains one lobe while the right contains 4 lobes.

Like other mammals, the rat trachea function is to bring air to the lungs, splitting into two branches in the chest cavity. The Bronchus is the passage through which the air enters the lungs. Bronchioles are branches of bronchus supplying air to alveoli which are tiny air sacs located at the end of bronchioles, in which gas exchange occurs.

Precautions

The learner must be able to know that dissection is different from cutting. They have to dissect with the aim of observing connections among parts and observe their structures. You can use other mammals available in your location like rabbits.

Guidance on evaluation

Assess the learners on the structure and adaptations of mammalian lungs by asking questions such as:

1. Describe the structure and adaptation of a mammalian lung.

UNIT: 12 GAS EXCHANGE IN PLANTS

Experiment 12.1: Draw stomata structure as observed under a light microscope

This experiment can be done when teaching the concept or topic related to gas exchange in plants.

Rationale

Stomata refer to the minute pores that can be found on the epidermis of a leaf. These pores vary in size and allow for the movement of water and gases in and out of the intercellular spaces. Stomata, surrounded by guard cells, play a major role in protecting the plant against water loss and regulating the gas exchange with the external environment. The small pores on the surfaces of leaves and stalks, regulate the flow of gases in and out of leaves and thus plants as a whole. It is essential to observe the structure of stomata under the light microscope.

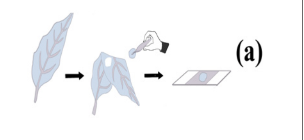
Objective

To observe the structure of stomata under a light microscope.

Materials

- Succulent Leaf
- Light microscope
- Razor blade
- Forceps
- Dropper
- Glass slides and cover slips
- Iodine solution
- Distilled water

Experiment set up



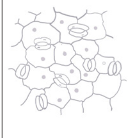
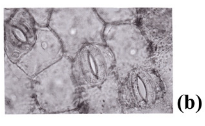



Fig.12.1: Observing stomata structure

Procedures and steps of the experiment

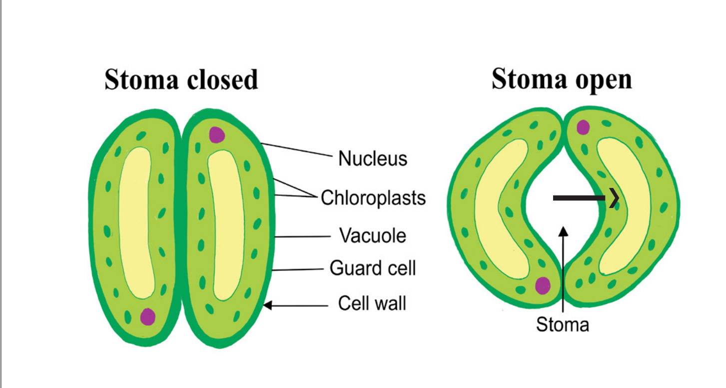
- Peel off gently the lower epidermis of a leaf
- Using a forceps to smear the epidermis on a slide
- Add one drop of iodine solution
- Put on a cover slip
- Observe under light microscope starting by lower magnification
- Draw your observations
- Reflection questions
- How does the observed structures look like?

Data recording

Item	Observation
Shape	A kidney-shaped epidermal cell along with an opening in the center

Interpretation of results and conclusion

Stomata are microscopic pores in the epidermis of the leaves and stems of terrestrial plants. They have kidney shape and have many chloroplasts. Stomata plays a function in gas exchange between plants and the atmosphere and in transpiration.



Source of errors

Using dirty slides or coverslip with air bubbles, imply an invisible image, indeed, without using lower epidermis (enough to allow light to pass through) it also implies invisible image

Guidance on evaluation

Assess learners on stoma structures and ask questions like:

What is the main difference between stomata and the guard cells?

Activity 12.2: Differentiate leaves of aquatic and terrestrial plants

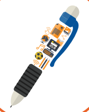
This activity can be done when teaching the concept or topic related to the structure of aquatic and terrestrial plants.

Rationale

Terrestrial plants are defined as any plant that grows on the land. By contrast, aquatic plants are plants that thrive when their roots are submerged in water. Terrestrial plants get plenty of air, so they usually have stomata on the bottoms of their leaves. Aquatic plants have their leaves near or under the water, but they also need to breathe. This experiment aims at differentiating the leaves of aquatic and terrestrial plants

Objective

To differentiate leaves of aquatic and terrestrial plants



Materials

- Leaves of aquatic plant
- leaves of terrestrial plants
- Papers or print news papers
- Magnifying lens

Experiment set up

Fig.12.2: Aquatic and terrestrial plants

Procedures and steps of the experiment

- Cover the desk with paper or newsprint
- Put both leaves on the paper
- Trace around both leaves
- Observe the types of the leaves with the magnifying glass.
- Record your observation

Reflection question

How do land plants' leaves differ from aquatic ones?

Data recording

	Observation	
Items	**Color of leaves**	**Position of the stomata**
leaf of terrestrial plant	Green	Lower side of the leaf
leaf of aquatic plant	Green	Upper side of the leaf

Interpretation of results and conclusion

Aquatic plants have stomata on the upper side or upper epidermis of the leaves except for submerged plants. This type of permanently opened stomata is present in floating and emergent plants like water hyacinth, duckweed, water primrose, bog moss etc. Aquatic plants have their leaves near or under the water, but they also need to breathe. Plants that float on the surface of the water have their stomata on top, where they have access to air.

Terrestrial plants get plenty of air, so they usually have stomata on the bottoms of their leaves. Land plants' leaves have a thick waxy cuticle to conserve water.

Guidance on evaluation

Assess learners on differences between aquatic and terrestrial plants' leaves and ask some questions like:

How can you differentiate aquatic and terrestrial plants based on the position of stomata?

UNIT: 13 GROWTH AND DEVELOPMENT IN PLANTS AND ANIMALS

Experiment 13.1: Investigation of the effect of temperature on development of frog eggs

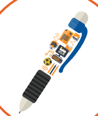
This experiment can be done when teaching the various stages of developments in frogs.

Rationale

A frog is an amphibian that lays eggs in water. The eggs hatch into aquatic larvae called tadpoles that have tails and internal gills. The life cycle is completed when they metamorphose into adults. The development of eggs depends on the environmental factors such as temperature. This experiment aims at highlighting the effects of temperature on the development of eggs of a frog.

Objective

To investigate the effects of temperature on development of frog's eggs



Materials

- Collected frog egg from a pond
- Bucket to extract frog egg from a pond
- Temperature-controlled chambers containing 2 litres of water
- Outside container with an average temperature of 11oC
- Spatula

Experiment set up

Fig.13.1: Investigating effect of temperature on development of frog eggs

Procedures and steps of the experiment

- Collect the frog eggs from pond (egged in water);
- Use a bucket to extract frog's egg from a pond water;
- Using the spatula place the eggs in temperature-control chambers containing 2 littres of water,
- Set them at different temperatures lower as 9°C, middle as 21°C, high as 26 °C.;
- Using spatula place other eggs in an outside container with 2 littres of water
- Incubate for a number of days by observing regularly to see the change;
- Record your observations

Reflective question

What might be the effect of temperature on the development of the frog eggs?

Data recording

Temperature	9°C	21°C	Room temperature	26°C
Hatching period	15 days	13 days	11 days	4 days

Interpretation of results and conclusion

Temperature is one of the factors affecting the development of frog's eggs. The hatching period decreases with the increase of temperature to the optimum.

Source of errors

Improper setting of temperature and wrong recording of growth change will affect the results.

Guidance on evaluation

Assess learners on the effect of temperature on development of frog's eggs and ask some questions like:

Discuss the effects of temperature variation on the development of frog's eggs

Activity 13.2: Carry out research on monocot and dicot plants to compare primary and secondary growth of their stems, root and meristems

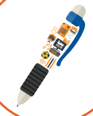
This activity can be done when teaching the concept of plant growth development, especially primary and secondary growth.

Rationale

Plant's primary growth refers to an increase in length of the shoot and the root. It results from the cell division in the shoot apical meristem. Secondary growth is characterized by an increase in thickness or girth of the plant and is caused by cell division in the lateral meristem. All plant species perform primary growth, and most monocots only show primary growth, whereas many dicots have primary and secondary growth. This experiment helps us to observe and compare the primary and secondary growth of stems, shoots and meristems in monocot and dicot.

Objective

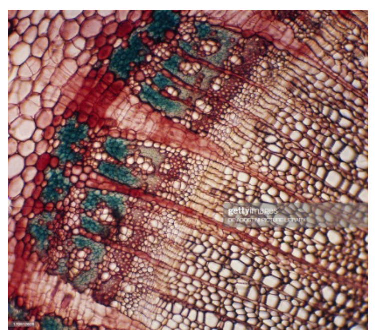
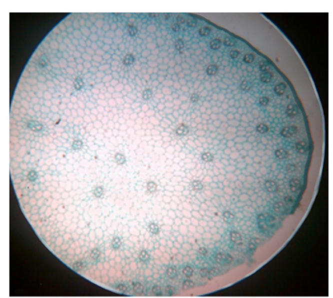
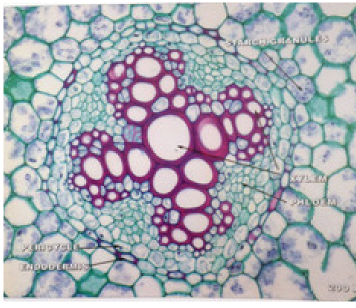
To compare the primary and secondary growth in monocot and dicot's stems, roots and meristems.



Materials

- Monocots plants
- Dicots plants
- Magnifying lens
- Razor blade
- Stem cut

Experiment set up

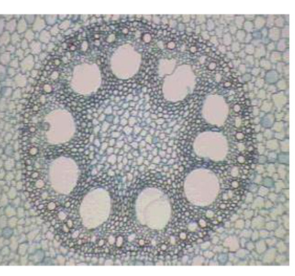


Fig.12.2: Comparing primary and secondary growth in monocot and dicot

Procedures and steps of the experiment

- Bring the woody and monocot stem;
- Cut the wood stem in transverse sections;
- Do the same for the monocot stem
- Place the woody stem section and monocot stem on a table
- Observe using a magnifying lens and note down the observations
- Using a cooled pencil highlight the cambial ring in woody stem
- Highlight the primary and secondary xylem and phloem
- Compare observations on woody stem and monocot stem.

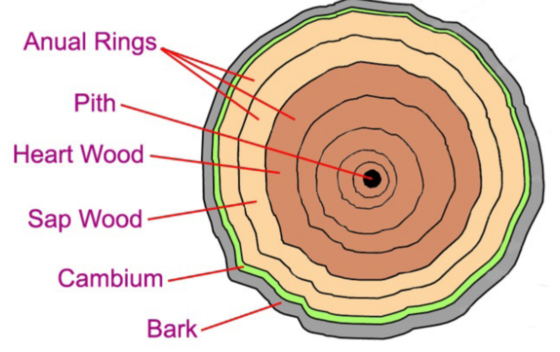
Reflection question

Is there any difference between the primary and secondary growth in monocot and dicots?

Data recording

Type of growth	Observation	
	Monocot	Dicot
Primary	**Root**: No cambium	**Root:** Presence of cambium
	Stem shows epidermis, hypodermis, ground tissue and vascular bundles.	**Stem** shows epidermis pith, pericycle, hypodermis, cortex, endodermis, Cambium, Xylem and phloem
	Meristem: apical meristem and intercalary meristem	**Meristem**: apical meristem and lateral meristem
Secondary	**Root** • No secondary growth • They are more roots at the shoot (radicle) • No cambium	**Root** • Secondary growth present • Presence of cambium • Secondary xylem • Secondary phloem • Taproot structure,
	Stem No secondary growth	**Stem** Secondary growth secondary vascular tissues periderm.
	Meristem The cambium appears in a direct continuation of a primary thickening meristem.	**Meristem:** lateral meristem made of vascular cambium and cork cambium.

Interpretation of results and conclusion



a. Primary and secondary growth in dicot's stems

b. Primary growth in monocot's stem

All plant species perform primary growth. Most monocots only show primary growth, whereas many dicots have primary and secondary growth.

The secondary growth occurs in dicot stems due to the presence of a secondary meristem called cambium. Cambium is a group of actively dividing cells that are present in between xylem and phloem. This cambium gives rise to secondary xylem and secondary phloem which increases the girth.

In general, monocots do not undergo secondary growth. If they do increase in girth (like palm trees and yucca plants), it does not result in the development of a secondary xylem and phloem, since monocots don't have vascular cambium. An increase in girth without secondary growth is referred to as anomalous thickening.

Guidance on evaluation

Assess learners on the comparison between monocots and dicots. Ask some questions like:

1. Explain the role of cambium;
2. Justify why monocotyledons do not grow in width while dicotyledons do

Activity 13.3: Carry out experiment on hypogeal and epigeal germination

This experiment can be done when teaching types and stages of germination

Rationale

There are two types of seeds germination: hypogeal and epigeal. Epigeal germination refers to the germination where seed cotyledons rise above the soil while hypogeal germination refers to the germination where seed cotyledons remain in the soil. In this experiment, we are going to plant seeds, observe their germination and differentiate hypogeal from epigeal germination.

Objective

To compare hypogeal and epigeal germination.

Materials

- Bean seeds or soybean seeds,
- Sorghum or maize grains,
- Water
- Plastic containers
- Fertile soil

Experiment set up

Fig.13.3: Comparing hypogeal and epigeal germination

Procedures and steps of the experiment

- Fill each container with fertile soil
- Put two grains of maize in the container labelled A and two seeds of bean in the container labelled B
- Pour some water in each container simply to moisture the soil
- Put both containers A and B in a secured place
- Record your daily observations changes

Reflection question

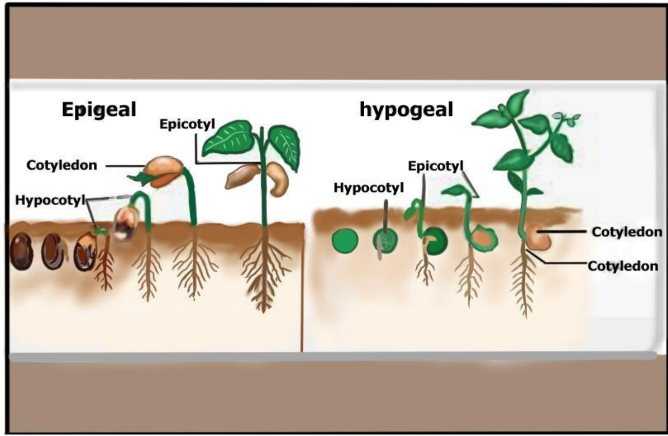
Is there a difference between the germination of the maize and bean seeds?

Data recording

Seed type	Observation
Maize	Cotyledons remain underground
Bean	Cotyledons are carried above the soil

Interpretation of results and conclusion

There is a difference between germination of bean and maize seeds. In beans cotyledons are carried above the soil, it is called epigeal germination while in maize seeds cotyledons remain underground, it is called hypogeal germination.



Source of errors

Planting the old seeds, shortage of water, unfertile soil

Guidance on evaluation

Assess learners on epigeal and hypogeal germination and ask some questions like:

1. What are the major differences between hypogeal and epigeal germination?
2. What are possible conditions for germination?

Experiment 13.4: Carry out investigation on phototropism and geotropism in plants

This experiment can be done when teaching the concept or topic related to plant movement and response to environment

Rationale

One of the characteristics of living things is their ability to respond to the environmental conditions. In plants, this response is not as quick as it is for animals. This experiment helps to investigate how plants respond to sunlight and gravity (gravitropism).

Objective

To investigate phototropism and geotropism (gravitropism) in plants

Materials

- Four bean seed;
- four pots or other container;
- Three boxes;
- Fertile soil
- Bean seeds that have been soaked in water overnight;
- Paper towels;
- Elastic bands;

Experiment set up

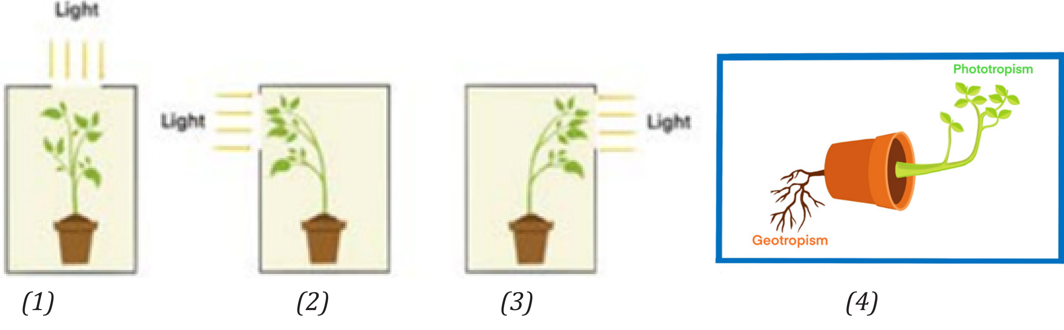


Fig.13.4: Tropic responses

Procedures and steps of the experiment

- Prepare four pot plant or other container
- put the soil into each pot plant or another container
- Plant the soaked bean in each pot
- Wait for the seed to germinate
- Put the plants in a place where they can get light from one side
- Place the pot number four in the horizontal direction
- Record your observation focusing on shoot and root direction

Reflection question

Does the light have the same effects on root and stem?

Data recording

Potted plant	Observation
1	Growth of shoot toward light source upright
2	Growth of shoot toward light source on the right side
3	Growth of shoot toward light source upright on the left side
4	Growth of root toward gravity and shoot toward light

Interpretation of results and conclusion

Phototropism is a directional growth depending on the direction of the light source. Growth towards a light source is a positive phototropism, while growth away from light is called negative phototropism. On the other hand, gravitropism is the response of plants' stems and roots to the effect of gravity. Plant stems grow upwards, against gravity and this is called negative gravitropism. However, plant roots grow downwards, in the direction of gravity. This is called positive gravitropism. In pots 1, 2, 3 and 4 there is positive phototropism of the stem and positive geotropism of the roots.

Source of errors

Placing a plant where there is no right stimuli

Guidance on evaluation

Ass learners on phototropism and gravitropism by asking questions such as:

What is the stimulus in phototropism and in geotropism?

UNIT: 14 SUPPORT AND LOCOMOTION

Experiment 14:1 Carry out an observation of the arrangement of muscles in fish (myotomes) to relate their structure to locomotion

This experiment can be done when teaching the concept or topic related to the arrangement of muscles in fish (myotomes).

Rationale

Undulatory swimming in fish is powered by the segmental body musculature of the myotomes. Power generated by this muscle and the interactions between the fish and the water generate a backward-travelling wave of lateral displacement of the body and caudal fin. The fish vertebral column is flexible and can move from side to side by contraction and relaxation of muscles (myotomes).This experiment aims to observe the arrangement of muscles and relate their structure to locomotion in fish.

Objective

To observe the arrangement of muscles in fish (myotomes) and relating their structure to locomotion.

Materials

- Tray/ Dissection board
- Cutting device (razor blade, sharp craft scissors, Scalpels)
- Cotton wool
- Flesh fish
- Forceps
- String
- Gloves

Experiment set up

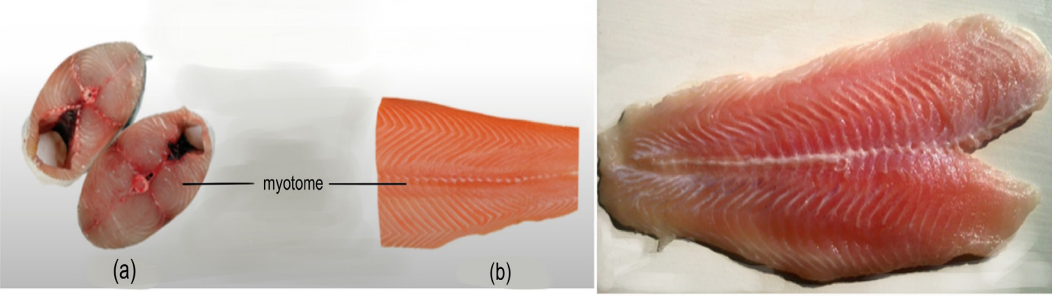


Fig.14.1: Observing arrangement of muscle in a fish

Procedures and steps of the experiment

- Putt on the gloves and grab your tray
- Place the flesh fish in tray or dissection board
- Expand the fins of fish.
- Cut it by cross section or longitudinal section
- Observe the arrangement of myotomes

Reflection question

How is the structure of myotomes in fish contribute to their locomotion?

Data recording

Type of muscles	Observations
Myotome	W-shaped muscle segment

Interpretation of results and conclusion

W-shaped muscle segment enables the fish to whip its tail, as the myotome on the right contracts, the one on the left relaxes. The tail will be whipped to the right. On the contrary, when the left myotome contracts, the right relaxes and the tail is whipped to the left. Alternating waves of contraction and relaxation occur along the myotome. The action causes parts of the body to move side to side, pushing water backwards and sideways, and hence moving the fish forward.

Guidance on evaluation

Assess learners on the impact of myotomes' structure to the locomotion in fish by asking questions like:

How do myotomes in fish influence the locomotion?

Experiment 14:2 Carry out observation on external features (fins) and internal features (swim bladder) of a fish (tilapia) that enable its locomotion.

This experiment can be done when teaching the concept or topic related to the movements and support of fish.

Rationale

Living organisms, particularly animals, need to move from one place to another. Locomotion in animals is an action of muscles on the skeleton. Fish like other aquatic animals are adapted to such habitat in terms of locomotion due to its structural adaptive features particularly swim-bladder and fin. This experiment will enable learners to observe external features (fins) and internal features (swim bladder) of a fish (tilapia) that enable its locomotion.

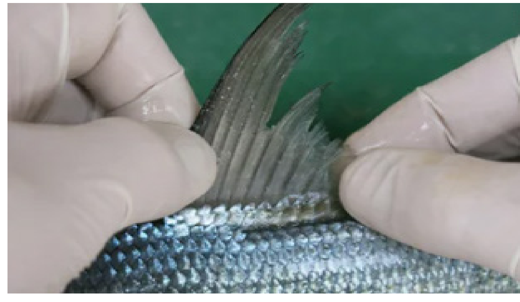
Objective

To observe fins and swim bladder of a fish enabling its locomotion.

Materials

- Tray/ Dissection boar
- Cutting device (razor blade, sharp craft scissors, Scalpels)
- Wood skewer for prodding (optional)
- Cotton wool
- Flesh fish
- Forceps
- String
- Gloves

Experiment set up



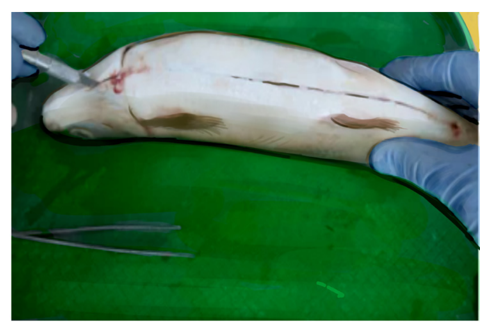
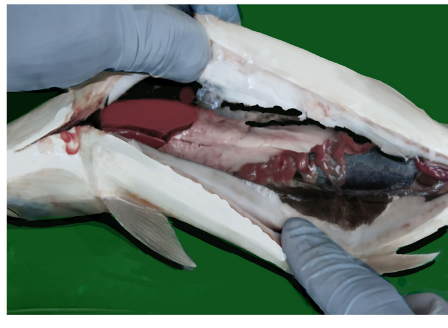
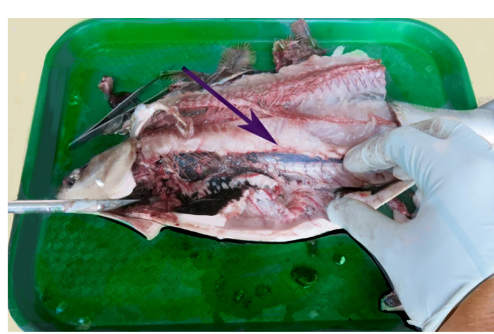




Fig.14.2: Observing fins and swim bladder in a fish

Procedures and steps of the experiment

- Putt on the gloves and grab your tray
- Place the flesh fish on the tray or dissection board
- Observe the structure of fins.
- Dissect following the ventral side from anus
- Open up and observe the gut
- Identify the swim bladder in the gut of fish

Reflection question

Do fins and swim bladders look the same?

Data recording

Parts	Observations
Fins	Made of bony spines Different types (caudal, dorsal, pelvic, anal)
Swim bladder	Consists of two gas-filled sacs located in the dorsal portion of the fish

Interpretation of results and conclusion

During locomotion, the tail or caudal fin increases the amount of water, and this provides much of the push during swimming, in this movement, pelvic fins bring about downward and upward movement. Internally, the fish has a swim bladder that helps it to change its buoyancy as it alters the gases pressure in the bladder so that the fish can float at any depth in water without using its muscles. It also helps fishes to maintain the same density as the surrounding water.

Source of errors

Damage of internal organs during dissection and using a non-fresh fish

Guidance on evaluation

Teacher may assess learners by asking questions such as:

What is the difference between fin and swim bladder found in fish?

Experiment 14:3 Carry out a microscopic observation of Amoeba and Paramecium from a culture medium to identify their mode of locomotion

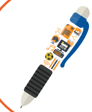
This experiment can be done when teaching the concept or topic related to support and locomotion in protozoa

Rationale

Non-muscular locomotion is identified in living organisms that belong to the Protoctista kingdom. Depending on the individual organism, locomotion is either amoeboid, ciliary, flagellated or euglenoid type. This experiment will help learners to know how to identify the mode of locomotion in Amoeba and paramecium.

Objective

To study the mode of locomotion of amoeba and paramecium by microscopic observations.

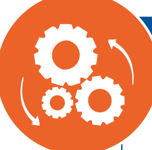


Materials

- A sample of water collected from a pond
- Pondweed from a pond
- Petri dish
- A compound light microscope
- Water
- A dropper
- Culture media

Experiment set up

Fig.14.3: Observing amoeba and paramecium locomotion



Procedures and steps of the experiment

- Using a dropper, place a few drops of the sample on a microscope glass slide (a sample of pond water or a small sample from the culture).
- Gently cover the sample with a cover slip
- Place the slide on the microscope stage for viewing
- Record your observation

Reflection question

Is there any difference between the mode of locomotion in Amoeba and Paramecium?

Data recording

Specimen	Observations
Amoeba	Locomotion by means of pseudopodia
Paramecium	Locomotion by means of cilia

Interpretation of results and conclusion

Amoeba moves by amoeboid locomotion by putting out pseudopodia. Amoeboid locomotion is controlled by cytoplasmic streaming and between a gel and sol state. Paramecium moves by means of cilia. It can move forward and backward. While moving forward, cilia strongly move from anterior to posterior.

Precaution: The student may either observe a sample of pond water directly to identify the organism or conduct a simple culture to grow and increase the number of amoeba.

Source of errors

Student should know that all samples from pond water are not contaminated by amoeba.

Guidance on evaluation

Assess learners by asking them to differentiate the locomotion of amoeba and paramecium.

Differentiate the mode of locomotion of the amoeba and paramecium

UNIT: 16 ASEXUAL REPRODUCTION IN PLANTS

Experiment 16:1 Carry out a microscopic observation of Amoeba and Paramecium from a culture medium to identify their mode of locomotion

This experiment can be done when teaching the concept or topic related to asexual reproduction in lower organisms.

Rationale

Asexual reproduction is the process where a new offspring is produced without gamete formation. New organisms are produced rapidly and are genetically identical to their parents. It is commonly found in unicellular organisms, plants, and lower animals like Sponges, Hydra etc. Some common modes of asexual reproduction are fission, budding, fragmentation, regeneration, spore-formation, and vegetative reproduction. Since asexual reproduction is commonly observed in lower animals and lower plants; Biologists use microscopes and permanent slides to examine how the process of asexual reproduction takes place.

Objective

To examine permanent slides on asexual reproduction in lower organisms.

Materials

- Compound microscope;
- Permanent slides of budding in yeast

Experiment set up

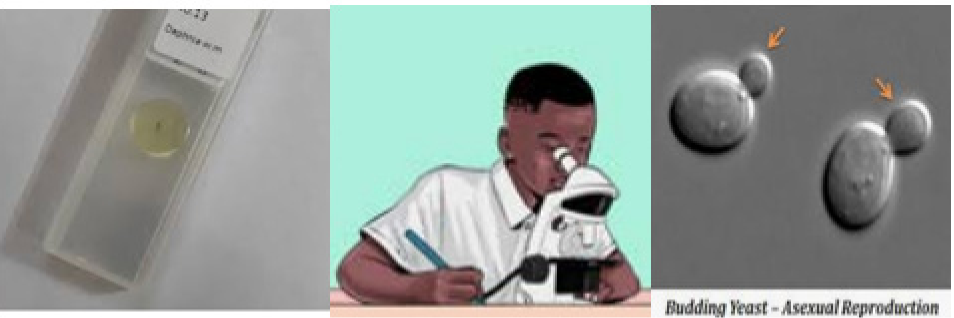


Fig.16.1: Microscopic observation of asexual reproduction in yeast

Procedures and steps of the experiment

- Install the Microscope;
- Place the permanent slide under a compound microscope;
- Focus the slide, first under low and later under high magnification;
- Draw your observation

Reflection question

Do lower organisms reproduce asexually in the same way?

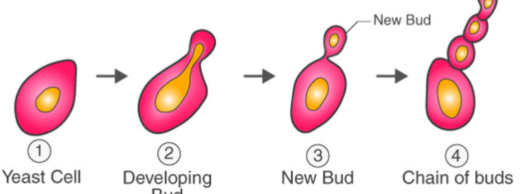
Data recording

	Observations
Permanent slide of yeast	Development bud stage, Formation of new bud stage Formation of buds chain

Interpretation of results and conclusion

In the observed prepared slide, the yeast cell is divided by budding resulting in a 'mother' and 'daughter' cells. The offspring organism is smaller than the parent.

Stages observed in the yeast are described in the following figure.



Source of errors

Using expired permanent slides may imply an invisible image.

Guidance on evaluation

Assess learners by asking questions such as:

1. How do yeasts reproduce?
2. Give examples of other organisms reproducing in the same way as yeast

Experiment 16:2 Vegetative propagation of at least two plant species by stem cutting suckers or layering (cassava, Banana, hibiscus)

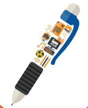
This experiment can be done when teaching asexual reproduction in plants specifically vegetative propagation by stem cutting, suckers or layering

Rationale

The most common form of asexual reproduction in plants is called vegetative propagation. Use of cuttings is an example of artificial propagation. It is currently applied in agriculture and horticulture. The main advantage of vegetative propagation methods is that the new plants contain the genetic material of only one parent, so they are essentially clones of the parent plant. The method relies on the use of pieces of vegetative plant parts such as stems, leaves, or roots to perpetuate the parent plants

Objective

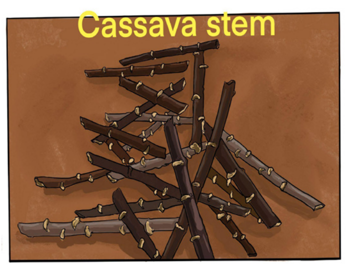
To prove that asexual reproduction can take place in plants by use of cutting method or layering.



Materials

- Moist soil
- Cassava stems,
- Banana Rhizome
- Sharp knife

Experiment set up



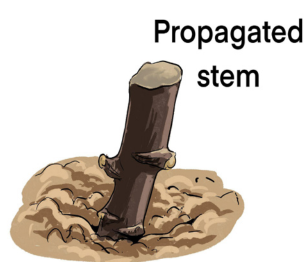


Fig.16.2: Asexual reproduction by cutting and sucker

Procedures

Collect clean and healthy stems of cassava

- Using a sharp knife, cut cassava stems into small cuts (20-25cm)
- Plant them in moist soil in the garden and wait for about 13 days
- Observe the development of roots and leaves at nodes.
- For banana, buy or dig up some banana suckers from the banana plantation

- Use a sharp shovel to remove the sucker with a piece of corm attached.
- Rinse dirt from the roots and dry in the shade for a couple of days
- Dig a $2m^2$ hole, 50cm deep.
- Plant the banana sucker in moist soil
- Observe sucker developing from a lateral bud

Reflection question

Do bananas and cassava have the same mode of propagation?

Data recording

Specimen	Propagation organ	Observations
Cassava	Stem	Development of roots toward soil and leaves at nodes (plants increase in size)
Banana	Sucker /Rhizome	Sucker develops from a lateral bud on the rhizome and emerges ...

Interpretation of results and conclusion

Vegetative propagation is an asexual method of plant reproduction. This can occur through fragmentation and regeneration of specific vegetative parts. Cassava is generally propagated vegetatively by planting properly lignified stem cuttings in soil. Vegetative multiplication is a simple approach and has the advantage of producing new plants. A sucker in banana is a shoot that develops from a lateral bud on the rhizome and emerges from the soil usually near the parent plant.

Source of errors

The inversion of the cassava stem by putting the nodes in the soil will give negative results. Further, planting the banana without fresh rhizome will lead to failure in growth and increase in size.

Guidance on evaluation

1. Ask learners to identify other plants that can be propagated by cutting methods.

Experiment 16:3 Field study on natural and artificial propagation methods

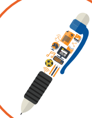
This filed study can be conducted when teaching the topic or concept related to vegetative propagation specifically natural and artificial propagation methods

Rationale

Natural and artificial propagation methods are commonly used in asexual reproduction in plants. It is currently applied in Agriculture and horticulture. The process is also used commercially. Natural propagation occurs through corms, bulbs, rhizomes, tubers, while artificial propagation occurs through grafting, budding, cutting, layering, and tissue culture. This field study will enable learners to differentiate natural and artificial propagation methods.

Objective

To prove that natural and artificial propagation are both methods of asexual reproduction in plants

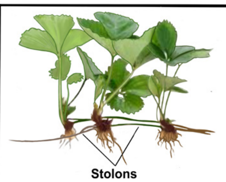


Materials

- Reporting format
- Note books
- Pens or pencils

Experiment set up

Natural



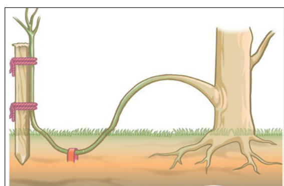


Fig.12.1: Natural and artificial propagation in plants

Procedures

Collect clean and healthy stems of cassava

- Identify the place where natural and artificial propagation methods take place
- Request for authorization of field visit
- Schedule the date and time

Reflection question

Is there any difference between natural and artificial propagation?

Data recording

Type of reproduction method	Observation
Natural	Occurs through corms, bulbs, rhizomes, tubers Naturally occurs in plants
Artificial	Occurs due to the interference of man Occurs through grafting, budding, cutting, layering, tissue culture, etc.

Interpretation of results and conclusion

Natural vegetative propagation occurs when an axillary bud grows into a lateral shoot and develops its own roots (also known as adventitious roots). Plant structures allowing natural vegetative propagation include bulbs, rhizomes, stolons and tubers.

Artificial vegetative propagation is the deliberate production of new plants from parts of old plants by humans. The most common types of artificial vegetative reproductive techniques include cutting, layering, grafting, suckering, and tissue culturing. These methods are employed by many farmers and horticulturists to produce healthier crops with more desirable qualities

As importance, it provides a way to avoid transmission of particular diseases, such as viruses. It maintains genetic variation, which increases the potential for plants to adapt to environmental pressures.

As conclusion, the main difference between natural and artificial vegetative propagation is that natural vegetative propagation naturally occurs in plants whereas artificial vegetative propagation occurs due to the interference of man.

Source of errors

If the environmental conditions are not favorable, they will not germinate.

Guidance on evaluation

Assess learners on natural and artificial propagation methods by asking to write a report describing what they learned on the field visit. You may also ask them some questions such as: 1) Differentiate the natural to artificial propagation

UNIT: 17 SEXUAL REPRODUCTION IN PLANTS

Experiment 17:1 Structure of a complete flower

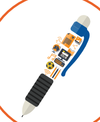
This experiment can be done when teaching the topic or concept related to the types and structure of flowers.

Rationale

Flowers are reproductive organs made of four specialized leaves namely sepals, petals, stamens, and carpels. A flower is important as it is the source of seeds and fruits eaten by humans and other animals such as primates and birds. Specifically, the ovule is differentiated into seeds, while the seed becomes the fruit, even though other parts may also contribute to the formation of the fruit.

Objective

To describe the structure of a complete flower



Materials

- Hibiscus flower
- Razor blade
- Paper and pencil

Experiment set up

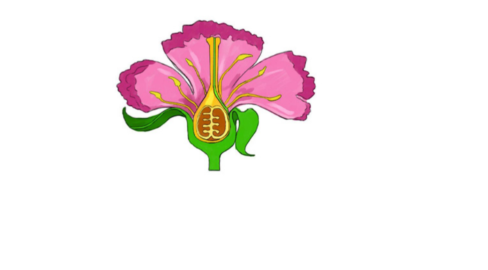


Fig.17.1: Complete flower

Procedures

- Collect different forms of flowers from the compound, such as hibiscus, morning glory, sweet potato, maize flower etc.
- Observe and describe the structures of collected flowers.
- Cut one of the flowers into two halves, draw and label one half of the flower.

Reflection question

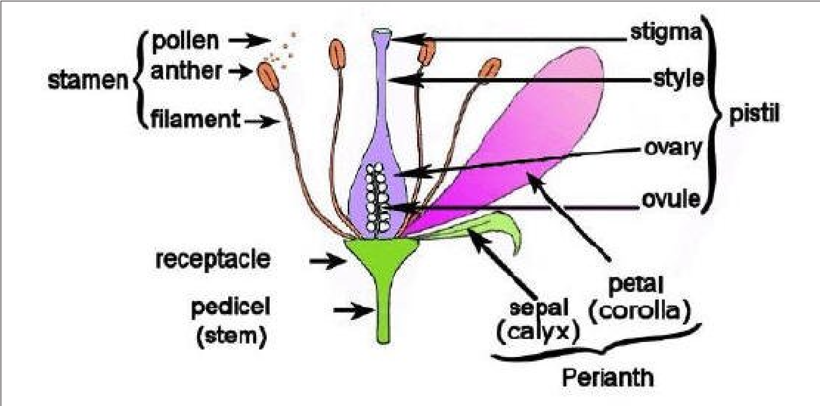
How do collected flowers differ externally?

Data recording

Item	Parts
Complete flower	• Stigma, Style and Ovary • Filament and Anther • Petal and sepal

Interpretation of results and conclusion

A flower is made of different parts. Considering the Hibiscus flower, these parts include stigma, style, anther, filament, petal, calyx, ovary, ovules, and stamen. A set of stigma, style and ovary is called pistil, while a set of anther and filament is called stamen. Flowers of other plants may not look like the flower of the Hibiscus and may contain more complex flower structure.



Guidance on evaluation

During the evaluation, students may be given a figure of flower which is not labeled. Each part is denoted by the letters A, B, C…and then, the teacher may ask students to name the parts represented by the letters.

Experiment 17:2 Types of inflorescences

This experiment can be done when teaching the topic or concept related to types and structure of flowers specifically types of inflorescences

Rationale

An inflorescence is a group of clusters of flowers arranged on a stem that is composed of main branch or different types of arrangement on branches. The organization of inflorescence on a plant can be isolated or grouped and varies from a plant species to another. Some can alternate on the peduncle with the same or different height. Others can develop from the same node. The arrangement of inflorescences has advantages on plant reproduction as the arrangement of inflorescence dictates the type of pollination and types of pollinators. Inflorescence also provides the ways by which pollen transfer and fruit sets take place.

Objective

To differentiate the types of inflorescences

Materials

- Specimens of flowers with different types of inflorescences
- Hand lenses

Experiment set up

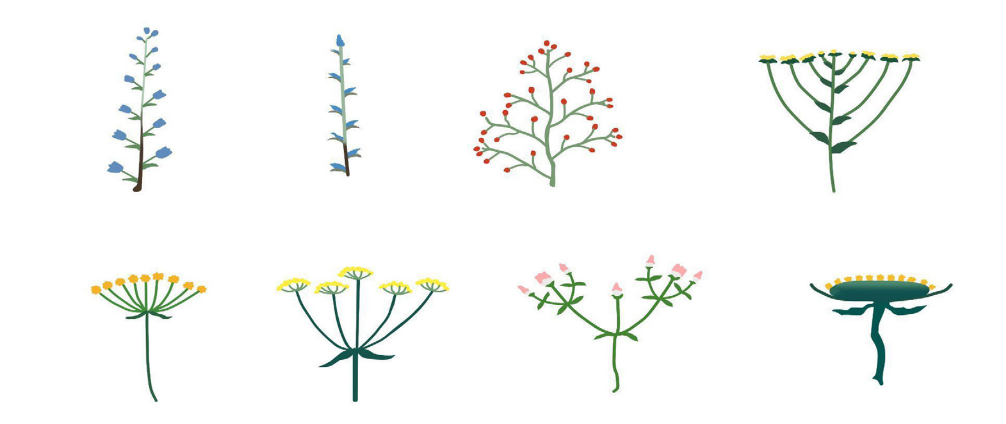


Fig.12.1: Inflorescences

Procedures

- Move in the garden and collect the following inflorescence: radish, sorghum, Masai stinging nettle, hawthorns, elder, carrot, onion, buttercup, sunflower, tobacco, rice, cauliflower
- Collect different plants with raceme, spike, catkin, corymb, panicle, umbel, cyme
- Group collected inflorescences and label each group A, B, C, D...
- Observe each specimen and identify its type based on the figure in the experiment set up

Reflection question

Is inflorescence different from other types of flowers?

Data recording

SN	Types of inflorescences	Name of the plant	Characteristics
1	Racemes	Radish, tobacco	Flowers have short floral stacks along the shoots that bear flowers
2	Spike	Sorghum	Flowers develop directly from the stem

3	Panicle	Masai stinging nettle (igisura), Rice	Much branched inflorescence compared to racemes and spike
4	Corymbs	Hawthorns, elder, cauliflower	Pedicels of the flowers are longer than those of the flowers above, bringing all flowers to about the same level
5	Umbel	Carrot	Flower stalks are more or less equal in length, and they arise from the same point
7	Cyme	Buttercup, onion	A flat-topped inflorescence having the central and peripheral flowers
8	Capitulum	Sunflower	Flowers are directly borne on a broad and plat peduncle, and they look like a single flower

Interpretation of results and conclusion

Inflorescences consist of a particular arrangement of flowers on a single main stalk of a plant. There are many different types of inflorescences some being simple while others are compound. These include raceme, spike, panicle, corymbs, umbel, cyme and capitulum.

Guidance on evaluation

During the evaluation, teachers may ask students to state the characteristic used to identify the types of inflorescences. To assess the understanding, the teacher can collect inflorescence of another type of plant not identified in the experiment and ask the type of inflorescence and the characteristics used to identify the type of inflorescence

Experiment 17:3 Use hand lenses to examine the structures of inflorescences

This experiment can be done when teaching the topic or concept related to types and structure of flowers.

Rationale

An inflorescence is a group of clusters of flowers arranged on a stem that is composed of main branch or different types of arrangement on branches. The organization of inflorescence on a plant can be isolated or grouped and varies from a plant species to another. Some can alternate on peduncle with the same or different height, others can develop from the same node. The arrangement of inflorescences has advantages on plant reproduction as the arrangement of inflorescence dictates the type of pollination and types of pollinators. Inflorescence also provides the ways by which pollen transfer and fruit sets take place. The study of flower structure is essential in plant identification and in understanding sexual reproduction in plants, pollination syndromes, plant breeding, and fruit structure. This experiment will help learners to understand the different types of flower arrangement and their relation to the fruits arrangement.

Objective

To examine the structures of inflorescences

Materials

- Flowers with different types of inflorescences
- Tables
- Lenses

Experiment set up

Fig.17.3: Observing structures of inflorescences

Procedures and steps of the experiment

- Move in the garden and collect flowers of different types of inflorescences
- When collecting flowers take the full inflorescence instead of single flower.
- Place the collected inflorescence on a table Observe the arrangement of flowers of collected inflorescence (you may use the hands lens to visualized the arrangement of flowers in small inflorescence.)
- Group collected inflorescences based on the flowers arrangements and label each group A, B, C, D,E , F and G
- Draw the observed structures representing inflorescences in each group.

Reflection question

Do you think that all flowers are arranged in the same way on the stem?

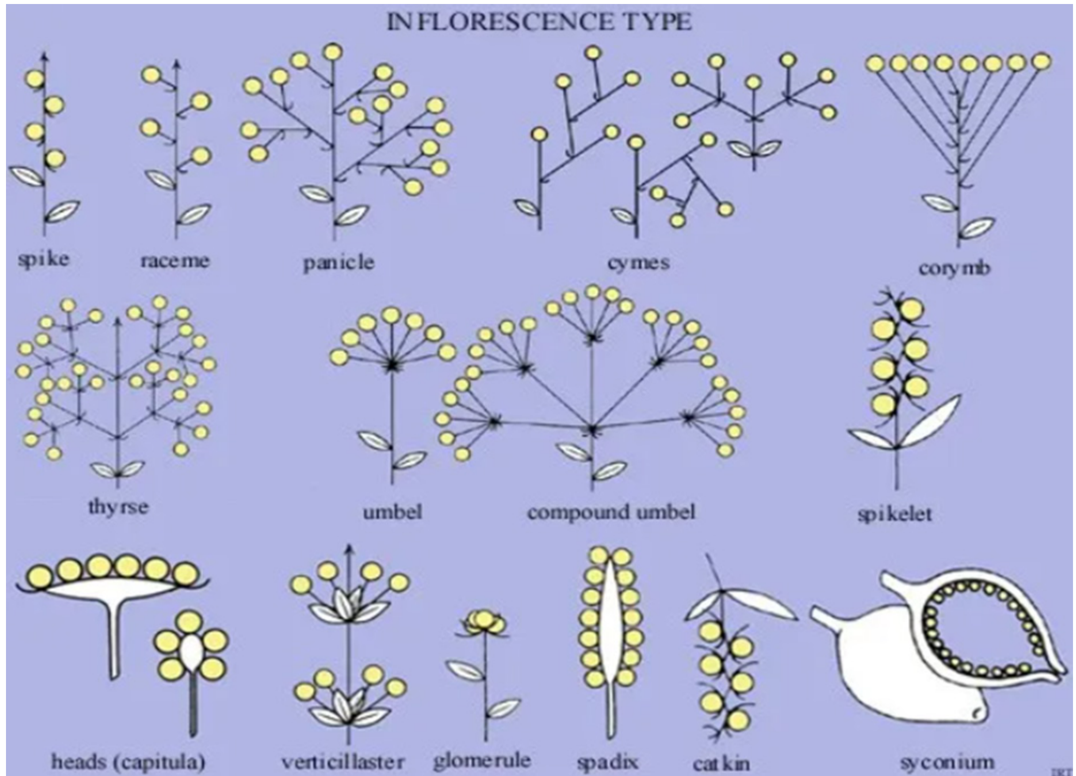
Data recording

SN	Group of observed inflorescence	Characteristics of observed inflorescence	Types of inflorescence	Name of the plant
1	A	Flowers have short floral stacks along the shoots that bear flowers	Racemes	Radish, tobacco
2	B	Flowers develop directly from the stem	Spike	Sorghum
3	C	Much branched inflorescence compared to racemes and spike	Panicle	Masai stinging nettle (igisura), Rice
4	D	Pedicels of the flowers are longer than those of the flowers above, bringing all flowers to about the same level	Corymbs	Hawthorns, elder, cauliflower
5	E	Flower stalks are more or less equal in length, and they arise from the same point	Umbel	Carrot
6	F	Compound umbel- instead of individual flowers radiating out from a single point, there are instead inflorescence branches. At the ends of each branch are secondary umbels	Compound umbel	Wild carrot, coriander
7	G	A flat-topped inflorescence having the central and peripheral flowers	Cyme	Buttercup, onion

8	H	Flowers are directly borne on a broad and plat peduncle, and they look like a single flower	Capitulum	Sunflower

Interpretation of results and conclusion

Inflorescence is the arrangement of flowers on the stem of a plant. It provides the chance of cross-pollination. There are many different types of inflorescences some being simple while others are compound. These include raceme, spike, panicle, corymbs, umbel, compound umbel, cyme and capitulum. Apart from the above described inflorescence, they are many other inflorescence structures as shown in the bellow images.



Guidance on evaluation

Ask learners to state the characteristic used to identify the types of inflorescences. To assess the understanding, the teacher can collect inflorescence of another type of plant not identified in the experiment and ask the type of inflorescence and the characteristics used to identify the type of inflorescence.

UNIT: 18 MCROBIOLOGY

Experiment 18:1 **Carry out observation on the permanent slides of *Entamoeba hystolitica*, *Plasmodium* and *Trypanosoma* to compare their structures.**

This experiment can be done when teaching the concept or topic related to the structure of the *Entamoeba hystolitica*, Plasmodium and Trypanosoma.

Rationale

Entamoeba histolytica, *Plasmodium* and *Trypanosoma* are parasites and pathogens organisms that belong to the kingdom Protista. These organisms are eukaryotes, meaning they are made up of single or multiple cells which all contain a nucleus enclosed by a membrane. Protists are defined by how they obtain food and how they move, which can range from cilia, flagella, and pseudopodia. In other words, they move by microscopic hair that flaps together, by a long tail that moves back and forth, or by extending its cell body, similar to an amoeba. This experiment aims to observe and compare their structures in relation to their mode of living.

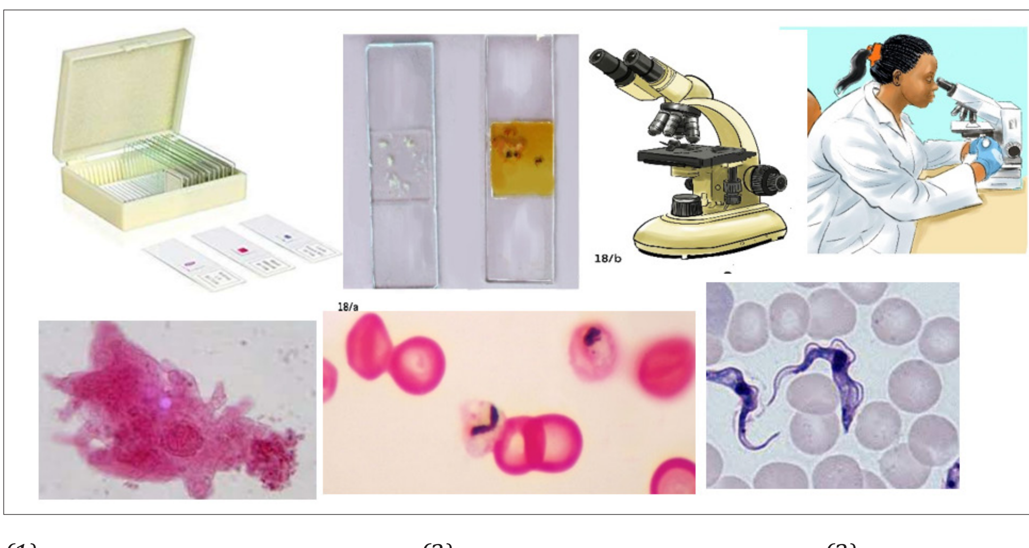
Objective

To compare the structure of *Entamoeba*, *Plasmodium* and *Trypanosoma* by using the permanent slides

Materials

- Light microscope
- Permanent slide of Trypanosoma
- Permanent slide of Plasmodium
- Permanent slide of Entamoeba hystolitica
- Notebook
- Pencil
- Rubber

Experiment set up



(1) *(2)* *(3)*

Fig.18.1: Observing Entamoeba, Plasmodium and Trypanosoma structure

Procedures and steps of experiment

- Set the microscope on the appropriate table in classroom or laboratory
- Fix the mounted slide of Trypanosoma on the microscope
- Observe the permanent slide starting from the lower objective;
- Draw the findings.
- Repeat the same process with the remained permanent slides of Plasmodium and Entamoeba
- Draw the findings.
- Compare the structures of organism observed under the microscope
- Tabulate your observations as shown in the table under data recording

Reflection question

Is there any difference between the images observed?

Date recording

Specimen number	Observation
1	Presence of pseudopodia Presence of two vacuoles (digestive and contractile vacuole). Presence of cytoplasm, plasma membrane and the nucleus.
2	No motile organ Presence of voluminous nucleus Sickled shaped structure with equally pointed ends
3	Presence of 2 flagellums Elongated body and mitochondria A pocket-like structure at the posterior end

Interpretation of results and conclusion

Plasmodium (2) is the genus of the class of Sporozoa that includes the parasite that causes malaria. It is a type of protozoa made up of a single cell that can divide only within a host cell. It has the sickle shaped structure with equally pointed ends; however, it does not have a fixed structure but undergoes continuous change during its life cycle.

The structure of amoeba (1) contains the cytoplasm, plasma membrane and the nucleus. The plasma membrane is a very thin, double-layered membrane composed of protein and lipid molecules. Amoeba movement occurs using pseudopodia, where the cytoplasm pushes the plasma membrane outward or inward, creating blunt, finger-like projections. There can be multiple pseudopodia at one instance. Hence, its shape rapidly changes.

The *Trypanosoma (3)* has a pocket-like structure at the posterior end near the basal body which is called the flagella required for locomotion and viability. A single, elongated, giant mitochondrion extends from its anterior to the posterior end of the body and differentiate into anterior mitochondrion or anterior chondriome and posterior mitochondrion or posterior chondriome.

Guidance on evaluation

Assess learners on *Entamoeba histolytica*, *Plasmodium* and *Trypanosoma* structures, based on their microscopic observation. Let them draw and label the image observed under the microscope. Indeed, you may ask them some questions such as:

Based on your microscopic observation, write a short note on the structure of *Entamoeba histolytica*, *Plasmodium* and *Trypanosoma*.

UNIT: 19

CULTURING MICROORGANISMS

Experiment 19:1

Staining bacteria and examine its structure under a light microscope

This experiment can be done when teaching the concept or topic related to culturing microorganisms specifically culturing bacteria.

Rationale

Bacteria contribute to the decaying and recycling of nutrients in the environment. Further, they can be used in medicine, industry, and food processing. Thus, their presence can be of great benefit to the human being. On the other hand, some bacteria cause diseases to human beings and other animals. Staining bacteria is essential in checking for bacteria at the site of a suspected infection or in certain bodily fluids. The bacterial cells are stained with specific stains to enable the person to visualize the bacteria physical features like shape, size, arrangement, etc., for classifying and determining the composition of the bacteria. This experiment will help learners to observe the stained bacteria and identify its structure.

Objective

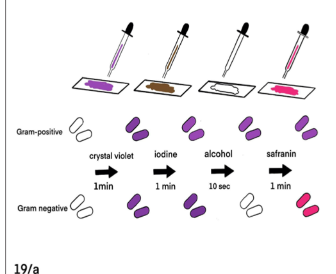
To carry out staining of bacteria to identify their structure under the light microscope

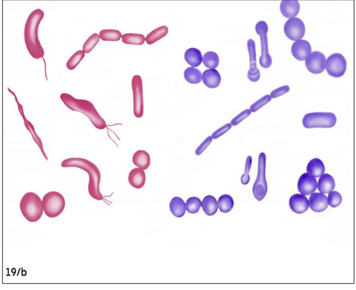
Materials

- Slide
- Inoculating loop
- Bunsen burner
- Forceps
- Two glass rods

- Staining tray
- Safranin,
- Iodine
- Crystal violet
- Alcohol
- Dropper
- Live yoghurt
- Timer
- Microscope

Experiment set up





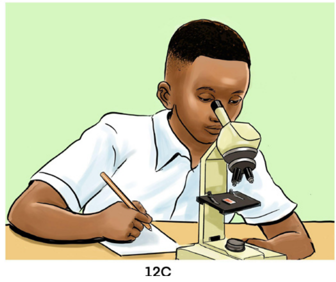


Fig.19.1: Observing stained bacteria specimen

Procedures and steps of experiment

- Smear yoghurt thinly over a glass slide
- Air-dry and then pass the slide through a yellow Bunsen burner flame
- Stain with crystal violet and wait for around one minute
- Rinse with Lugos' iodine and wait for around one minute
- Rinse with distilled water
- Flood with acetone-alcohol and leave for around 3 seconds
- Rinse with distilled water
- Counterstain with Safranin and leave for around one minute
- Blot dry and examine under a microscope
- Write down your observation for each observed slide with different stains.

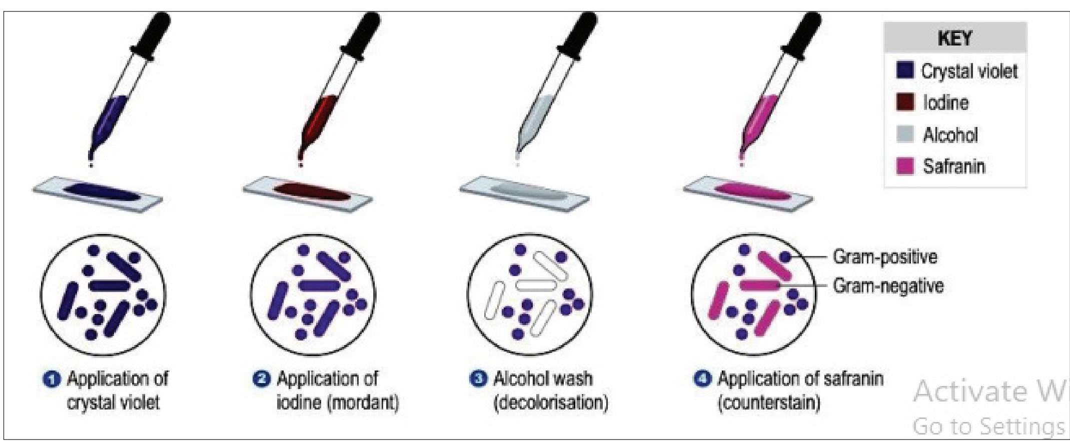
Reflection question

Is there any difference between the structures of bacteria observed in the light microscope?

Date recording

Gram stain process			
Gram staining steps	**Cell effects**	**Gram positive**	**Gram negative**
1. CRYSTAL VIOLET Primary stain added to specimen smear	Stains cells purple or blue		
2. IODINE Mordant makes dye less soluble so it adheres to cell walls	Cells remain purple or blue		
3. ALCOHOL Decolorizer washes away stain from gram negative cell walls	Gram positive cells remain purple or blue Gram negative cells are colourless		
4. SAFRANIN Counterstain allows dye adherence to gram negative cells	Gram positive cells remain purple or blue Gram negative cells appear red or pink		

Interpretation and conclusion



Gram staining is a common technique used to differentiate two large groups of bacteria based on their different cell wall constituents. The Gram stain procedure distinguishes between Gram positive and Gram-negative groups by coloring these cells red or violet.

After the treatment of the specimen with Gram stain, either purple or pink colors can be observed. Purple color after treatment indicates gram-positive bacteria whereas the pink color indicates gram-negative bacteria. Differences are due to cell wall structure of two types of bacteria. Gram-positive cells stain purple because they retain the crystal of the violet dye in their cell walls and because of the presence of thick layers of peptidoglycan in their cell walls.

Regarding the structure, Gram-positive bacteria have cell walls that contain thick layers of peptidoglycan, a substance that forms the cell walls of many bacteria. The peptidoglycan forms about 90% of the cell wall in gram-positive bacteria. This causes them to appear blue to purple under a Gram stain.

Gram-negative bacteria have cell walls with thin layers of peptidoglycan (10% of the cell wall) and high lipid (fatty acid) content. This causes them to appear red to pink under a Gram stain. This causes them to appear red to pink under a Gram stain. Hence, staining bacteria is essential in checking for bacteria at the site of a suspected infection or in certain body fluids. Negative Gram stain or “no organism seen” usually means that there are too few bacteria present while positive Gram stain means that bacteria were present. Based on the structure, we identify the types of bacteria based on stained gram positive and negative.

Guidance on evaluation

Assess learners using open and critical thinking questions such as:

1. How to differentiate bacteria?
2. What are the advantages of gram positive and gram-negative stained bacteria.

Experiment 19:2 Investigate the bacterial content of fresh and stale milk

This experiment can be done when teaching the concept or topic related to culturing microorganisms, specifically to observe and compare the numbers of bacteria present in fresh and stale milk

Rationale

Milk is an essential source of food for humans due its richness in nutrients. In addition to being a nutritious food for humans, milk provides a favorable environment for the growth of microorganisms. Especially a broad spectrum of bacteria that can grow in milk. Microbes can enter milk via the cow, air, feedstuffs, milk handling equipment and the milker. Once microorganisms get into the milk their numbers increase rapidly. Milk that is no longer fresh is named as stale milk, its texture color may be lumpy, thick, or slightly yellow, its smell is sour. The consumption of stale milk can cause harm to human life such as: abdominal pains, vomiting, diarrhea etc. Fresh or pasteurized milk is smooth, thin, and white, however can contain some heat resisting bacteria like thermophiles. It is important to monitor these microorganisms to help prevent spoilage or potential pathogenic contamination. This experiment will provide information on the bacterial content of fresh and stale milk and help learners to know that even fresh milk can be a source of infections.

Objective

To investigate the bacterial content of fresh and stale milk

Materials

- Four sterile nutrient agar plates,
- Inoculating loop,
- Bunsen burner,
- Indelible marker or wax pencil,
- Flesh milk, (pasteurized)
- Stale milk (milk left at room temperature for 24 hours)
- Incubator set at 350C

Experiment set up

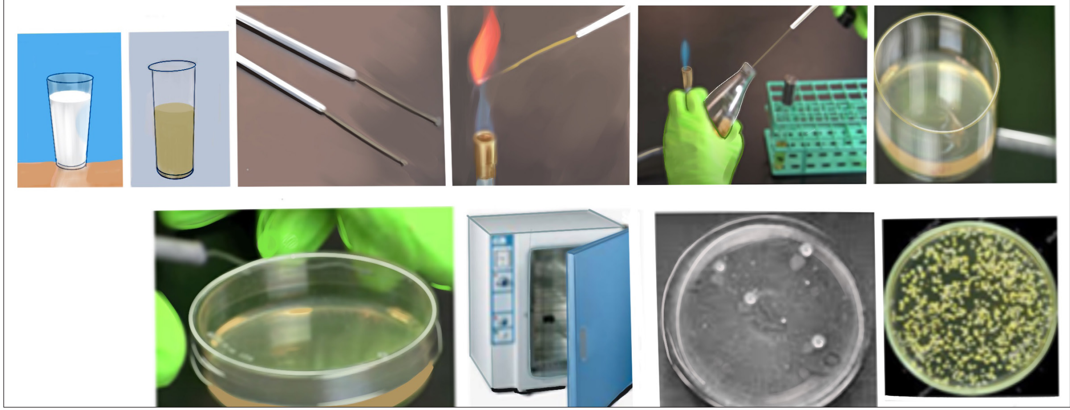


Fig.19.2: Investigating gaseous exchange surface

Procedures and steps of experiment

- Place the inoculating loop in the Bunsen burner flame until the loop is red hot.
- Allow the loop to cool and then dip into a sample of fresh, well shaken milk.
- Lift the lid of the sterile agar plate slightly with the other hand and lightly
- Spread the contents of the inoculating loop over the surface of the agar.
- Close the lid of the plate and return the loop to the Bunsen burner flame until red hot.

- Label the base of the plate with an indelible marker or pencil.
- Repeat the process with the second plate and another sample of fresh milk.
- Flame the loop again and after cooling, place it in a sample of stale milk.
- Spread the contents of the loop over the surface of a third plate and then close the lid.
- Label the base of the plate with an indelible marker or pencil.
- Repeat the process with the fourth plate and second sample of stale milk.
- Put the four plates in an incubator at 35oC or about 3 days.
- They should be placed upside down to prevent condensation falling onto the cultures.
- After incubation, the two halves of each plate should tape together for safety. Record the appearance of the colonies

Reflection question

1. Why do we start culturing microorganisms by sterilization of inoculating loops?
2. What do you expect to observe after culturing bacteria from fresh and stale milk?

Data recording

Sample	Observation
Stale milk	High number of bacteria colonies
Flesh milk (Pasterilized)	Fewer bacteria colonies.

Interpretation

Milk is important source of vital nutrients for human being and constitutes an excellent medium for bacterial growth and source of bacterial infection. Fresh or pasteurized milk contain no bacteria colonies, this is because, and pasteurization kills harmful microbes in milk without affecting the taste or nutritional value and all bacteria are destroyed. Stale however contain a high number of bacteria contaminations. To detect the bacteria content of fresh and

stale milk, one should apply aseptic techniques of culturing microorganisms. In this experiment inoculating loop was sterilized before being inserted in fresh milk as well as in stale milk with the purpose of avoiding contamination of new bacteria from outside. The bacteria sample were transferred in different sterile plates containing nutrients agar and were incubated for three days 35OC. Few number of colonies grown on the pretri-dishe with sample from fresh milk while many colonies grown from stale milk. This showed the difference in bacteria contamination between fresh and stale milk. Fresh or pasteurized milk may contain bacteria contamination, this happen when raw milk contained high heat resisting bacteria like bacillus species.

Source of errors

Culturing without following aseptic techniques may cause contamination of fresh milk and this will cause biased results.

Guidance on evaluation

Assess learners by focusing on aseptic techniques of culturing microorganisms. Teacher can ask questions like:

1. What do you think can happen if we culture bacteria from fresh and stale milk without using aseptic techniques?
2. Is there any difference between fresh and stale milk in terms of bacteria colonies?

Experiment 19:3 Carry out an experiment of culturing of fungi on agar using sterile techniques

This experiment can be done when teaching the Concept or topic related to the culturing of microorganisms especially when teaching the use of sterile techniques to prepare agar plates to culture bacteria and fungi.

Rationale

Aseptic technique is a method that involves target-specific practices and procedures under suitably controlled conditions to reduce the contamination from microbes. Aseptic technique use sterilized equipment and solutions to prevent contamination. Sterilization is the removal or destruction of all living microorganisms, including spores. Fungal spores are abundant in most environments including laboratories. Autoclaves is used to sterilize the equipment and culture media before experiments and also to sterilize equipment and specimens before disposal. The conduct of this experiment will

help learners to understand and perform the aseptic techniques in culturing microorganism specifically fungi. Importantly, this experiment will teach learners about different types of culture media, their preparation and uses for fungi culturing by sterile techniques.

Objective

To culture fungi on agar using sterile techniques

Materials

A. Culture media preparation

- Balance
- Spatula
- Weighing paper
- 1-L graduated cylinder
- Glass stirring rod
- A large flask or beaker
- Culture tubes or petri dishes
- Potato dextrose agar (PDA) or Sabouraud dextrose agar (SDA) the commonly used media for fungi culture
- Distilled water
- Marker
- Magnetic stirrer

B. For sterilization

- Autoclaves
- Gas
- Tape water
- Aluminium foil paper
- Heat resistant gloves
- Materials/solution to be sterilized.

C. For culturing using sterile techniques

- Sterile medium in petri dishes or culture tubes
- Disinfectant solution such as 70% ethanol
- Bunsen burner
- Inoculating loop
- Fungi with abundant spores; (Stock culture; the original culture from which other cultures will be started).
- Scalpel or half-spear point needle
- Soap for washing hands
- Lamina air hood
- cotton

Experiment set up

A. Preparation of culture media

B. Sterilization

C. Culturing using sterile techniques

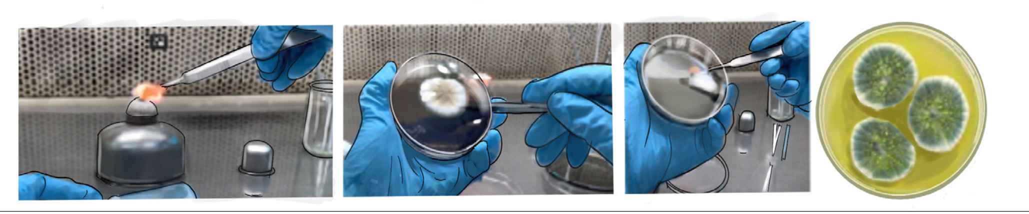


Fig.19.1: Investigating gaseous exchange surface

Procedures and steps of experiment

A: Media preparation

- Assemble the equipment and ingredients
- Weigh 39 gm of Commercial PDA Powder
- Putt it into a large flask or beaker

- Add 1 Littre of distilled water.
- Boil while mixing by magnetic stiller to dissolve.
- Label the petri dishes (put the name of culture media, date of preparation and petri dishes number)

B. For sterilization

- Wrap the flask congaing the prepared media by aluminium paper
- Autoclave 15 min at 121°C
- Wear heat resistant gloves and remove the media from autoclave
- Wrap the petri dishes, Scalpel or half-spear point needle, inoculating loop by aluminium paper and autoclave for Autoclave 15 min at 121°C

C: For culturing using sterile techniques

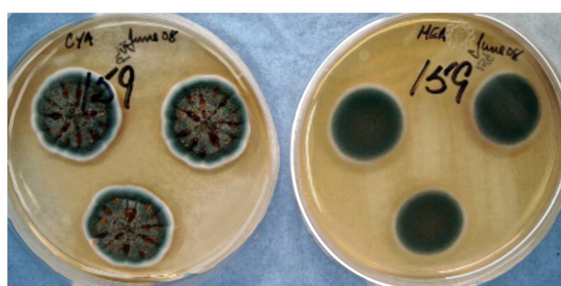
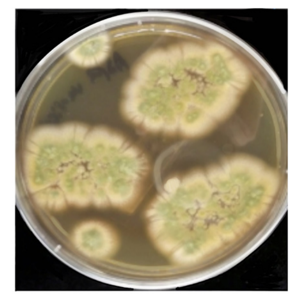
- Wear your lab coat and gloves.
- Switch on and open the lamina air hood if it is there and decontaminate its work place by using 70% ethanol
- Decontaminate your lab bench (place to use in lab if no lamina air hood)
- On the Bunsen burner
- Sterilize the inoculating loop on Bunsen burner flame
- Let's it cool
- Use sterile inoculation loop to take fungi culture
- Take sterile medium in petri dishes or culture tubes
- Inoculate the fungi (Aspergillus, Pold, or Penicillium, ...)
- Close the petri dishes
- Mark the petri dish on the base of main dish (Date, fungi species)
- Incubate in sterile environment at 30oCfor three to five days
- record your observations

Reflection questions

1. Why do we have to do in clean the working place by 70% ethanol?
2. Why do we have to sterilize inoculating loop on Bunsen burner flame before using it?

Data recording

Culturing of fungi on agar using sterile techniques	Observations	Images of fungi colony
Aspergillus	They have a cottony appearance; initially white to yellow and then turning black	Order: Eurotiales Family: Trichocomaceae Genus: Aspergillus Species: Aspergillus caelatus **Aspergillus caelatus** Order: Eurotiales Family: Trichocomaceae Genus: Aspergillus Species: Aspergillus candidus **Aspergillus candidus** Order: Eurotiales Family: Trichocomaceae Genus: Aspergillus Species: Aspergillus cervinus **Aspergillus cervinus**
Penicillium	They are initially white and become blue-green, gray-green, olive-gray, yellow or pinkish with time	1m 1m

Mold	Molds are microscopic, plant-like organisms, composed of long filaments called hyphae. ... When mold hyphae are numerous enough to be seen by the naked eye they form a cottony mass called a mycelium	 

Interpretation of results and conclusion

A culturing of fungi on agar using sterile techniques happen in steps, that require the preparation of culture media such as Potato dextrose agar (PDA) or Sabouraud dextrose agar (SDA), sterilization of culture media and materials like inoculating loop, spatula, petri dishes, and culturing itself. The result depends on the stalk culture used. When the aspergillums species are used, the grown colonies look like cottony appearance; initially white to yellow and then turning black while Penicillium look like white and become blue-green, gray-green, olive-gray, yellow, or pinkish with time. When mold hyphae are numerous enough to be seen by the naked eye, they form a cottony mass called a mycelium. The results above in data table depend on the cultured fungi species, other fungi cultures may be observed accordingly.

Source of errors

Conducting experiment in non-cleaned place, or use of non-sterilized media and materials can cause the contamination by another micro-organism.

Guidance on evaluation

Assess learners by asking them the process of culturing fungi, ask learners to perform fungi culture individually.

UNIT: 20 BIOTECHNOLOGY AND ITS APPLICATION

Experiment 20:1 Alcoholic fermentation using yeast

This experiment can be done when teaching the concept or topic related to biotechnology and its application specifically the topic of alcoholic fermentation by using yeast.

Rationale

Alcoholic fermentation is a biological process which converts sugars such as glucose, fructose, and sucrose into cellular energy, producing ethanol and carbon dioxide as by-products. It is an essential process for a wide range of applications. It is involved in several important transformation, stabilization, and conservation processes for sugar-rich substrates, such as the juices of fruits and vegetables. Different yeast strains have varied characteristics and are used to produce beer, wine, liquors, and bread. This experiment will help learners to explore the role of yeast in the fermentation process.

Objective

To explore the role of yeast in alcoholic fermentation

Materials

- 5 grammes of sugar
- 1 gramme of yeast (active dry yeast)
- Petri dishes
- Pipette
- Slides
- Cover slips
- Microscope
- Boiling tube
- Warm water
- Balance

Experiment set up

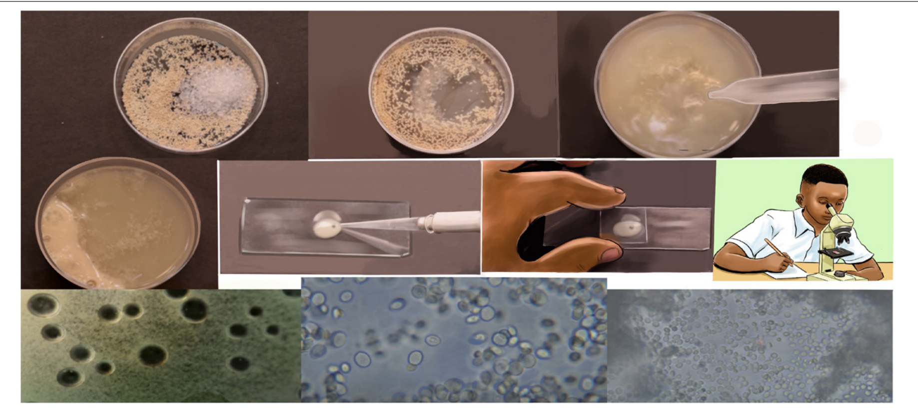


Fig.12.1: Investigating gaseous exchange surface

Procedures and steps of experiment

- Put 5g of sugar in a petri dish and dd 50 cm3 of warm water
- Stir to dissolve the sugar
- Add 1g of active dry yeast
- Wait for few minutes while fermentation takes place and note the smell of the solution
- Use the pipette to take the sample from the Petri dish
- Put the sample on the cleaned slide and cover with the cover slide
- Set the microscope on the appropriate table in the laboratory
- Observe the mounted slide under low and higher magnification
- Draw the observed characteristics

Precaution

Make sure that you do not add any other kind of liquid in your preparation. Indeed, the environment and the amount of oxygen should be carefully controlled as fermentation is an anaerobic process. In the presence of oxygen, acetic bacteria can convert sugars or ethanol into acetic acid.

Reflection question

What are the causal agents of the occurrence of the smelling released after the addition of dry yeast?

Data recording

Activity	Observation
Mixture of yeast and sugar	No reaction observed
After adding warm water and stirring	Production of CO_2 bubbles Flavor is produced from yeast metabolism
Slide observation under microscope	Appearance of yeasts around the CO_2 bubbles at higher magnification The yeasts look like sand when viewed at lower magnification

Interpretation of results and conclusion

Beer and wine are produced by the fermentation of glucose with yeast. The yeast species that is most used in beer, bread, liquors preparation and winemaking is Saccharomyces cerevisiae. It is preferred because of its predictable and strong fermentation qualities and tolerance to high levels of alcohol and Sulphur dioxide.

During fermentation, yeast cells consume and convert cereal-derived sugars into ethanol and CO2. At the same time, hundreds of secondary metabolites that influence the aroma and taste of beer are produced. Variation in these metabolites across different yeast strains allows the yeast to influence beer flavor.

Source of errors

Errors may come from mixing inappropriate quantities of yeast

Guidance on evaluation

Assess learners on alcoholic fermentation by asking some questions such as:

1. Describe the role of yeast in alcoholic fermentation
2. What are the most common by-products of fermentation?

Experiment 20:2 Bread preparation

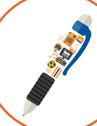
This experiment can be conducted when teaching the concept or topic related to biotechnology and its application.

Rationale

The enzyme biotechnology is the branch of applied science that uses living organisms and their derivatives to produce products of interest. For instance, the amylase and glucose oxidase enzymes found in yeast are used in bread-making by breaking down flour into soluble sugars. The main purpose of this experiment is to prepare bread and to understand different steps followed.

Objective

To prepare a bread



Materials

- 8 Gramm of active dry yeast
- Two cups of warm water (about 40oC)
- Water or milk
- Spoons
- Two spoons of table sugar
- One tablespoon of salt
- Two tablespoons of oil
- Six cups of bread flour
- Bowls or large container
- Oven
- Bread plate

Experiment set up

Fig.12.1: Investigating gaseous exchange surface

Procedures and steps of activity

- For field visit
- Identify the location of the nearest bakery
- Schedule the date and time
- Request for authorization for the field visit
- Collect all the information about how to make a bread
- Discuss on how you can make bread at your school
- Bread making
- Avail all the ingredients indicated in the list of materials needed for making the bread
- Mix the ingredients until there is a formation of the dough
- Knead the formed dough by hand continuously
- Leave the dough for around one hour for fermentation
- Divide the fermented dough into small pieces and give the wanted shape to each piece

- Put the made pieces of the bread-making plate
- Leave the pieces for around 15-20 minutes to take the shape and for fermentation
- Bake the pieces into bread oven and remember to control the heat
- Once there is a change of colour, take the bead outside of the oven for around 30 minutes
- Test the bread you have made (cut it into two pieces to see if it is well cooked inside and then taste)

Reflection question

1. Why do we have to keep the dough for some time (1 hour) while making the bread?

Data recording

Steps in bread preparation	Observations
Prepare ingredients	Bread-flour, dry yeast leaven (sourdough), salt, water or milk, sugar, and oil.
Mix the ingredients	Incorporating ingredients and then developing the structure of the dough. Dough can be kneaded by hand, or mixed in a tabletop mixer
Primary fermentation	Rising, or proofing of dough
Divide and pre-Shape	Divided dough into pieces
Bench rest	Elastic and more extensible dough
Final Shaping	Dough sliced into bread final shape
Final Fermentation	Increased size of shaped dough before baking
Scoring	Decollated dough before baking
Baking	Lean dough into oven
Cooling	Final bread from the oven placed at room temperature.

Interpretation and conclusion

The main ingredients used for making bread include bread-flour, dry yeast, leaven, salt, water, sugar, and oil. Bread preparation starts by dough making through mixing ingredients. Mixing can be done by hand or mixed in a tabletop mixer. After mixing the ingredients, the formed dough is kept for fermentation. Primary fermentation referred to as rising, or proofing, and this is where the yeast starts to do its work. When the dough is properly fermented, it is divided into small pieces and given a pre-shape. After the dough has been pre-shaped, the gluten network, which has been made more elastic through handling, will relax, and become more extensible, this is named as bench rest which is typically 15-20 minutes long. After this, the dough needs time to finally ferment, and this may take 15 minutes to one hour. The next step is baking that consists of a process of cooking by dry heat in bread oven. After baking, the bread is ready for cooling and consumption.

Source of errors

Errors may come from the use of dead yeast and the use of too hot milk or water

Guidance on evaluation

Learners can visit a nearby bakery to learn how bread is prepared for commercial purposes and compare it to their prepared bread. Assess learners on key ingredients and steps followed while making bread.

Experiment 20:3 Visit to a biogas plant to study the stages of biogas production

This field visit can be conducted when teaching the concept or topic related to biotechnology and its application specifically when teaching the role of biogas production in reducing the environmental degradation.

Rationale

Biogas is a mixture of gases, primarily consisting of methane and carbon dioxide, produced by anaerobic fermentation of organic wastes such as agricultural waste, manure, municipal waste, plant material, sewage, green waste, or food waste. The gases methane, hydrogen, and carbon monoxide (CO) can be combusted or oxidized with oxygen and the released energy allows biogas to be used as a fuel; or used for any heating purpose, such as cooking. It can also be used in a gas engine to convert the energy from the gas into electricity. Biogas

is a renewable energy source that is advisable for food security and climate change. This field visit will introduce to learners the biogas production process and its role in reducing the environmental degradation.

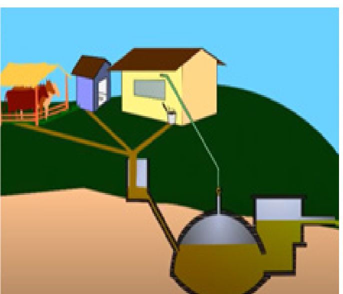
Objective

To study the stages of biogas production through a field visit to a biogas plant.

Materials

- Biogas plant
- Reporting format
- Notebooks

Experiment set up



Procedures

- Identify the place where the biogas plant is situated in the region
- Request for authorization of field visit
- Schedule the date and time
- Ask the biogas plant intendant to explain to the learners the stages of biogas plant constructions and biogas production
- Ask learner to be attentive and take key notes from the explanations
- Inform them that they will present the report when back in class.

Reflection question

1. Why are organic wastes important in biogas production?

Data recording

Item	Observations
Part of Biogas plants	Mixing tank, digester tank, outlet tank, biogas outlet tube
Raw materials	Animal's (cow) manure slurry
Use of biogas	In cooking

Interpretation and conclusion

The production of biogas involves basically anaerobic fermentation of organic wastes. Biogas plant is constructed by three main tanks: a mixing tank where the cows' manure is collected and mixed, digester tank which is liquid storage tank that is used for digestion of stored complex slurry/wastewater into simpler compounds and in turn, releases gases. And the outlet tank where a released gas is stored and let out.

The production of biogas involves three stages and three communities of microorganisms namely:

- Anaerobic fermentation by bacteria including lactobacillus, which converts the organic waste into a mixture of organic acids and alcohol, with some Hydrogen, Carbon dioxide, and acetate
- Acetogenic (acetate-producing) reaction by bacteria such as Acetobacterium which, in addition to acetate, produce hydrogen and Carbon dioxide from the organic acid and alcohol.
- Methanogenic (methane-producing) reactions by archaebacteria, including Methanobacterium, Methanococcus, and Methanospirillum. The produced gas is released out passing through a biogas outlet pipe and it is used for any heating purpose, such as cooking.

It can also be used in a gas engine to convert the energy from the gas into electricity. Biogas production and use protect the environment by decreasing the emissions of methane which is converted into CO2 during combustion. Besides, its use reduces forest abuse by cutting of trees needed for energy production in domestic life.

Precaution: It is not mandatory to use cows 'manure. The one of humans also can serve for the same purpose specifically in place like school, jail (place where many people live).

Source of errors

Errors may come from the selection of inappropriate biogas plant region to visit.

Guidance on evaluation

Assess learners by asking them to explain the main stages in biogas production. Learners should also be assessed on the raw materials for biogas production and their characteristics. These are some of the questions we may ask:

1. What are the main stages in biogas production?
2. What are the materials needed for biogas production?

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