SC/BES/MCS/2006/7
December 2006
Original: English

BIOLOGY

Microscience Experiments

Teaching and Learning Materials for Biology

TEACHER NOTES - First Edition

Compiled by B. Thorne, J. Ovens and B. Bell
Edited by Prof. JD Bradley and J Ovens

The UNESCO-Associated Centre for Microscience Experiments
RADMASTE Centre
University of the Witwatersrand, Johannesburg

Prepared under UNESCO Contract No. 4500027250

This Booklet of Biology Microscience Experiments has been Prepared in Cooperation with UNESCO and IUPAC

UNITED NATIONS EDUCATIONAL, SCIENTIFIC AND CULTURAL ORGANIZATION

INTERNATIONAL UNION OF PURE AND APPLIED CHEMISTRY – IUPAC

IN COLLABORATION WITH

THE UNESCO-ASSOCIATED CENTRE FOR MICROSCIENCE EXPERIMENTS
THE RADMASTE CENTRE
UNIVERSITY OF THE WITWATERSRAND
JOHANNESBURG, SOUTH AFRICA

THE INTERNATIONAL FOUNDATION FOR SCIENCE EDUCATION
JOHANNESBURG, SOUTH AFRICA

SESI
SCIENCE EDUCATION SOLUTIONS INTERNATIONAL
P.O. BOX 681, WITS 2050,
JOHANNESBURG, SOUTH AFRICA

Worksheets Prepared By : Mrs B. Thorne (The RADMASTE Centre);
Mrs J. Ovens and Ms B. Bell (UNESCO-Associated Centre for Microscience Experiments, The RADMASTE Centre, University of the Witwatersrand)

Worksheets Edited By : Prof. J. Bradley (International Foundation for Science Education);
Mrs J. Ovens (UNESCO-Associated Centre)

CONTENTS

PART 1

CHAPTER 1

LIVING ORGANISMS

NOTES TO THE TEACHER

SERIES OF ACTIVITIES - LIVING ORGANISMS

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE LIVING ORGANISMS ACTIVITIES

Activity 1: Flowering Plants - Seed Structure

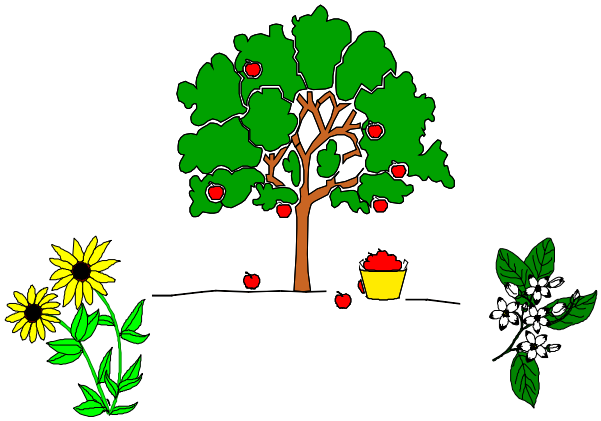
INFORMATION

There are over 250,000 species of flowering plants which are also called angiosperms. Angiosperms are divided into two classes according to the stucture of the seeds. One of these classes is the 65,000 or so species of monocotyledons which include grasses, lilies, irises, and aloes. The other, larger class of dicotyledons includes tomatoes, sunflowers, geraniums, roses, most trees including fruit trees, carrots, cabbages, and acacias. This series of activities will start with an examination of seeds and how they germinate.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

Some monocotyledons

Some dicotyledons



Questions

3 Try to break the maize or wheat seed (grain) into two parts in the same way. Is it possible to break these seeds into two?
No. It is not possible.

Internal Structure of the Seed

1 In what ways is the soaked seed different from a dry seed?
HINT: Compare size, shape, texture.
The soaked seed is larger, swollen and not as hard as the unsoaked seed.

2 Match the word in column A with the phrase in column B by writing out the word with the correct phrase next to it.
1e 2a 3b 4c 5d

The role of a seed is to ensure efficient dispersal to a new place where it can germinate. Most seeds are adapted to survive for long periods of time in conditions eg cold and dry seasons, where growth is unsuitable.

In most monocotyledonous seeds the endosperm supplies nutrients for further requirements of germination. Whereas in most dicotyledonous seeds, the endosperm is initially absorbed by the growing embryo. Nutrients are stored in the enlarged cotyledons.

Here are some other parts you may want your learners to identify:

dicotyledon: hilum (scar when attached to fruit); micropyle (small hole)
monocotyledon: coleorhiza (protective covering of the radicle)

Questions

1 How do the embryos obtain food?
They use the stored food inside the seed until they are able to manufacture their own food by photosynthesis. The two cotyledons contain the food for dicotyledons.

Testing Seeds for the Presence of Stored Food (Starch) - *Optional Activity*

Questions

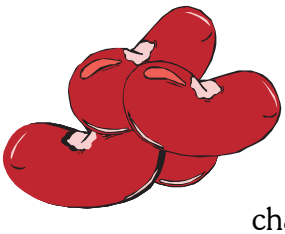
1 What do you see?
Parts of the tissue stain deep blue or black, indicating the presence of starch.

2 Which seeds seem to store the most starch?
Maize and other grains seem to store a lot of starch; as does rice and certain types of beans and peas, (like chick-peas).

Activity 2: Observing Germination

Stage 2 - Germination of the Seed

INFORMATION

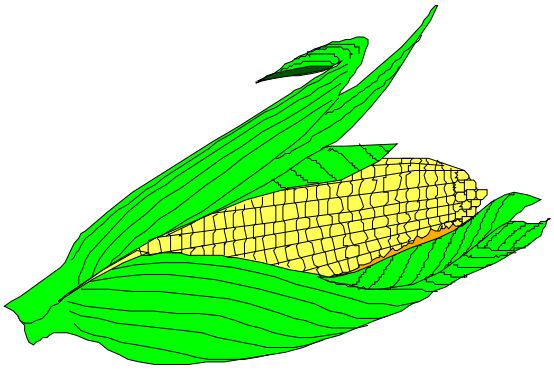


The word "germination" refers to the first stages of growth in a seed, spore, or pollen grain. Seeds germinate when they are exposed to factors such as moisture, oxygen and a favourable temperature. The process begins with the uptake of water by the seed. After this, the metabolic rate of the seed increases markedly and various physiological changes take place. Enzymes convert food reserves in the seed to monomers which are absorbed by the seedling.

The embryonic root, or radicle, normally appears first, with the plumule second. In dicotyledons the first structure to appear above the soil is the hypocotyl. In monocotyledons it is the coleoptile. The appearance of the first leaves signals the end of germination and the start of growth.

The endosperm is the nutritive tissue in the seeds of most flowering plants. It contains food reserves such as starch, fat, and protein . Your learners may have tested certain seeds for these foods in a previous activity. Seeds are a good source of food for the developing embryo and are also a good source of food for us. Photosynthesis begins when the first green leaves open out.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.



Activity 3: Vegetative Structures of Angiosperms

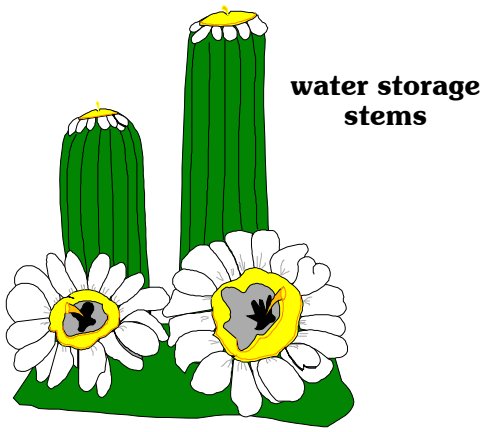
Stage 3 - The adult plant

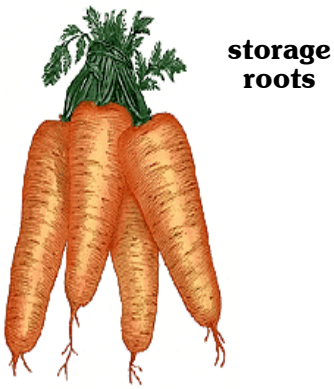
INFORMATION

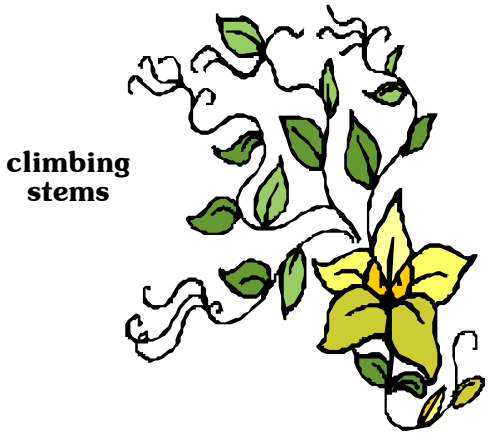
The vegetative structures of plants are the roots, stems and leaves. These parts play no role in the production of pollen or seeds. In other words they play no role in sexual reproduction but may play a role in vegetative reproduction. The angiosperms are classified into mono- and dicotyledons according to seed structure, but their roots, stems and leaves differ as well.

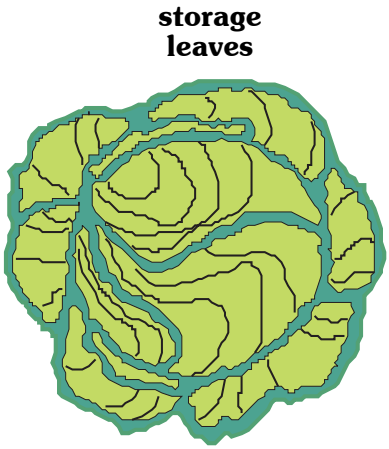
In addition, the vegetative parts of many angiosperms are adapted for a variety of functions such as storage of food, climbing, trailing and, as mentioned, vegetative reproduction.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.









A External Structure

Questions

1 Does the plant have a tap root or does it have adventitious roots?
Monocotyledon: Adventitious roots.
Dicotyledon: Tap root.

2 Is the stem branched or unbranched?
Monocotyledon: Unbranched.
Dicotyledon: Usually branched.

3 Are the leaves long and thin or are they another shape?
Monocotyledon: Sword-shaped or strap shaped (like grass).
Dicotyledon: Many different shapes as described in the box above including sword-shaped occasionally.

4 Are the leaves simple or compound?
Monocotyledon: Most have simple leaves.
Dicotyledon: Some have simple leaves and others have compound leaves.

5 Does the base of the leaf wrap around the stem or not?
Monocotyledon: yes
Dicotyledon: no

6 Examine the margin (edge) of the leaf. Is the edge smooth or not?
Monocotyledon: yes
Dicotyledon: sometimes, sometimes not

7 Look at the veins of the leaf. Do the veins run parallel to each other or do they branch out and form a network?
Monocotyledon: They run parallel to each other.
Dicotyledon: They form a network.

8. Drawing skills: Learners are required to accurately draw what they see. Encourage learners to do the following:

- give the drawing a heading
- draw sharp continuous lines
- no shading
- include labels and label lines that do not cross.

B Internal Structure (*Optional*)

The following section is to be used in conjunction with a light microscope.

Learners should note the distribution of different tissues. Further details of the internal structures of monocotyledons and dicotyledons may be found in any standard textbook.

Activity 4: Structure of Angiosperm Flowers

Stage 4 - Structure of the flower

INFORMATION

The flower is the reproductive unit of a flowering plant. Flowers consist of four whorls, or concentric rings of modified leaves. The whorls, from the outside in, are called the :

- calyx of sepals (usually green)
- corolla of petals (often coloured, sometimes scented)
- androecium of stamens (male parts)
- gynoecium of carpels or pistils (female parts).

These arise from a central receptacle which is borne on a stalk called the pedicel.

Flowers adapted for insect and bird pollination have coloured and scented petals. Wind-pollinated flowers have dull petals if they have them at all. Together, the sepals and petals are called the perianth (peri - around; anth - anthers). Each stamen is composed of a filament which has an anther at its tip. The anther contains pollen. The gynoecium consists of one or more pistils each composed of an ovary with ovules, a stalk called a style and a sticky tip called a stigma. Pollen sticks onto the stigma.

Many flowers are hermaphroditic or bisexual which means that they have both male and female parts. Unisexual flowers have either male or female parts. After pollination and fertilisation, the ovary ripens to form a fruit and the ovules ripen to form the seeds.

When teaching this section, ensure that the learners have a variety of both monocotyledon and dicotyledon flowers.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

A External Structure

Observation Questions

a Are there distinct sepals and petals?
Monocotyledon: no
Dicotyledon: yes

b Are the parts of the flower in multiples of three or not?
Monocotyledon: multiples of three
Dicotyledon: multiples of four or five

c Are the petals joined to each other or are they free?
Monocotyledon: no distinct petals but inner perianth parts usually joined
Dicotyledon: joined or free

d Are the sepals joined to each other or are they free?
Monocotyledon: no distinct sepals but outer perianth parts usually joined
Dicotyledon: joined or free

e Does the flower have both male and female parts?
In both cases the answer is usually "yes" but there are exceptions. The answer will depend on the example/s selected for study.

B Internal Structure (*Optional*)

The androecium

Examples of different pollen grains

The pollen of wind-pollinated plants is light, smooth and often winged. The pollen of animal-pollinated plants may be rough, sticky and spiky. There are different patterns and colours, which are quite easy to observe.

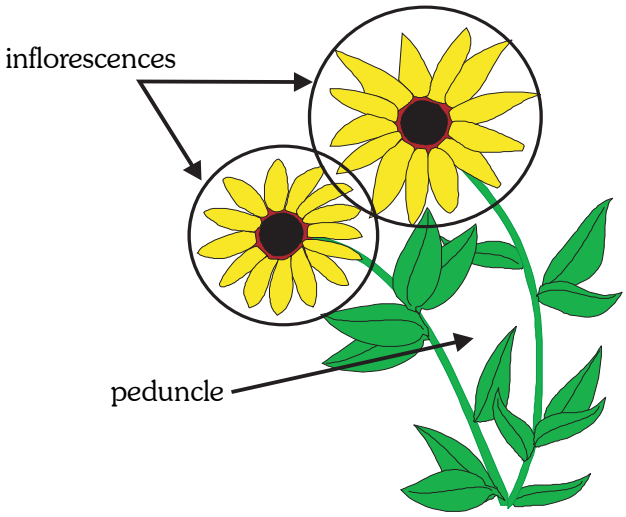
The gynoecium

The flowers of beans, peas, aloes, agapanthus, sweet peas, tomatoes and squash are useful for this exercise. Learners should observe the number of chambers (locules), and the position of the ovules.

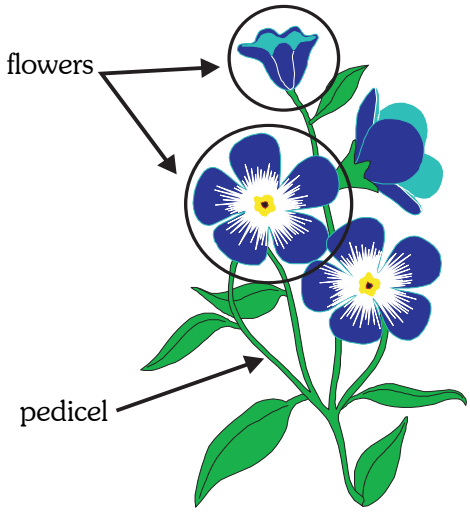
Activity 5: Structure of an Inflorescence

INFORMATION

Sunflowers, daisies, dahlias, zinnias and many other plants belong to the Family Compositae of the angiosperms. The flowers are grouped together in inflorescences called **capitula** or heads. At first sight, the inflorescence looks just like a flower, but on closer examination, we can see that the "flower" is a group of flowers. The structures which, in everyday speech, we call "petals" are whole, highly modified flowers.



Composite



Simple

In this activity, students will examine an inflorescence of a member of the Compositae. If you have not sown sunflower seeds, the heads of these flowers (or large daisies) will have to be obtained some other way.

In the real world, the logical pattern of flower parts is not so obvious. In some cases the petals may fuse to make a tube. In other instances different parts, like filaments, are fused with petals. With an infloresence many flowers combine. The inner flowers which have no sepals or petals are called **disc florets**. The outer flowers, called **ray florets**, produce the petals along the edge of the flower.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

For interest

Learners may wish to examine the pollen of the sunflower using a light microscope. The hairy "stem" is also a good subject for microscopic investigation.

Activity 6: How are Bacteria Cultured?

INFORMATION

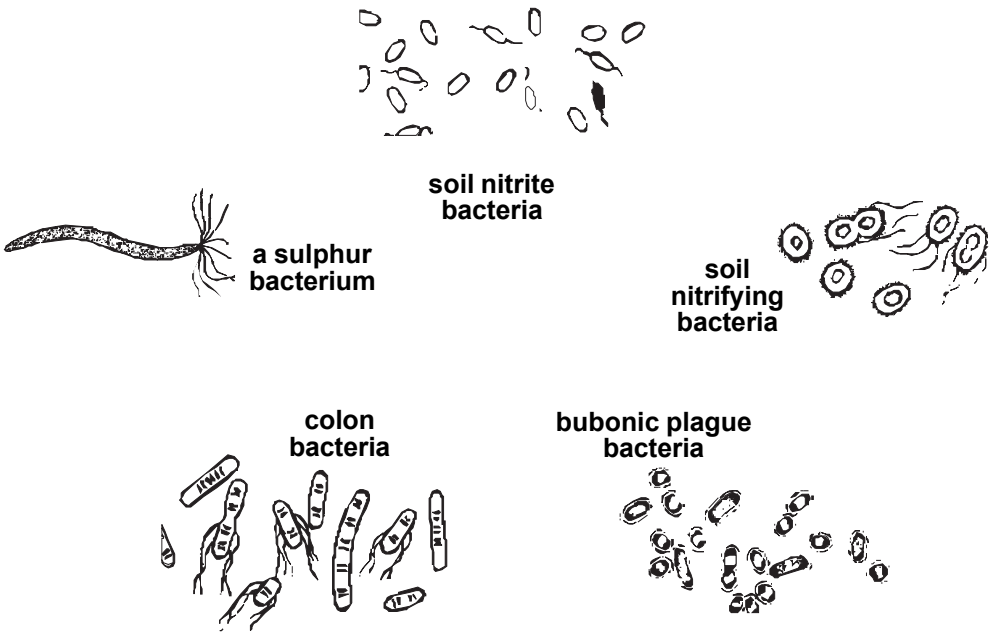
The bacteria (**Kingdom Monera**) are simple, unicellular organisms. Cell shape varies from species to species, some being rod-shaped (bacilli), some spherical (cocci), and others spiral (spirilla). These different shapes are visible only under a microscope. Bacterial **colonies** are of various colours which are visible with the naked eye. Bacteria are either autotrophs or heterotrophs, also varying in their modes of respiration; some being aerobes which need oxygen to respire, some obligate anaerobes (which are poisoned by oxygen), and others facultative anaerobes (which can respire both aerobically and anaerobically).

Recently, scientists have also classified bacteria according to other criteria which rely on techniques like DNA sequencing, protein analysis, immunology (in which the reaction of various species to specific antibodies is compared), phage typing (which employs bacteria-infecting viruses called bacteriophages), and electron microscopy.

It is important for learners to refine their ideas about bacteria. Many people have negative ideas about bacteria. Although several bacteria cause disease, the majority play a vital role in the ecosystem. Many bacteria, by their feeding, break down materials in sewage, compost and both dead and living organisms. Materials which can be broken down in this way are biodegradable.

It is also important to relate the concept of conservation of matter to the processes of decay and recycling. When a substance has decayed, the substances of which it was composed have been changed into gaseous and dissolved substances. The decay products are incorporated into the bodies of other organisms. No atoms are destroyed or created; they change their combinations.

A VARIETY OF BACTERIA



Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

Questions

1 From which source did the largest growth develop?
Answers will depend on the sources. Soil, and items used for cleaning (dishcloths for example) will yield large numbers of bacteria.

2 From which source did the greatest variety of colonies develop?
Findings will vary.

3 Did any bacteria grow on the control nutrient medium?
A few usually do.

4 Suggest ways in which one could design an even better control.
Example: A whole comboplate kept under sterile conditions could be a better control.

5 Explain how people contract infections even though precautions are taken to avoid the spread of infection.
Some infections are caused by bacteria. There are always bacteria in the air. Under normal conditions, people's natural resistance and immunity ward off these bacteria. Sometimes, if resistance is low, a person will contact an infection.

Assignment

You may need to make other reading resources available for the learners in order for them to answer these questions.

1 In which areas would you expect to find sources of bacteria?
Example: All of them, especially the bin, mop and other cleaning materials. Bacteria are very likely to be in the vicinity of the wash basin. Depending on how recently surfaces were wiped, there may well be colonies on the stove, in and on the refrigerator, table, chair and cupboards and of course the floor. This is not to say that the bacteria are all harmful. For example, certain cheeses and yoghurts are made using bacteria.

2 Explain why you would expect to find bacteria in these areas.
Example: Bacteria are everywhere. Those feeding on dead or decaying materials will multiply very rapidly near food if conditions, like temperature, are favourable. Soil bacteria could have been brought in from outside on a person's shoes. This may be untidy but it is not necessarily health threatening.

3 Outline the method you would use to test some of these areas for bacteria.
Example: Use the method described for culturing bacteria in this activity. Then examine the cultures using a good microscope. Later conduct further tests to establish the identity of the bacteria.

4 Imagine that you find the following:

Region	Observations
handbasin	colonies of bacteria - (E. coli)
refrigerator, table	colonies of bacteria - (Lactobacillus species)
surface of stove	no bacteria found
cupboard	colonies of unidentified bacteria
doorway	colonies of bacteria - (Yersinia pestis)

4.1 Suggest reasons for the appearance of the colonies in each of the places.

Example:

E.coli: this is a common bacterium found in the intestine; probably in the handbasin from people washing their hands.

Lactobacillus species: a harmless bacterium, used in cheesemaking, very likely to be found in kitchens.

No bacteria on stove: the area was most probably very recently wiped and disinfected.

Unidentified bacteria: possibly having been blown from nearby bin.

Yersinia pestis : very surprising; a dangerous organism which causes plague.

4.2 Provide a brief outline of how you would react in each of these cases on finding the bacteria.

Example:

E.coli: encourage continued handwashing in places other than kitchen, check handbasin facilities in bathroom; insist on more frequent disinfection of all handbasins

Lactobacillus: do not bother except to encourage washing of utensils to prevent further invasion of possibly harmful types

no bacteria: resample from the area; check methods of culturing and identification.

unidentified: identify or arrange for someone to do so; remove bin from utensils and sources of food.

Yersinia pestis: notify public health authorities; close place down; isolate all persons in the place; conduct tests; check identification.

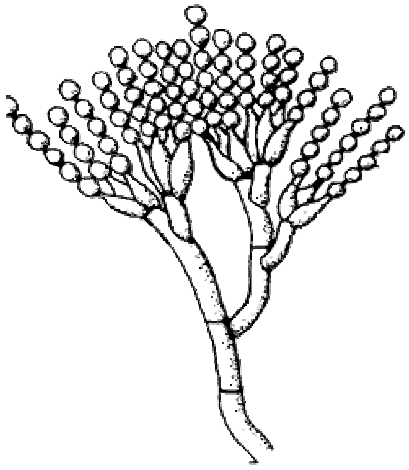
Activity 7: What Moulds will Grow on Bread?

INFORMATION

The **Kingdom Fungi** is one of the five kingdoms of living organisms. It contains about 100,000 species. Included in the kingdom are mushrooms, puffballs, truffles, stinkhorns, yeasts, and moulds as well as the pathogenic forms which cause athlete's foot, potato blight, ringworm and dry rot.

Most fungi are multicellular as is the bread mould. These are usually filamentous, composed of strands called hyphae. The hyphae are clustered together to form a mycelium. Fungi reproduce by means of spores, which, under favourable conditions, germinate and grow into new fungi.

Most fungi feed on dead and decaying matter and grow very easily on a suitable source of food like bread, potato, cake, fruit and other things. These fungi play an important role in any ecosystem because they usually start the process of decomposition. Some fungi, like bread mould, cause us inconvenience when they grow on our food, spoiling it. People use extracts of other fungi to fight disease. The antibiotic, penicillin, is produced from a fungus called ***Penicillium***.



Penicillium sp

The instructions for the maintenance of a fungus colony can be followed quite easily by the learners. Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

Stage 1: Colonies of Moulds

Questions

1 Which type of mould did you identify most frequently?

2 Did you notice that any type of mould was more common on any of the substrates?

3 What is happening to the bread or cake as the mould gets bigger?

The answers to the above questions will vary from one situation to another. There are no right or wrong answers.

Stage 2 Detailed Study of Bread Mould

Initially the hyphae are all identical but later three types are produced. Each type of hypha is specialised for the job it has to perform. The **stolons** cover the surface of the substrate. The **rhizoids** grow down into the substrate. The **sporangiophores** grow up from the stolons.

Stage 3 Examining a section of fungal mycelium - *Optional Activity*

By using a light microscope, learners will see more detail of the structure of the sample of mould, including the spores.

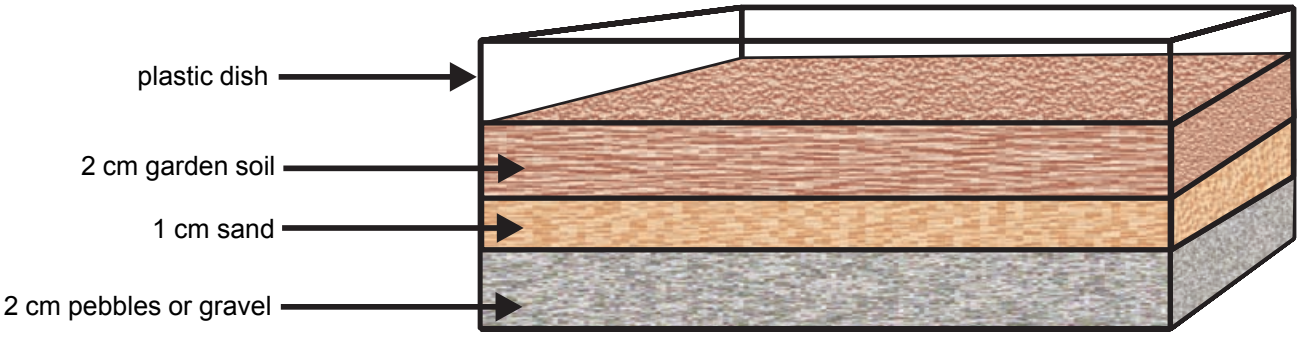
Activity 8: What is the Structure of a Moss Plant?

INFORMATION

Mosses are not always available at exactly the time they are needed. For this reason it is a good idea to collect them when they are available and to maintain them in a suitable place. When you collect them, be sure to gather some of the soil on which they are found. Transport them in a plastic bag and place them in a terrarium as soon as possible. A large plastic dish with several holes in the base is ideal for a short-term terrarium. The terrarium should be set up as illustrated below. (Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.)

The teacher is free to decide whether there is to be one moss colony or whether the learners are to maintain their own moss colonies as part of project work. If there is to be one colony maintained by the teacher, the learners can start the activity at Stage 2. If learners are to maintain their own colonies, they can start at Stage 1, using a small plant-pot.

Add water to the depth of 1 cm above the bottom of the terrarium. Cover the dish with the lid. Ensure that the moss colony is not attacked by moulds. If moulds appear, add no more water until the moulds disappear.



Stage 2

- **rhizoid:** an outgrowth that acts like a root. It is not a root as it does not have conducting tissue.
- **'leaf':** moss does not have true leaves as they do not contain highly specialised tissues.
- **gametophyte:** phase in the life cycle of a moss which produces gametes.

The Gametophyte

1 Use your knowledge of the meaning of the above words to help you identify parts a and b in the drawing of the moss plant below.
a - leaf-like structures ("leaves")
b - rhizoids

3 How tall is the moss plant?
It depends on the species. Usually less than 1 cm high (without sporophyte).

4 Describe the arrangement of the "leaves" around the shoot.
The "leaves" are spirally arranged round the shoot.

5 Of what value to the moss is this arrangement of leaves?
The leaves can absorb maximum light this way and can also hold some water.

6 Make a drawing of your own moss plant. Label the parts you have identified.
The reason for asking students to draw the moss they see is to encourage observation because not all mosses are the same.

7 a In what ways is your moss similar to the one given?
b In what ways is your moss different from the one given?
Answers will depend on the species.

The Sporophyte

8 Meanings of biological terms:

- **capsule** - the moss sporangium which bears spores.
- **calyptra** - a sheath covering the capsule.
- **operculum** (not the gill cover of fish) - the cap of the moss sporangium.
- **seta** - stalk of sporophyte.
- **peristome** - ring of teeth-like projections around the rim of the mouth of the capsule.
- **sporophyte** - the spore-bearing generation in the moss life cycle.

9 From what cell did the sporophyte develop?
The fertilised egg or zygote.

10 Find the capsule at the tip of the seta. Remove the calyptra if one is present. Of what value is the calyptra to the moss plant?
It provides a covering and protects the capsule.

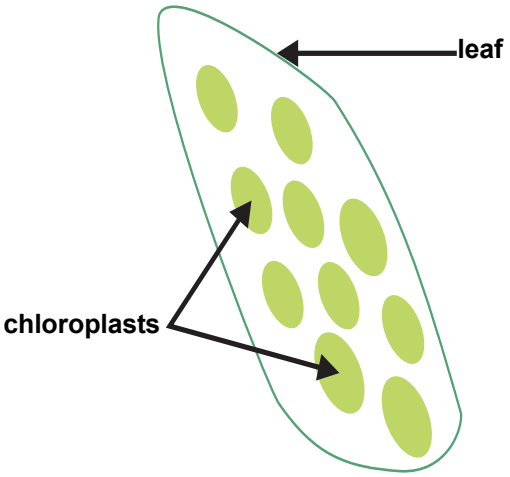
Use the dissecting needle to squash the capsule. Examine the squashed capsule using a light microscope (if available) and hand lens.
Learners may see the peristome teeth at the mouth of the capsule. They may be lucky enough to see a few spores (visible as dots).

11 The sporophyte remains attached to the gametophyte. Discuss the symbiotic relationship between the sporophyte and the gametophyte.
The sporophyte and gametophyte have a symbiotic relationship in that they "live together". In this case, the sporophyte benefits but the gametophyte is not affected. The sporophyte absorbs water and mineral salts from the gametophyte but has photosynthetic tissue so manufactures its own organic nutrients. For this reason, the sporophyte is not a full parasite but a semi-parasite on the gametophyte.

Stage 3 Microscopic examination of moss - *Optional Activity*

A Examining a section of moss gametophyte

The most striking feature of the specimen will be the abundance of chloroplasts. Encourage learners to focus on these and to attempt to see them as clearly as possible.



B Examining a section of moss sporophyte

Your learners may need to remove the operculum first before they can see the peristome teeth.

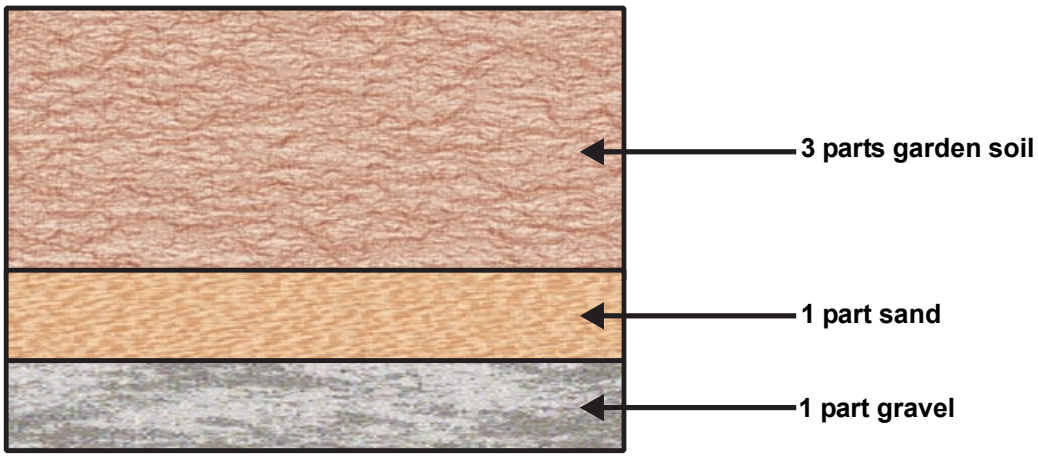
Activity 9: What is the Structure of a Fern Plant?

INFORMATION

Ferns are vascular plants, having well developed conducting tissue. Although they are land plants, most ferns depend on water for reproduction. Unlike mosses, the actual fern plant is the sporophyte generation.

Sword ferns are ideal for use in the classroom because they are plentiful and are easily propagated. At least 3 weeks before the fern is to be studied, obtain a sufficient number of fern plants so that all the students can observe these. Dig up the ferns together with the rhizome (underground stem) the roots and some of the soil in which they are growing. Transport these in damp newspaper and transplant them as soon as possible.

Ferns will thrive in the classroom in terraria or in pots. Prepare the habitat using sand and soil as shown below for both terrarium and plant pot. The teacher is free to decide whether there is to be one fern terrarium or whether the students are to maintain their own potted ferns as part of project work. If there is to be one terrarium maintained by the teacher, the students can start the activity at **Stage 2**. If students are to maintain their own ferns, they can start at **Stage 1**.



Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

Stage 2

Meanings of biological terms:

- **root -** underground organ that absorbs water and mineral salts, and usually anchors a plant.
- **rhizome -** elongated horizontal underground stem.
- **adventitious root system -** fibrous roots that arise from the stem.
- **tap root system -** system of roots which arise from one root, the tap root.

- **fronds -** fern leaves.
- **fiddleheads/croziers -** young curled up fronds.
- **pinna (pl pinnae) -** leaflet on fern frond.
- **pinnule -** leaflet of a pinna.
- **rachis -** central stalk to which pinnae are attached.
- **sporangium (pl sporangia) -** structure where spores are formed.
- **sorus (pl sori) -** a cluster of sporangia.

Questions

1 How tall is the fern?
Height varies according to the species and according to environmental conditions. Sword ferns are about 60 to 70 cm high ; tree ferns are several metres high; maidenhair ferns may be 15 cm high.

2. Do you see an upright stem?
Very unlikely, unless a tree fern has been selected for study. Sword ferns do not have upright stems. Like most ferns they have underground stems or rhizomes.

3. The roots anchor the fern in the ground. Examine the roots carefully. From what structure do the roots arise?
The roots arise from the stem or rhizome.

4. Are these tap roots or adventitious roots?
They are adventitious roots.

5. Explain your answer to Question 4.
Adventitious roots arise from a structure other than the main root. As these roots arise from the stem, they are adventitious roots.

Fern fronds (leaves) grow upwards from the rhizome.

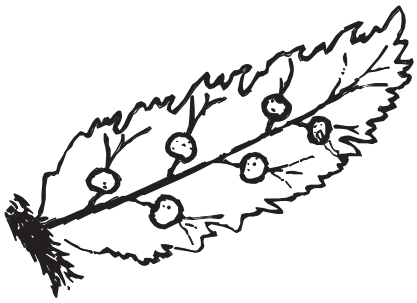
6. Are they simple or compound leaves?
They are compound leaves.

7. Draw one of the fronds of your fern.
8. Examine a very young fern frond. Describe its appearance at the tip (i.e. the end furthest away from the soil).
It is curled up. These curled up fronds are the fiddleheads or croziers. The pinnae are also curled up.

9. Use the hand lens to examine a single pinna with sori or sporangia. Describe the number and position of the sori or sporangia.
The sori are on the ventral surface of the pinnae. Within the sori are several sporangia. The position varies according to the species - some are marginal, some are attached to one side of the frond, some are central. Certain ferns do not have sori, just sporangia.

10. Sketch a frond of your fern, showing the venation in detail.
This also varies with the species. The reason for giving the students these questions is that they learn to observe carefully.

11. Sketch part of a frond of your fern showing the position of the sporangia.
This also varies according to the species. An example is shown below.



Stage 3 Examining the spores using a light microscope - *Optional Activity*

The learners may observe the annulus of a sporangium moving slowly if it splits and curls open.

Activity 10: What is the Structure of a Free-living Flatworm?

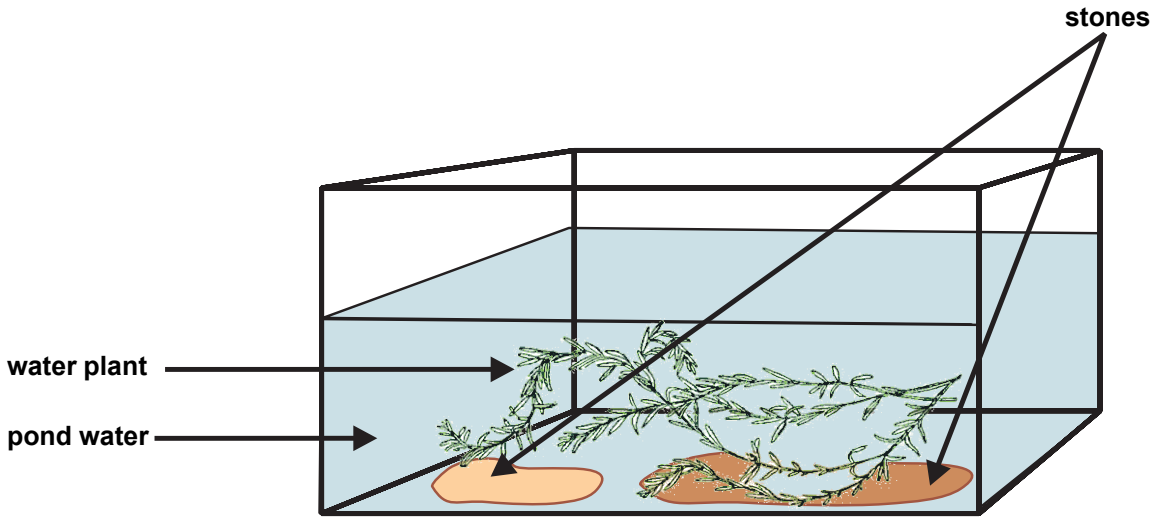
INFORMATION

The phylum Platyhelminthes (literally FLATWORMS) consists of parasitic flukes and tapeworms as well as free-living forms. Free-living flatworms are commonly referred to as **planarians**.

Planarians live in fresh water ponds, dams and streams. To bait them, attach a piece of liver to a piece of string and place it in the water. The planarians will be attracted to the meat and after one to two hours, there will be several planarians on the underside of the meat. Brush the planarians into a container of pond water. Alternatively, hunt for them by turning over rocks in bodies of water and collecting them this way.

They are easily maintained in the classroom in dark* containers about the size of a large laundry bath or plastic baby bath (dark because they are negatively phototropic). The teacher can decide whether to have a single colony or to let students maintain their own colonies of planarians as part of project work. If the latter is the case, the lunch box makes a suitable habitat for planarians. (Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.)

Place pond water in the container so that it is about half full. Place stones or rocks from the pond in the container, together with some vegetation and place the planarians in this environment.



***an opaque, solid green or dark blue is ideal**

If pond water is in short supply, artificial pond water may be made the following way:

Stock Solution A	Stock Solution B
13.3 g sodium chloride (s)	3.8 g sodium bicarbonate
26.6 g calcium chloride (s)	1 litre distilled water
1 litre distilled water	

Add 10 ml of each stock solution to 4 litres of distilled water.

Questions

1 What is the length and the width of the planarian?
Size depends on species. They are between 2 cm and 5 cm in length and less than 1 cm wide.

2 What colour is the planarian?
They are greyish or black to light brown.

3 Does it have a definite front (anterior end) and rear (posterior end)?
Yes it has definite anterior and posterior ends. The light-sensitive eye spots are situated anteriorly.

4 Does the planarian move in a specific direction all the time?
It usually moves forward.

5 How do you think the planarian receives information about its surroundings?
The eyes are sensitive to light. The auricles are sensitive to touch and chemicals dissolved in the watery environment.

6 Locate the ventral (under) side of the planarian and identify the **pharynx**. This is a long tube to which the mouth is attached. Collect some food from your teacher. Place the food in the container with the planarian and observe it feeding. You must be patient - keep observing the planarian over a period of time. Once you have seen it feeding, describe what you see.

- *Provide small strips of fresh liver or fresh, lean beef.*
- *Please remind students that the water becomes heavily polluted by the decay of the food.*
- *The water must be changed regularly.*
- *If planarians have not had food for about 5 days, they are more likely to respond to the food.*

Planarians are saprozoic which means that they feed on dead or decaying material. When feeding, they evert (turn inside out) the pharynx and place the opening at the end of the pharynx on the food. They secrete digestive enzymes onto the food and suck the liquid food into the body by pumping the pharynx.

7 Consider the following report.

Plenty of planarians?
A biologist placed a single planarian in an aquarium, making sure there was enough food for the planarian. Some time later, two smaller planarians were seen and there was no sign of the original planarian.

Where do you think the two planarians came from?
The original planarian underwent asexual reproduction. Planarians reproduce in this way by splitting along the longitudinal axis i.e. by "dividing into two".

8 What do you think happened to the original planarian?
It has become two identical planarians or "clones".

9 Devise an investigation which could test your ideas. Write down the steps of the method for your investigation.
Several possible answers

- We could watch a planarian in shifts and observe everything it does.

Note: Planarians readily undergo fission (splitting) if they are very well fed.

- We could use a camera to record the planarian's behaviour.
- We could cut a planarian in half and see what happens.

(This last scenario is not feasible at secondary level. Special instruments are needed and the procedure is very time consuming. It has been conducted by professional biologists who confirm that planarians do indeed regenerate in this way.)

Activity 11: What is the Structure of an Earthworm?

INFORMATION

Earthworms belong to the Phylum Annelida, a group of worms that possess a soft, cylindrical body divided into ring-shaped segments. Annelids possess a closed circulatory system and a series of body muscles which enables them to move by successive contractions and relaxation. They are found in a variety of habitats, living as scavengers, predators and a few as parasites.

Examples of Annelida

marine fanworms

segmented worm

leech

Many species, including earthworms, burrow throughout their lives.

Setting up an Earthworm Environment

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit. - especially for learners to keep their own earthworm populations. Additional equipment is available in the accompanying RADMASTE Biology Teacher Resource Kit

A One Population

A large plastic basin or container will house 20 to 30 worms. The earthworm home must be covered with a lid of some type to prevent escape and to retard evaporation. Plastic sheets punched with holes, cardboard punched with holes, close wire (such as a wire screen of aperture 1 to 2 mm) and muslin all make adequate lids. If the worms are to be kept outside, ensure that they are safe from birds.

Fill the container with a mixture of potting soil and compost. DO NOT USE CLAY. It is preferable to use the same soil from which the worms are to be collected. Ensure that there are plenty of dead and rotting leaves for the worms to feed on. Keep the soil mixture slightly moist by sprinkling with water as needed. However, do not allow the soil to become waterlogged as the worms will drown. Earthworms are very easy to find in good loamy soil or compost heaps. The best time to collect them is after rain, at night or in the early morning. They can be dug out with a spade or trowel. Ensure that at least some of the soil and leaf litter is also collected with the worms.

B Several Learner Populations

Prepare the habitat at least a day or two before collecting the worms. The plastic lunch box is adequate for two to three worms. The teacher is free to decide whether there is to be one earthworm population or whether the learners are to maintain their own earthworms as part of project work.

If there is to be one population maintained by the teacher or groups of learners, it is suggested that some learners set up the habitat described in the worksheet, using coloured chalk because it is a useful demonstration. The learners should notice that the coloured chalk becomes very mixed.

The colours become dispersed throughout the soil as a result of the worms' burrowing activities.

Questions

2 Is there a clear front (anterior) and rear (posterior)?
Yes there is.

3 Are there visible sense organs?
No.

4 Is the earthworm asymmetrical, radially symmetrical or bilaterally symmetrical?
It is bilaterally symmetrical.

5 Is the body flat or rounded?
It is rounded.

6 Hold the worm in the palm of one hand. Feel the body along the dorsal, lateral and ventral surfaces. What do you feel?
It is rough, bristly, hairy.

7 Does the body appear to be composed of a single unit or of several units?
It is composed of many units.

8 Count the number of segments in the earthworm's body. Compare your answer with the answer of other groups. Is the number of segments always the same?
They have about 150 segments. There is little variation within a species.

9 Now examine the earthworm with a hand lens and locate the bristles (setae, chaetae). Where on the body are they situated?
On the ventral and ventro-lateral regions of all segments except the first and last.

10 How many bristles are on each segment?
There are two pairs per segment.

11 The earthworm lives in soil. Of what value are the bristles to the earthworm when it burrows? To help you answer this question, find out if the earthworm moves easily on glass or on a clean petri dish.
The earthworm cannot move easily on a smooth surface. The bristles help it move in soil.

12 Observe the earthworms moving in their environment (i.e. moist soil in the lunch box). Describe their locomotion using the words in the box to help you.
Example: The worm digs the chaetae of some segments into the soil. In this way, part of the earthworm's body is anchored. Segments with retracted or pulled in chaetae in front of or *anterior* to this area become elongated and *thinner* when *circular muscles contract* and *longitudinal muscles relax*. Segments with retracted chaetae behind or *posterior* to the anchored area shorten and become *thicker*. The segments which were anchored then retract chaetae and elongate. The process is repeated continuously.

13 Keep the earthworm moist and observe the dorsal blood vessel.

a In which direction does the blood flow?
It flows forward.

b Time the pulse rate per minute.
At room temperature the rate is about 15 to 20 beats per minute.

14 Observe the anterior end of the earthworm. Find the structures illustrated.
Use the hand lens to look carefully along the length of the earthworm. Find the little holes or pores on most segments. What do you suppose is their function? To help you answer this question, think about the characteristics of life - nutrition, movement . . . and so on.
Their function is excretion.

15 Replace the earthworms in the lunch box. Discuss how their behaviour is related to the fertility of the soil OR discuss the reasons why gardeners like earthworms.
Example: Earthworms burrow in the soil, mixing and aerating it. In this way, air with oxygen becomes available to the roots of plants. Earthworms also feed on decaying vegetation, speeding up the process of decomposition whereby soil nutrients become available to plants. In addition, the earthworm's own waste products fertilise the soil.

16 The drawing above shows a ventral view of the body of an earthworm.

a List the letters a to h in your notebook. Beside each of these, write the appropriate label from the box below.

a mouth	**d openings of spermathecae**	**g clitellum**
b prostomium	**e female reproductive opening**	**h last segment**
c peristomium	**f male reproductive opening**	

b List the structures which can be seen only in dorsal view.
Dorsal pore

17 The sketches below are representations of possible transverse sections through a number of worm-like animals. Which of them do you think best represents the earthworm?
Number 5 is the one most like the body plan of the earthworm because it shows one tube within another. The muscles of the body-wall are represented by the outermost solid layer; the gut musculature by the inner solid layer and the coelom and enteron by the outer and inner blank layers respectively.

Activity 12: What is the Structure of a Garden Snail?

INFORMATION

The garden snail belongs to the group of animals called Molluscs which have soft bodies. Molluscs are invertebrates, having no internal skeleton. However, many species have a hard shell covering the body. Most molluscs have a head, a muscular foot, and a hump that contains the body's organs.

The garden snail is an unusual mollusc in that it lives on land. Other molluscs live in fresh water or in the sea. Garden snails are herbivorous. They feed on green leaves, scraping them with rough files in their mouths, called radulae. Snails have a membrane, or mantle, which has tiny blood vessels, and acts as a lung, allowing gaseous exchange between blood and environment. They move on a muscular foot over a trail of mucus which they produce.

Either the teacher or the learners may collect the snails for study. They should be collected in the early morning or early evening. Take some of the plant material on which they are feeding as well. Place them in a large container with damp soil and vegetation until the class is ready to study them. Ensure that a lid of wire screen (aperture 1 mm to 2 mm) is loosely placed on the container otherwise the snails will escape.

Examples of Molluscs

(not to scale)

zebra mussel

squid

marine mollusc

Stage 1 Setting up an Environment for Snails

The teacher is free to decide whether there is to be one snail population or whether the learners are to maintain their own snails as part of project work. If there is to be one population maintained by the teacher or groups of learners, the learners can start the activity at **Stage 2**. If learners are to maintain their own populations, they can start at **Stage 1**.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

Stage 2 The Structure of the Snail

Questions

1 Examine the shell of the snail.

a Is it symmetrical?
No.

b Does it spiral clockwise or anticlockwise?
There is variation.

c Are your answers to the above questions true for all snails?
No.

d Support your answer with some observational evidence.
Example: Of the 20 snails in our class, 12 have clockwise spirals and 8 have anticlockwise spirals.

2 Examine the head of the snail.

a Find the tentacles. What is the difference between the two pairs of tentacles?
One pair is longer than the other.

b Where are the eyes?
They are at the tips of the long tentacles.

c Offer the snail a small piece of lettuce. Describe its response.
It moves along the lettuce, scraping at the upper surface.

3 Locate the large muscular foot of the snail. Place the snail on a leaf. Allow the snail to move across the leaf.

a What do you observe on the leaf behind the snail as it moves across the leaf?
A slime trail.

b In what way does the snail benefit from what you observed on the leaf?
The slime helps the snail to move. The slime reduces friction between the snail and the leaf.

c Describe what you see, using the words in the box to help you.
Example: The foot of the snail shows light and dark bands which are the alternate waves of contraction and relaxation of the muscles of the foot.

d In which direction does the snail move?
Usually forward i.e. upwards in this case.

e In which direction does the snail move now?
It turns and moves upwards.

4 Look carefully at the anterior end of the snail. You may see the action of the radula in the mouth of the snail. What does the radula do?
It scrapes at the leaves.

5 Hold the petri dish with the snail horizontally. Look carefully at the widest end of the snail's shell. Locate two openings. The anterior (front) one is the pneumostome (hole for breathing). Observe it for a few minutes. What do you see?
It opens and closes.

6 Explain in your own words what you understand by the term "hermaphroditic".
It means bisexual. Snails are both male and female.

Activity 13: What is the Structure of an Insect (Locust)?

INFORMATION

Insects form the largest group of arthropods all of which have jointed legs. The bodies of insects are divided into three parts namely head, thorax, and abdomen. The thorax bears three pairs of legs, and usually two pairs of wings. Some insects are wingless and Diptera (flies) have a single pair of wings. The head bears a pair of antennae and both simple and compound eyes. The abdomen bears the spiracles and the organs of reproduction. Insects are found everywhere and are of great economic importance.

Locusts undergo incomplete metamorphosis. The juvenile stages of the locust are called hoppers or instars. The first hopper or instar hatches from the egg and when the fifth hopper or instar moults, the final, adult stage is reached.

The learners and/or the teacher can catch a few locusts in grassy areas during spring. Locusts are quite easy to keep in captivity for a short time. It will be easier if there are few locust colonies, rather than many. A temporary locust home can be made in the following way.

Making a Locust Home

Requirements:

Empty cardboard box approximately 35 cm x 35 cm x 25 cm,* Large vial, Wire mesh of aperture 0.5 cm to 1 cm, Plenty of fresh grass which has not been treated with insecticide, Sand and twigs, Elastic bands, Paper fasteners, Cotton wool. (Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.)

* the boxes which contain duplicating paper are of these dimensions.

1 Remove two of the sides of the cardboard box.

2 In one of the sides cut a hole of the same diameter as that of the large vial. (See Figure 1)

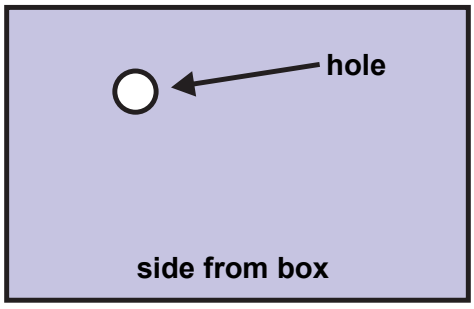


Figure 1

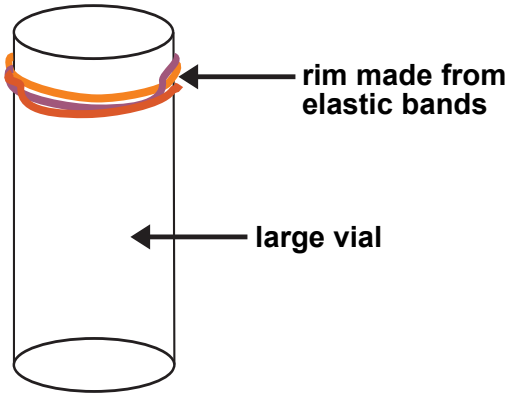


Figure 2

3 Fasten two or three elastic bands around the large vial to make a rim around the neck. (See Figure 2).

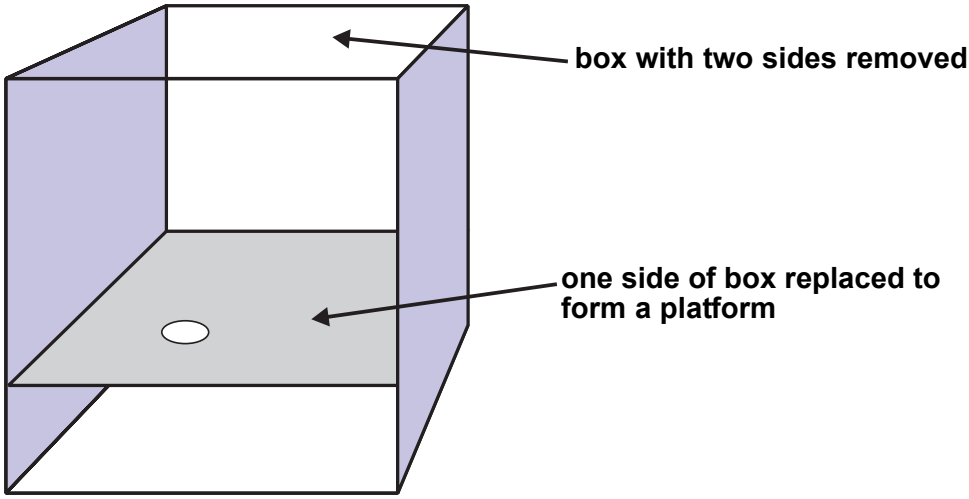


Figure 3

4 Place the side back in the box to make a platform about one-third of the way up. (See Figure 3).

5 Place water with fresh grass in the vial and seal the neck of the vial with cotton wool. (See Figure 4).

6 Pass the vial with the grass through the hole in the "platform". It will hang securely by the rim of elastic bands.

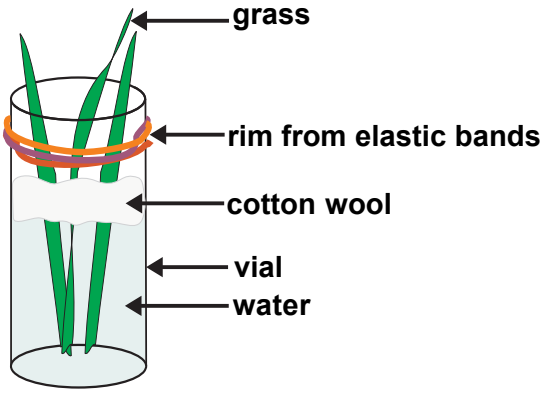


Figure 4

7 Place sand and twigs in the box.

8 The home is ready for the locusts. (See Figure 5).

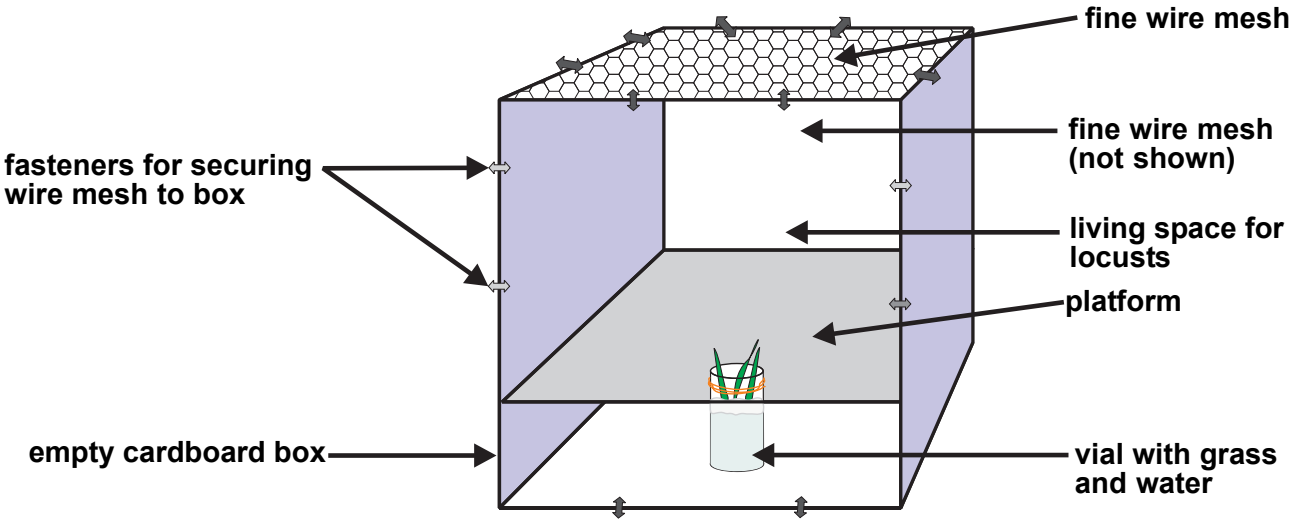


Figure 5

9 Secure the wire mesh to the open sides of the box with the paper fasteners when the locusts are placed in their home.

OBSERVING INCOMPLETE METAMORPHOSIS

The teacher can do the introductory investigation, included here, if the learners are to investigate incomplete metamorphosis.

Introductory Questions

1 Locusts are usually found in dry areas. Examine the locusts in the colony and list all the ways you can see how these animals are adapted to dry conditions.

Example: they have a waterproof covering; their waste products are dry; the body openings like the spiracles are tiny and do not allow much water loss.

2 Why do you suppose the juveniles are called "hoppers"?
They cannot fly and they hop from place to place.

3 In history, we hear and read of "locust plagues". Why are swarms of locusts a plague, do you think?
Example: An average swarm contains over five thousand million individuals. Both adult and juvenile locusts eat a lot and the adults can eat their own body mass of green food every day. When they swarm, they land on crops and eat everything. There is nothing left for people to eat and they starve.

4 Consider a small swarm of 10 million adult individuals. Each locust has a mass of three grams. They feed for two days. What mass of green material is consumed in this time?
Example: 1, 000, 000 x 10 x 3 x 2 = 60 million grams (6×10^6g)

= 60, 000 kg of green material

(This is a small swarm and we have not considered the juveniles.)

Stage 1 Structure of the locust

Answer the following questions.

1 Does the locust have an exoskeleton?
Yes it does.

2 Find out from a suitable text the name of the substance of which it is composed.
Chitin.

3 Into how many parts is the body divided?
Three.

4 Is the body segmented?
Yes.

5 How many appendages are there?
Three pairs of legs and two pairs of wings.

6 From which body part do they arise?
The thorax.

7 List the sense organs of the locust and note where they are located; how many there are and their function.
One pair of compound eyes at the side of the head for sight.
Three simple eyes on the head for sight.
One pair of antennae on the head for touch and smell.
2 pairs of palps with the mouthparts for touch and taste.

8 Locusts can hear. How do you think they can do this?
There are tympanic membranes on the first abdominal segment. These act like our eardrums and the locust can perceive vibrations.

9 Watch the locust feeding. Which structures do they use when they feed?
They use their mouthparts and sometimes their front legs.

10 How is undigested food eliminated?
Dry waste is passed out the anus.

11 Along the sides of the body are several holes or pores. Watch them. What do you think they are there for?
They open and close. Their function is to allow air into and out of the body of the locust.

12 Watch a locust walking. Describe how they use their legs. Observe carefully and note which legs on either side are used simultaneously (at the same time).
They use the front and hind legs of one side at the same time as the middle leg of the opposite side. In this way, the locust stands on three legs, like a tripod.

13 You will notice that the hind legs are different from the others. What do you think is the function of the hind legs?
The hind legs are muscular. They are the jumping legs.

14 Identify the following structures on an adult locust. If you do not know the meanings of the terms, refer to a biology dictionary or other text.
A quick verbal test may be conducted at this stage, where the teacher asks learners to point out one or two different structures. Alternatively, learners could test each other's knowledge.

15 Refer to the diagram below. In your notebook, write the letters a to j underneath one another. Beside each letter, write the correct label.

a	**antenna**	**d**	**mouth parts**	**g**	**walking leg**
b	**pronotum**	**e**	**abdomen**	**h**	**hind leg or jumping leg**
c	**compound eye**	**f**	**foot**	**i**	**spiracles**
				j	**hind wing**

Stage 2 Examining insect parts using a light microscope - *Optional Activity*

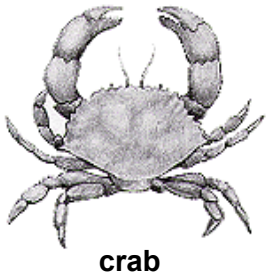
If time allows, this exercise could be used to help learners develop skills of observation.

Activity 14: What is the Structure of a Crustacean?

INFORMATION

The crustaceans belong to a diverse group of arthropod invertebrates. There are about 38 000 species which include crabs, lobsters, crayfish, prawns, shrimps, and woodlice. Crustaceans are mainly aquatic with a few exceptions. A few crustacean species like woodlice are also found on land where they live beneath stones and bits of rotting wood.

The body of a crustacean is jointed as are the appendages. The body is covered by a tough exoskeleton. In certain crustaceans, such as lobsters, the exoskeleton is hardened with calcium carbonate and is like a "crust". The head bears two pairs of antennae, a number of paired mouthparts and a pair of compound eyes. Most of the thoracic and abdominal segments also bear appendages.



crab

woodlouse

crayfish

It is convenient to buy, from a fish shop or supermarket, one or more dead prawns, crayfish or lobsters for observation.

Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit.

Questions

A General characteristics

1 Feel the outer covering of the specimen. Why do you suppose the organisms in this group are called ***crust***aceans?
There is a hard, crusty outer covering.

2 Of what substances is the outer covering composed?
Chitin and calcium carbonate.

3 Into how many parts is the body divided?
Two.

4 Is the body clearly segmented?
Yes in the abdomen, but not obviously elsewhere.

B The Cephalothorax

1 How many antennae are there? Compare the antennae with respect to length and structure.
There are two pairs of segmented antennae. One pair is much longer than the other.

2 How many eyes are there? Are they sunken at the surface?
There is a pair of compound eyes. In some species, they are sunken at the surface.

3 What is the carapace? What is its purpose?
The carapace is a shield-like outer covering of the thorax. It is protective in function.

4 Examine the walking limbs. How many are there? To what part of the body are they attached?
There are five pairs of walking limbs attached to the thorax.

5 Are any of the limbs modified in any way? Explain.
Answers will depend on the species. In many cases, the first pair of limbs is modified to form a pair of chelae or pincers. In certain species, the chelae are of unequal size.

6. Why is it important that the gills are attached to the walking legs?
The walking causes water to move over the gills.

C The Abdomen

1 What is the function of the pleopods (swimmerets), do you think?
They assist in swimming and they also have a function in reproduction.

2 What is the function of the uropod?
They assist in propelling the body forward.

Activity 15: What is the Structure of a Spider?

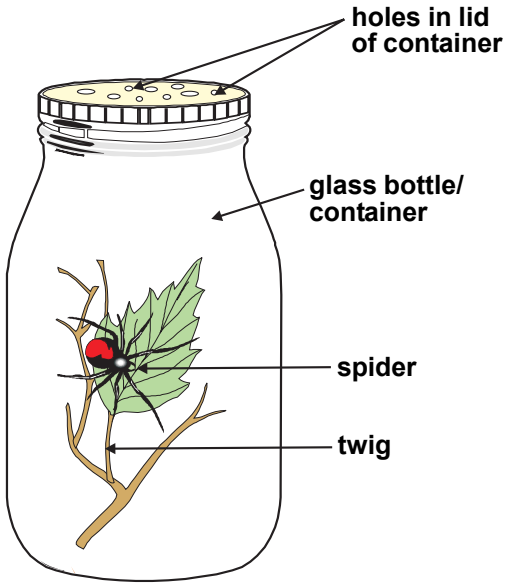
INFORMATION

Spiders, scorpions, ticks and mites belong to the arachnid class of the arthropods. They have a body divided into two parts, namely the cephalothorax (head-and-thorax) sometimes called the prosoma and the abdomen, sometimes called the opisthosome. They have eight legs arising from the prosoma and a pair of limb-like mouthparts called pedipalps. In spiders, the pedipalps are used for sensing and signalling. In scorpions, they are highly modified and are the pincers. All arachnids are carnivores, either hunting or trapping prey. They perform a useful ecological function by consuming many insects such as flies.

spider

scorpion

It is not easy to keep spiders in captivity for any length of time. It is suggested, therefore that the spiders are viewed at a discreet distance in their natural habitat. Alternatively, they can be captured in glass bottles with punched lids, examined and then returned to their habitat. Stress to the learners not to interfere with or annoy the spiders.



Note that most of the equipment for this activity can be found in the RADMASTE Microscale Biology Kit.

Questions

1 What is the outer covering called?
Exoskeleton.

2 Describe the substance forming the outer covering.
It is a leathery substance.

3 Into how many parts is the true body divided?
Two.

4 Is the body clearly segmented?
No.

5 How many walking appendages are there?
Eight.

6 From which body part do they arise?
The cephalothorax or prosoma.

7 Study the dorsal surface of the spider and locate the following structures:
a eyes - how many there are and their position.
Eight eyes clustered on the head.

b pedipalps - their position and possible function.
Two pedipalps with the mouthparts - they are for feeling the environment.

c anus.
One at the end of the opisthosoma for removal of waste.

8 Study the ventral surface and identify the following:
a chelicerae - position and possible function.
One pair at the mouth - they pierce the prey.

b reproductive opening.
On opisthosoma - release of sex cells and eggs.

c openings to book lungs.
On opisthosoma - allow air in and out for gaseous exchange.

d spinnerets (if present - not all spiders spin).
Release of silken threads to spin webs or lines.

9 Watch a spider feeding. Which structures do they use when they feed?
Chelicerae, pedipalps and sometimes front limbs.

10 Refer to the diagram below. In your notebook, write the letters a to j underneath one another. Beside each letter, write the correct label.

a	**first walking leg**	**b**	**third walking leg**	**c**	**opisthosoma**
d	**spinneret**	**e**	**prosoma**	**f**	**chelicera**
g	**anus**	**h**	**book lung**	**i**	**last walking leg**
j	**pedipalp**				

PART 2

CHAPTER 1

ENZYMES

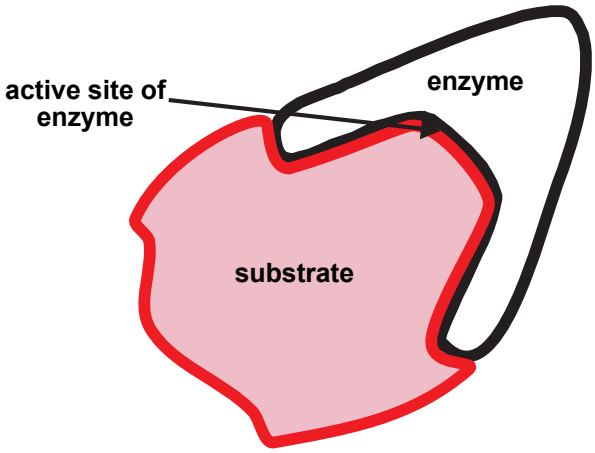
NOTES TO THE TEACHER

ENZYMES

INFORMATION

Enzymes are biological catalysts produced by living tissue which change the rate of the chemical reactions necessary for life. They are large, complex proteins. Enzymes are highly specific, which means that each biochemical reaction requires its own particular enzyme. The enzyme's specificity is related to the shape of the enzyme. Enzymes have active sites, which are parts of the enzyme molecule with specific shapes. The active site of an enzyme molecule fits precisely onto part of the substrate molecule.

The following diagram represents this lock and key theory of enzyme specificity.



an enzyme-substrate complex

As illustrated above, the enzyme and the substrate fit closely together, forming an enzyme-substrate complex. After the reaction has taken place, the enzyme drifts away unchanged and is free to act on other substrates.

Enzymes are influenced by various factors, like temperature and pH.

REQUIREMENTS

1 CHEMICALS

Please inform students of the following potential hazards. The reagents are perfectly safe if due care is taken. Keep all chemicals out of the reach of children.

√ Glucose
√ Iodine solution (I_2/KI) [1]
√ Amylase
√ Catalase
√ Buffer at pH 6.5
√ Starch
√ Gelatin
√ Bromelin
√ Rennin

[1] stains skin and clothing
toxic - do not ingest or inhale

Note that the chemicals mentioned can be found in the RADMASTE Biology Chemicals Kit.

PREPARATION OF REAGENTS

Glucose solution
Dissolve 1 teaspoon of powdered glucose in 100 ml water and store in a brown, stoppered bottle.

Starch suspension
1 Make a slurry (runny paste) of 1 tablespoon with 10 ml water.
2 Add 75 ml very hot water to this mixture.
3 Shake and stir the mixture until the starch powder is completely mixed with the water.
4 Add water to the starch mixture until the final volume is 125 ml.
Store in a brown, stoppered bottle.

Iodine solution
Dilute 1.0 ml of stock solution supplied to 100 ml with water. Store in a brown, stoppered bottle.

Amylase
Store in a cool place. Use as directed mixed with buffer.

Catalase
Obtained from plant and animal tissue.

Bromelin
Obtained from fresh pineapple.

Rennin
Use as provided.

Gelatin
Use as directed.

Buffer at pH 6.5
Store in a cool place.

2 EQUIPMENT

All the equipment you need is listed under the Requirements for each investigation. Most of these items can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

NOTES TO THE TEACHER

ENZYMES

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE ENZYME ACTIVITIES

Activity 1: The Action of Amylase on Starch

Questions

1 What is the colour of the I_2/KI solution (iodine solution)?
A. Yellowish-brown.

2 What happens when we add iodine solution to starch suspension or to a food which contains starch?
A. The mixture turns dark blue or blackish.

3 What is the colour of the mixture in well F2 after iodine solution has been added?
A. Blackish.

4 What does this observation suggest?
A. There is starch present in well F2.

5 What is the colour of the solution in well F1 after iodine solution has been added?

A. Any of:
- **yellowish**
- **brown**
- **pale black or grey.**

6 What does this observation suggest?
A. There is no (or very little) starch present in the well.

7 What substance did well F1 have which well F2 did not have?
A. Amylase.

8 What did the amylase do?
A. Amylase converts starch to something else.

9 Where do we find amylase in ourselves?
A. In our mouths and our intestines.

10 Amylase is an enzyme. What sort of enzyme is it?
A. Amylase is a digestive enzyme.

Activity 2: The Action of Amylase on Starch Over a Period of Time

Table to Show the Effect of Amylase on Starch over a Period of Time

Well	F1	F2	F3	F4	F5	F6
Colour	blue-black	blackish	greyish	pale grey	streaky grey	yellowish

Note to the Teacher

The colours listed in the table do not represent the only correct answers. They serve as an indication of the gradual colour change over time.

Questions

1 What was the substrate in this investigation?
A. Starch.

2 What was the enzyme in this investigation?
A. Amylase.

3 What do you think the end-products of the reaction are?
A. A disaccharide / maltose.

Note to the teacher

The answer will depend on how much the students already know. They should at least be able to deduce that the end products are molecules smaller than starch molecules.

4 What do your observations suggest?
A. The longer an enzyme has to act, the more substrate it can convert.

5 Amylase acts in the mouth which has a pH around 7. What do you suppose happens when the food and enzyme is swallowed into the stomach which has a pH around 2 to 3?

Note to the Teacher

The answer depends on what the students already know. They should be able to deduce that the enzyme could be denatured to some extent. The low pH of the stomach stops the action of amylase. The gastric enzymes function in a low pH medium.

Activity 3: The Effect of pH on the Action of Amylase on Starch

Table to Show the Effect of Amylase on Starch in Solutions of Different pH

Well	F1	F2	F3	F4
Solution	no reaction allowed	acidic	slightly acidic to neutral	alkaline
Colour	black	black	brownish	black

Questions

1 What was the substrate in this investigation?
A. Starch.

2 What was the enzyme in this investigation?
A. Amylase.

3 What do you think the end-products of the reaction are?
A. Maltose.

4 What do your observations suggest?
A. Amylase functions best in a pH medium around 7.

5 Amylase acts in the mouth which has a pH around 7. What do you suppose happens when the food and enzyme is swallowed into the stomach which has a pH around 2 to 3?
A. The enzyme is denatured.

6 Explain your answer in terms of the lock-and-key theory of enzyme activity.
A. The shape of the molecule is distorted. It can no longer function.

Activity 4: The Effect of Temperature on the Action of Amylase on Starch

Questions

1. What are the possible variables in this investigation?
A. Time, temperature, pH, substrate concentration, enzyme concentration . . .

2 What was the altered variable in this investigation?
A. Temperature.

3 What do your observations suggest?
A. Amylase works best in temperatures around 35 ^{0}C to 40 ^{0}C.

4 What is the significance of a temperature around 30 ^{0}C to 40 ^{0}C?
A. Mammals have a constant body temperature of about 37 ^{0}C.

5. What do you suppose happens to the enzyme at low temperatures?
A. At low temperatures, enzymes cannot function. Their reaction with substrate has an activation energy. There is little or no denaturation hence, when the temperature rises, the enzyme is able to function normally.

6 What do you suppose happens to the enzyme at high temperatures?
A. At temperatures higher than 40 ^{0}C, the enzyme becomes denatured in a similar way to how it is affected by pHs which are too low or too high.

7 An experiment, similar to the one which you have just done, was conducted in order to determine the effect of temperature on an enzyme. The enzyme was allowed to react for half an hour. The results of the experiment are shown in the graph below.

7.1 What is the optimum temperature for this enzyme?
A. Around 34 ^{0}C to 39 ^{0}C.

7.2 At which temperature does the enzyme function at 20% activity?
A. 10 ^{0}C and 80 ^{0}C.

7.3 How do you suppose enzyme activity is measured?
A. By measuring the quantity of substrate remaining or by measuring the quantity of end-product produced in a given period of time

7.4 Why does the enzyme activity not reach 100%?
A. The reaction was not left long enough to go to completion. As the quantity of substrate remaining gets smaller, the rate of reaction gets less. It takes an infinite time to reach 100%.

Activity 5: What is the Effect of Bromelin on Gelatine?

Questions

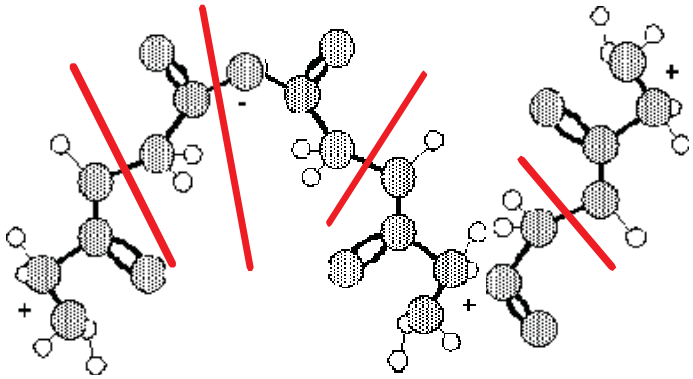
1 What is the effect of bromelin on gelatine?

A. Bromelin makes the gelatine runny. Bromelin stops the jelly setting.

2 The pancreas of mammals secretes an enzyme called **trypsin** which is also a proteolytic enzyme. Trypsin breaks certain peptide (amino acid) bonds in proteins.

The diagram below ***represents*** part of a protein molecule. Copy the diagram into your notebook and then use a coloured pen to show how trypsin breaks peptide bonds.

Suggested Answer



3 You have shown what trypsin does to proteins. If we have a meal which contains proteins, do you think we can absorb the products directly after trypsin has acted on the protein?

A. We cannot absorb the products yet.

4 Give a reason for your answer.

A. Peptides and polypeptides are still too large to pass through from the intestine into the blood vessels. Small enough to dissolve in water does not necessarily mean small enough to pass through membranes.

Activity 6: The Action of the Enzyme Catalase on Hydrogen Peroxide

Table showing the Effect of Types of Tissue on Hydrogen Peroxide

Tissue	Effect
example: **liver**	**greatest**

Note to the Teacher
Plant tissues usually show less effect than animal tissues.

Questions

1 What is the effect of the enzyme catalase on hydrogen peroxide?
A. Catalase causes hydrogen peroxide to decompose into oxygen and water.

2 Suggest another name for the enzyme catalase.
HINT: Enzymes are often named after the substrate on which they act.
A. Peroxidase

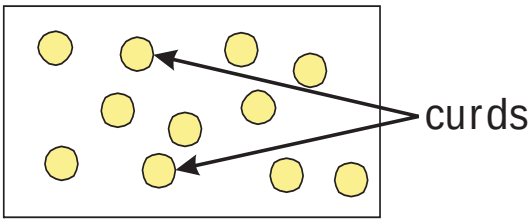
Activity 7: What is the Effect of the Enzyme Rennin on Milk?

Questions

1 What is the effect of the enzyme rennin on milk?
A. Rennin causes milk to become curdled.

2 We can say that rennin curdles or coagulates milk. It converts a soluble protein to an insoluble protein. Specifically, it converts caseinogen to casein. In other words, casein is not soluble in water. That is why the curdled mixture looks lumpy. In your notebook, draw a diagram of what you think curdled milk would look like if we could see it under high magnification.

To the Teacher
Diagrams should show the curds as indicated below.



Rennin acts on milk and milk products before other proteolytic enzymes act on these substrates. Rennin actually prepares milk for further digestion by other enzymes.

3 The young of mammals produce the enzyme rennin in far higher quantities than adults do. Try to suggest a reason WHY baby mammals produce more rennin than adults do.
A. Milk is the main food of baby mammals. Adults do not require as much milk. Adults take in a variety of protein-containing foods.

4 How have we used our knowledge of rennin in industry?
A. In the manufacture of some cheeses.

PART 2

CHAPTER 2

FOOD TESTS

NOTES TO THE TEACHER

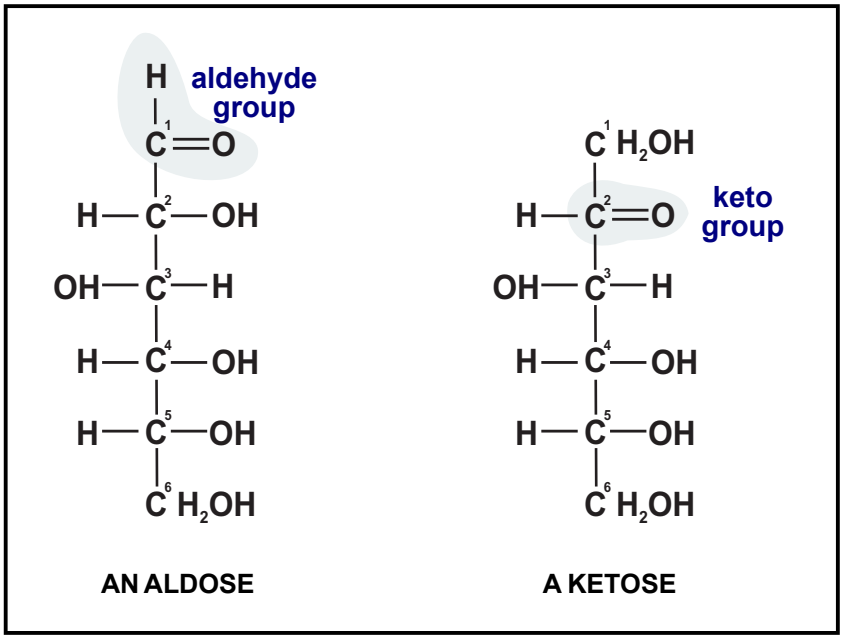
SERIES OF ACTIVITIES: FOOD TESTS

INTRODUCTION

You have already learnt that the basic foods are carbohydrates, lipids and proteins. We can test for the presence of these substances by using a number of chemical tests.

1. Tests for Carbohydrates

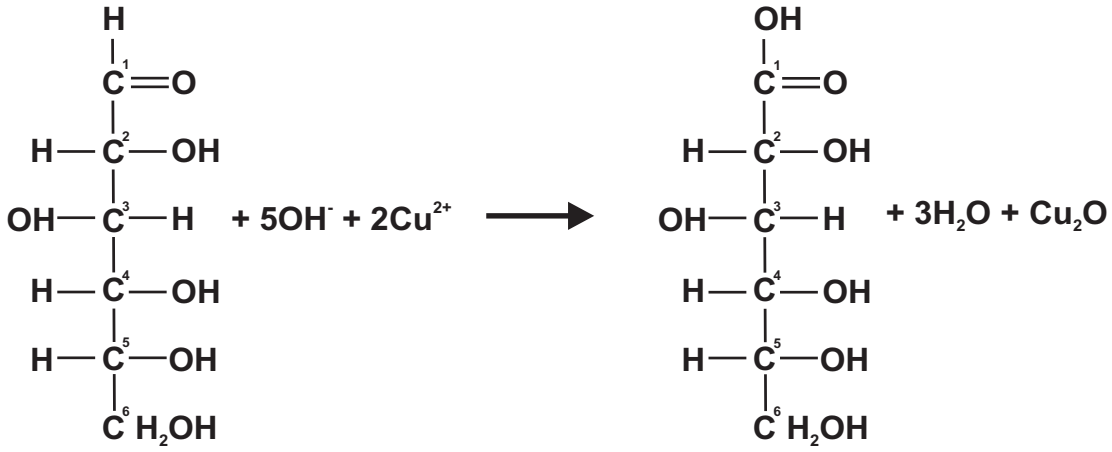
The building blocks of all carbohydrates are the monosaccharides, which are single sugar molecules. The monosaccharides are classified according to the number of carbon atoms in the molecules, the pentoses (5C) and the hexoses (6C) being the most common. All the carbon atoms in a monosaccharide molecule, except one, have an hydroxyl group attached. The remaining carbon atom is part of either an aldehyde (**-CHO**) group or a keto (**>C=O**) group. When the monosaccharide contains an aldehyde group, it is called an **aldose** or **aldo sugar**. If it contains a keto group, it is referred to as a ketose or **keto sugar**. The chemistry of the monosaccharides, and derivatives thereof, is greatly influenced by these groups.



i) The Reducing Sugars Test

There are two tests which are used to show the presence of reducing sugars; one is the Benedict's test and the other the Fehling's test. The Benedict's test is preferred. The reagent used in this test is called Benedict's solution. It contains copper(II) sulphate in an alkaline medium of sodium tartrate and sodium citrate. When Benedict's solution is heated in the presence of a reducing sugar, the blue copper(II) sulphate (in solution) is reduced to brick -red copper(I) oxide (a precipitate).

The chemistry of the reduction is related to the activity of the free aldehyde in aldo sugars, and the combined activity of the ketone and primary alcohol groups in keto sugars. In an alkaline medium, these groups are able to reduce Cu^{2+} ions to Cu^{+} ions. The sugars are themselves oxidised to the corresponding carboxylic acids. For example:

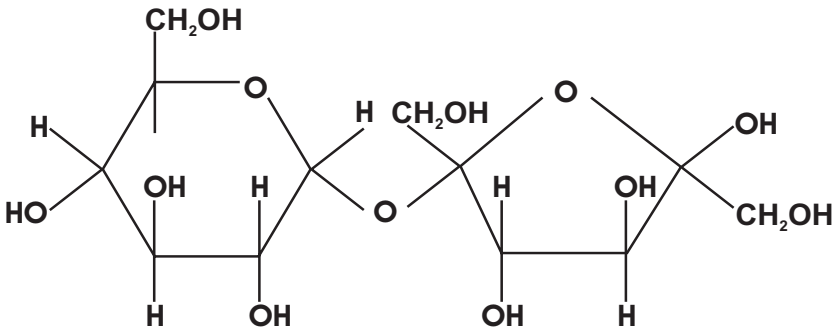


glucose **gluconic acid**

The test can not only indicate the presence or absence of reducing sugars, but also gives a rough estimation of the amount of reducing sugar present in a sample. The solution will appear green to orange to red-brown with increasing amounts of reducing sugar. Since copper(I) oxide is insoluble, a precipitate will settle if the test tube containing the solution is allowed to stand.

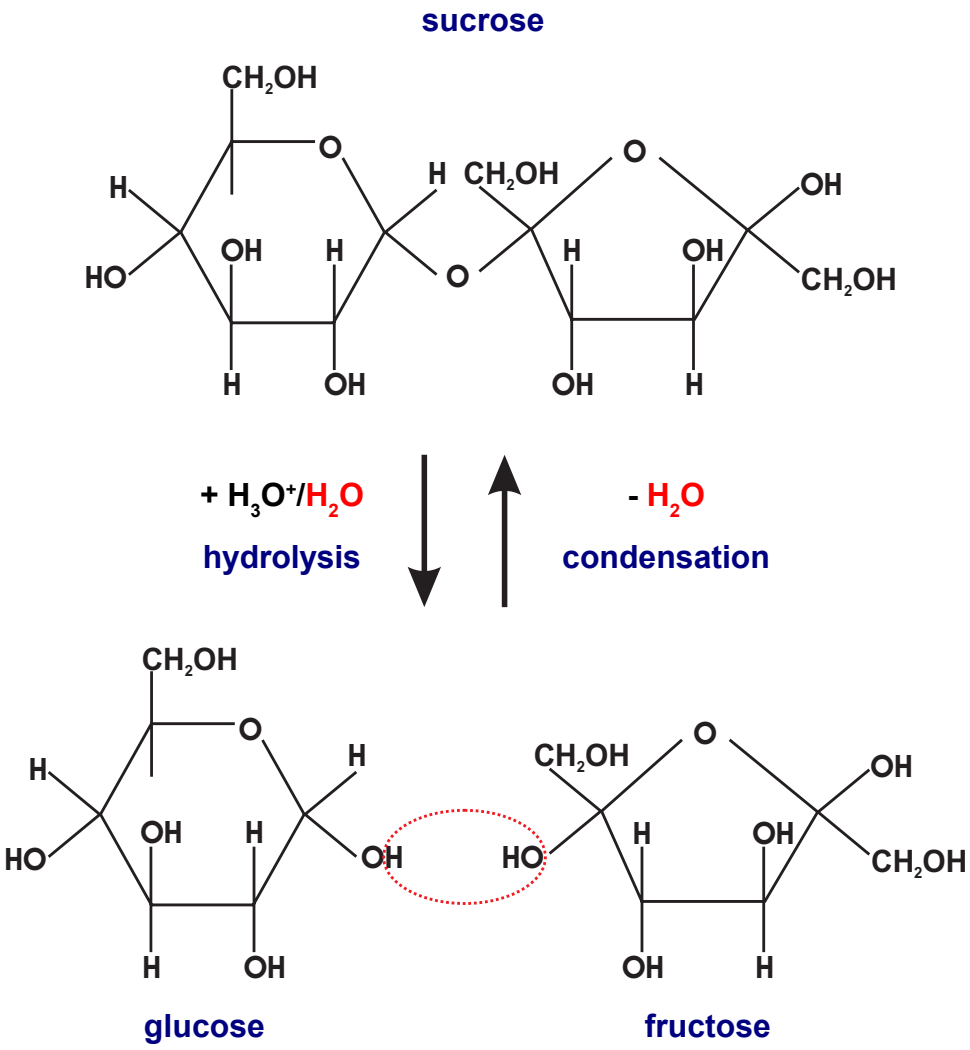
ii) The Non-reducing Sugars test

Since all monosaccharides are either aldoses or ketoses, they are all reductants and will give a positive test with Benedict's solution. Disaccharides eg. sucrose, are neither aldoses nor ketoses. As a result, the disaccharide lacks reducing activity and a negative result will be given with Benedict's solution.



sucrose

However, the disaccharide can be hydrolysed to its monosaccharide constituents by boiling with dilute hydrochloric acid. The monosaccharides, being reducing sugars, then give a positive result with the Benedict's test.



iii) The Iodine Test for Starch

Starch is a polysaccharide of glucose. It is formed by successive condensation reactions of glucose molecules. Starch consists of two components, amylose and amylopectin. Amylose has several thousand glucose residues in a straight chain structure of 1,4 glycosidic bonds. Amylopectin also has straight chains of glucose residues with 1,4 glycosidic bonds, but further condensation reactions occur within these chains to form 1,6 glycosidic bonds that give the amylopectin a branched structure.

X - ray diffraction studies on amylose have indicated that because of the 1,4 links between glucose units, each residue is angled with respect to the next. The amylose chains can therefore assume a regular helical conformation. This helix is not stable if it does not interact with other molecules, and amylose is more likely to occur as a random coil structure. One molecule that does stabilise the helix of amylose is **iodine**. Strings of iodine molecules are able to fit into the hollow, non-polar core of the structure.

Elemental iodine, I_2, has a low solubility in water. To use it as a starch indicator, solid iodine is dissolved in a olution of potassium iodide (KI(aq)). Here it forms the tri-iodide complex by the reaction:

$$I_2 + I^- \rightarrow I_3^-$$

In the presence of starch, iodine molecules are adsorbed into the helical structure to give an intense **blue** colour.

2. Tests for Lipids

i) The Grease Spot Test

This test relies on the fact that lipids leave a transluscent stain on absorbent paper, such as filter paper or brown paper. Water, aqueous solutions and organic solvents will evaporate from the paper, without leaving transluscent stains.

ii) The Emulsion Test

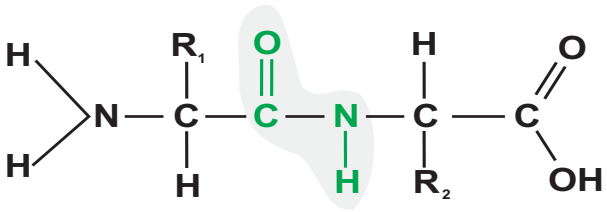
True lipids are esters of fatty acids and an alcohol. Fatty acid molecules contain the acidic **carboxy**l (**-COOH**) group attached to hydrogen or an alkyl group. They have the general formula RCOOH where R is a hydrogen atom or the alkyl group. Usually R contains many carbon atoms to form a long hydrocarbon tail. The - C-H bonds in the tail are non-polar and therefore hydrophobic fatty acid molecules with long hydrocarbon tails are insoluble in water for this reason. The alcohol involved in the formation of lipids is **glycerol**. Each glycerol molecule reacts with 3 fatty acid molecules in a condensation (esterification) reaction. A lipid therefore has three hydrophobic tails, explaining why lipids do not dissolve in water.

When lipids are added to water, the lipids float on the surface of the water as a result of their lower density. Organic liquids like ethanol, benzene and ether are solvents for lipids because their molecules have enough of a hydrocarbon-type structure. If lipids are extracted with ethanol and water is added to this solution, an emulsion of tiny lipid droplets in water is formed. These lipid droplets reflect light and give a white, opalescent appearance.

3. Test for Proteins

The Biuret Test for Proteins

Proteins are polymers in which the monomers are amino acids. The majority of amino acids have one basic amino (**-NH_2**) group and one acidic carboxylic (**-COOH**) group. Peptide molecules are formed when two or more amino acid molecules react with each other. The amino group of one amino acid molecule reacts with the carboxylic group of another amino acid molecule in a condensation reaction. A molecule of water forms. The resulting bond is called a **peptide** or **-CONH-** bond. When only two amino acids are involved in such a reaction, the product is a **dipeptide**. When many amino acids bond together, the product is a **polypeptide**.



peptide bond

It is the presence of this peptide bond that forms the basis of the Biuret test. Biuret reagent consists of copper(II) sulphate in alkaline solution with potassium tartrate. The test carried out in the school laboratory does not use Biuret reagent, but mimics its action in that the sample solution is first made alkaline with sodium hydroxide. When a dilute solution of copper sulphate is added, the Cu^{2+} ions form a co-ordination complex with four -NH groups present in the peptide bonds of proteins. The colour of the complex varies according to the number of peptide bonds present. When a protein has many peptide bonds, it also has a higher molecular weight than the proteins with only a small number of peptide bonds. These polypeptides are usually referred to as **higher** proteins, and the simple peptides as **lower** proteins. Higher proteins are also more likely to have secondary and tertiary structures, where hydrogen bonding between amino acids in the protein chain, as well as chain folding, occurs. A purple or mauve colour indicates the presence of higher proteins, whilst lower proteins result in a red coloured complex. If the solution is pale blue, no proteins are present.

NOTES TO THE TEACHER

SERIES OF ACTIVITIES: FOOD TESTS

EQUIPMENT

Most of the equipment for the Food Test activities can be found in the RADMASTE Microscale Biology Kit. Additional items required are available as part of the RADMASTE Biology Teacher Resource Kt.

CHEMICALS

The chemicals required per activity can be found in the RADMASTE Biology Chemicals Kit. Food items for testing are not included in the kit.

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE FOOD TEST ACTIVITIES

Tests for Carbohydrates

Carbohydrate Activity 1: Benedict's Test for a Reducing Sugar

Observations

Enter your results in Table 1 below.

Table 1

WELL	COLOUR CHANGE OBSERVED DURING HEATING	FINAL COLOUR OF SOLUTION AFTER 5 MINUTES
F1	blue to green to orange to red	bright red
F3	blue to green to orange-brown	orange-brown
F5	blue to pale green	pale blue-green
F6	none	blue

Questions

Q1. Why did the colour of the Benedict's solution change when it was heated with each of the glucose solutions?

A1. Glucose is a reducing sugar. It reduced the copper(II) sulphate, which is blue, to copper(I) oxide.

Q2. Which well contained the highest concentration of glucose? Explain.

A2. Well F1. Four large spatulas of glucose powder were added to this well and dissolved in 1.0 ml of water.

Q3. What do you notice about the colour changes observed in well F1?

A3. The solution in well F1 showed the most colour changes. It also had the darkest colour (red) of all the glucose solutions after 5 minutes of heating.

Q4. Which well contained the lowest concentration of glucose? Explain.

A4. Well F5. Only one small spatula of glucose powder was added to well F5 and dissolved in 1.0 ml of water.

Q5. What do you notice about the colour changes observed in well F5?

A5. The solution in well F5 showed the least number of colour changes. It also had the palest colour (pale green) of all the glucose solutions after 5 minutes of heating.

Q6. From your answers to questions 3 and 5, deduce the relationship between the concentration of reducing sugar present in a sample, and the colour change/s observed in the Benedict's test within a specified time period.

A6. The greater the concentration of the reducing sugar in the sample, the more colour changes that are observed and the more intense the red colour of the copper(I) oxide formed within the specified time period.

Q7. Why did the colour of the solution in well F6 show no change?

A7. There was no glucose present in the solution.

Q8. How can one test for the presence of reducing sugars in food?

A8. A solution of the food to be tested is heated in a water bath with Benedict's solution. If reducing sugars are present, the blue colour of the solution changes to green and then orange and finally red. The solution will remain blue if no reducing sugars are present. (If other reducing agents are present in the food, a colour change may also be observed.)

Extension Questions

(These questions are aimed at students who also have a chemistry background.)

Q9. What was the purpose of testing water with the Benedict's solution?

A9. The test serves as a control. When the solution containing water did not change colour, it showed that the water itself could not reduce the copper ions in Benedict's solution. Hence, it must have been the glucose in the glucose solution that caused the reduction.

Q10. Write down the ionic equation for the reduction of copper sulphate to copper oxide.

A10. $Cu^{2+} + e^- \rightarrow Cu^+$

Q11. When glucose is oxidised, gluconic acid is formed. Which functional group in glucose do you think is responsible for the reduction of copper(II) to copper(I)?

A11. The aldehyde group at position 1.

Q12. Give a reason for your answer to question 5.

A12. The aldehyde group at position 1 has been oxidised to a carboxylic acid group. The carbon atom at position 1 in glucose has an oxidation state of +1, whereas the carbon atom at position 1 in the corresponding carboxylic acid has an oxidation state of +3. The aldehyde functional group is known to be easily oxidised.

Carbohydrate Activity 2: Does the Food we Eat contain Reducing Sugars?

Observations

Table 1

WELL	FOOD SOLUTION	COLOUR OF SOLUTION AFTER HEATING
F1	apple	brick-red
F2	carrot	bright orange
F3	potato	pale blue-green
F4	cooked white rice	blue
F5	cooked white mealie meal	blue
F6	milk	orange-green

Questions

Q1. How is the colour of the solution related to the concentration of reducing sugar detected in the food during the time specified? (Hint: look at the results for Activity 1.)

A1. The more reducing sugar/s present in the food, the greater the number of colour changes observed. In other words, if the whole series of colour changes is seen (blue → green → red), the food contains a large concentration of reducing sugar. If only the blue → green colour change is observed, the food contains little reducing sugar.

Q2. Which food contains the highest concentration of reducing sugar/s? Explain.

A2. Apple. The solution turned brick-red, indicating that all the copper(II) in the Benedict's solution was reduced to copper(I). The other solutions underwent colour changes that showed partial reduction of the copper(II).

Q3. Which food contains the lowest concentration of reducing sugar/s? Give a reason for your answer.

A3. White rice and white mealie meal. After 7 minutes, the colour of the solutions was still blue.

Q4. What is the answer to the focus question?

A4. Apples and carrots contain high concentrations of reducing sugars; potatoes and milk contain lower concentrations of reducing sugars. White rice and white mealie meal do not contain detectable concentrations of reducing sugars.

Extension Questions

Q5. Besides the colour change that occurred, what other change did you notice in the appearance of the milk when it was heated with Benedict's solution?

A5. Tiny white clumps appeared in the milk solution, i.e. the milk coagulated.

Q6. Why did the appearance of the milk change?

A6. The heat caused the protein in the milk to denature.

Carbohydrate Activity 3 **How can one test for the presence of a non-reducing sugar in food?**

Questions

Q1. Does the colour of the solution in well F2 change after floating the comboplate in the water bath for a few minutes? What does this observation imply?

A1. No. Sucrose is not a reducing sugar.

Q2. What happens when the sodium bicarbonate is added to the acidified sucrose solution?

A2. Effervescence occurs.

Q3. What happens to the colour of the solution in well F5 during heating? What does this observation imply?

A3. It changes quickly from blue to green, and then becomes clear as a brick-red precipitate settles. The solution contains reducing sugars.

Q4. From your observations, what do you think is the function of the hydrochloric acid in this experiment? Explain your answer.

A4. The hydrochloric acid breaks the disaccharide into its constituent monosaccharides. Since all monosaccharides are reducing sugars, the blue copper(II) sulphate in the Benedict's solution is reduced to insoluble, red copper(I) oxide which precipitates.

Q5. Which reducing sugar/s caused the Benedict's solution to change colour? Give a reason for your answer.

A5. Glucose and fructose. These are the monosaccharides that form sucrose.

Q6. What is the name given to the reaction in this experiment where hydrochloric acid breaks up the disaccharide to form its constituent monosaccharides?

A6. Hydrolysis.

Q7. What is the answer to the focus question?

A4. The food is first heated with hydrochloric acid to hydrolyze any non-reducing sugars into reducing sugars. The resulting solution of reducing sugars is then neutralised and tested with Benedict's solution, which changes from blue to red.

Extension Questions

Q8. What other biological compound will perform the same function as the hydrochloric acid in hydrolysing sucrose?

A8. The enzyme sucrase (also called invertase).

The following questions are aimed at students with a chemistry background.

Q9. Write down the chemical equation for the reaction of the sodium bicarbonate with the acidified (HCl(aq)) sucrose solution.

A9. $NaHCO_3(s) + HCl(aq) \rightarrow NaCl(aq) + CO_2(g) + H_2O(l)$

Q10. Use your answer to question 9 to explain why "fizzing" was heard when the sodium bicarbonate was added.

A10. As soon as the sodium bicarbonate was added, carbon dioxide ($CO_2(g)$) was given off and caused the fizzing sound.

Carbohydrate Activity 4 Iodine Test for Starch

Questions

Q1 What is the colour of the solution in well A1 after adding a drop of iodine solution?
A1 Yellow-brown.

Q2 What is the colour of the solution in well A2 after adding a drop of iodine solution?
A2 Blue-black.

Q3 How can one test for the presence of starch in food?
A3 A solution of the food is tested with a dilute iodine solution. If starch is present, the solution will become blue-black. If starch is absent, the solution should remain brown.

Carbohydrate Activity 5 Does the Food we Eat contain Starch?

Questions

Q1. Prepare a table like Table 1 below in your books. Record your results in Table 1.

Table 1

WELL	FOOD SOLUTION	COLOUR OF SOLUTION AFTER IODINE ADDED
A1	apple	brown
A3	carrot	brown
A5	potato	blue-black
A7	milk	brown
A9	white rice	blue-black
A11	white mealie meal	blue-black

Q2. What is the answer to the focus question?
A2. Apples, carrots and milk do not contain starch. Potatoes, white rice and white mealie meal do contain starch. (NB: some varieties of apples may contain some starch.)

Extension Questions

Q3. Starch is a polymer of glucose. What does this statement mean?
A3. A starch molecule is formed from successive condensation reactions between a very large number of glucose molecules (monomers).

Q4. Starch molecules (polymers) can be broken down into glucose molecules (monomers) by hydrolysis, in the same way that sucrose is broken down into fructose and glucose. Using this information, choose the food/s from Table 1 above which you would eat the most of if you were going to run a long race the next day. Explain your choice.

A4. Potatoes, rice and mealie meal. Running is an action which requires energy. Glucose is a major source of energy for humans. Since starch is made up of many repeating units of glucose that can be released into the body by hydrolysis, eating foods that contain starch can provide the body with energy over a long period. Potato, rice and mealie meal are the foods in Table 1 that contain starch.

Q5. Consider the statement made above in question 4. What result would you expect in the Benedict's test if the potato, rice or maize solutions were heated with 5.5 M HC@(aq), neutralised with sodium bicarbonate, treated with Benedict's solution and then placed in a boiling water bath? Explain your answer.

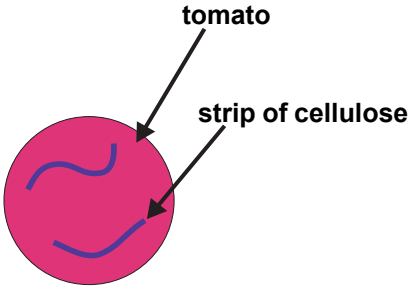
A5. The colour of the Benedict's solution would gradually change from blue to green to orange to red. Starch is non - reducing because the reducing functional groups of its monomers are linked together in glycosidic bonds in the starch polymer. However, hydrochloric acid would hydrolyze the glycosidic bonds, resulting in the release of glucose molecules into solution. These reducing sugars would then reduce the copper(II) in Benedict's solution to copper(I).

Notes to the Teacher

The following list provides some information about a number of foods which can be tested for the presence of starch.

Chick Peas ..... yes but it does not react unless the seed coat is removed
Milk Powder ..... no
Split Peas ..... yes
Soya Mince ..... full of starch
Sugar ..... no - a different carbohydrate but many people are confused
Red Apple ..... sometimes if the apple is very "floury"
Green Apple ..... no
Tomato ..... no
Carrot ..... no
Orange ..... possibly on the white bits - cellulose. See underneath
Celery ..... as above
Pasta ..... yes
Popcorn Mealies ..... yes after cutting
See note underneath
Rice ..... yes
Oats ..... yes
Barley ..... yes
Rye (bread) ..... yes
Wheat (bread) ..... yes
Yellow Maize Meal ..... yes

1 If you find a positive test in certain plants eg tomato it is possible that you have found a strip of cellulose which also tests positive with iodine solution. You won't find the whole tomato going black - but an isolated area. If they don't believe you, they can drop some iodine solution on the tissue paper. Paper is made from cellulose.



2 The interesting point about starch in soya mince, peas and chick peas is that these items are used by vegetarians as a source of protein. Many people don't realise that there is a lot of starch, too.

3 The starch will not be obvious in the chick pea until the outer covering of the seed (pea) is removed. This covering is not starchy but you MAY find a small quantity of cellulose.

4 The popcorn mealie like other mealies is of course a source of starch. The outer covering - yellow bit - is composed of other materials including a bit of protein. It is better to eat yellow mealie meal because it has other nutrients in addition to starch. In fact, yellow mealie meal (as opposed to white) goes some way towards preventing kwashiorkor in communities who eat mainly mealie meal.

Carbohydrate Activity 6 Iodine Test for Cellulose

Questions

Q1. What is the colour of the cotton wool saturated with iodine? What does this observation imply?

A1. Yellow-brown. Cotton wool does not contain starch.

Q2. What happens to the cotton wool where the sulphuric acid is added?

A2. The cotton wool becomes blue-black.

Q3. How can one test for the presence of cellulose in food?

A3. When cellulose is treated with iodine, the yellow-brown colour of the iodine is unchanged. However when sulphuric acid is added, the yellow-brown iodine stain becomes blue-black. If cellulose is not present in a food, the iodine stain remains brown.

Carbohydrate Activity 7 Does the Food we Eat contain Cellulose?

Questions

Q1. Prepare a table like Table 1 below in your books. Record your results in Table 1.

Table 1

FOOD TESTED	COLOUR OF FOOD AFTER SULPHURIC ACID ADDED
apple	blue - black
carrot	blue - black
milk	brown

Q2. What is the answer to the focus question?

A2. Apples and carrots contain cellulose. Milk does not.

Q3. Potatoes, rice and maize also contain cellulose. Suggest why the potato, cooked rice and cooked mealie meal were not tested for cellulose. (Hint: examine your results of potato, rice and meal with iodine in the starch test.)

A3. Potato, rice and meal stain blue-black with iodine whether they are treated with sulphuric acid or not, but this reaction is due to the starch in these foods and not the cellulose.

Extension questions

Q4. Cellulose molecules consist of long chains of about 10 000 linked glucose molecules. Hydroxyl groups (-OH) project from each chain and form hydrogen bonds with neighbouring chains to produce a rigid cross-linked structure. Use this information to explain why the solid apple and carrot were tested for cellulose, and not their solutions.

A4. The chains of the cellulose molecules are too long, and the bulk structure of cellulose is too complex, to dissolve in water. If solutions of the foods were tested, the iodine - sulphuric acid test would have been negative.

Q5. Consider the foods that you have tested for cellulose together with the information supplied in question 4. On this basis, suggest the location and function of cellulose in cells. *(Hint: Why is there no cellulose in milk?)*

A5. Cellulose is found in plant cell walls. Its rigid structure provides support and strength for the cell, and the plant as a whole. Carrots and apples are both plants, but milk is of animal origin and has no structural function: it contains no cellulose.

Tests for Lipids

Lipid Activity 1: Emulsion Test for Lipids

Questions

Q1. What do you observe in well F1 after adding the vegetable oil?
A1. The oil forms a globule that floats on the water.

Q2. What do you see in well F1 after stirring?
A2. Tiny droplets of oil form in the water, but the oil and water quickly separate again into two layers.

Q3. What happens to the oil in well F3 when the ethanol is added?
A3. The oil dissolves in the ethanol.

Q4. What happens in well A1 after adding the water to the ethanol/oil mixture?
A4. The solution becomes cloudy and tiny droplets of oil can be seen in the solution. No separation into layers occurs.

Q5. What is the general name given to the kind of cloudy liquid observed in well A1?
A5. An emulsion.

Q6. How can one identify lipids in food using the emulsion test?
A6. A sample of the food is mixed with ethanol. If lipids are present in the food, they will dissolve in the ethanol. As soon as the ethanol/oil solution makes contact with water, a cloudy emulsion is formed because the oil is not soluble in water. The solubility of the lipid decreases as the proportion of water added to the ethanol increases.

Extension question

(The following question is aimed at students with a chemistry background.)

Q7. The structure of a a complete lipid molecule is given below. Use this structure to explain your observation when oil was added to water.
A7. The long hydrocarbon tails are hydrophobic i.e. they are excluded by water. Lipid molecules have three hydrophobic tails, explaining why the oil did not dissolve in the water and why the oil and water layers soon separated after the oil was stirred with the water.

Lipid Activity 2: Grease Spot Test for Lipids

Questions

Q1. What do you see on the surface of the filter paper once it has dried?
A1. The oil spot has stained the paper. The water spot has dried up and left no stain. The water in the spot of the emulsion has dried up, but there are small oil stains where the drop of the emulsion was placed. There is also an oil stain where the ethanol/oil solution was placed. The ethanol has left no stain.

Q2. What do you notice about the oil stains on the paper when the paper is held up to the light?
A2. The light shines through the oil stains. The oil stains are translucent.

Q3. It was found in the emulsion test that oil dissolves in ethanol. Why, then, was an oil stain left where the ethanol/oil spot was placed on the filter paper?
A3. The ethanol evaporated from the filter paper, leaving the oil.

Q4. Explain your observations concerning the spot of the oil/water mixture.
A4. When the oil and water were shaken together in the bulb of the propette, a temporary emulsion of tiny oil droplets in the water was formed. When a spot of this emulsion was placed on the filter paper, the water evaporated, leaving small oil stains where the tiny droplets made contact with the paper.

Q5. What would you have seen on the dried filter paper if the oil and water were not shaken together in the propette before placing a spot on the paper? Explain.
A5. Nothing. Only water would have constituted the spot, since the oil would have formed a layer on top of the water in the propette so that only water would have filled the stem of the propette.

Q6. How can the grease spot test distinguish between lipids and non-lipids in food?
A6. Lipids form translucent stains on absorbent paper. Non-lipids do not.

Lipid Activity 3: Does the Food we Eat Contain Lipids?

Questions

Q1. Does an emulsion form in well A1 when the water is added to the apple solution?
A1. No.

Q2. Does an emulsion form in well A3 when the water is added to the carrot solution?
A2. No.

Q3. Do emulsions form with rice and mealie meal?
A3. No.

Q4. Prepare a table like table 1 below in your books. Complete the table.

A4. Table 1

FOOD TESTED	APPEARANCE OF PAPER AFTER DRYING
apple	No stain
carrot	No stain
white rice	No stain
white mealie meal	No stain
full cream milk	Pale translucent patches

Q5. What is the answer to the focus question?

A5. Apples, carrots, rice and mealie meal do not contain lipids, but milk does.

Q6. Give reasons for your answer to question 5.

A6. When the grease spot test was applied to carrot-ethanol, apple-ethanol, rice-ethanol and maize-ethanol solutions, the ethanol solvent evaporated and no stain was left on the filter paper. Similarly, when the emulsion test was carried out on these same solutions, an emulsion did not form. In contrast, the milk spot left transluscent patches where the lipid in the milk stained the filter paper.

Extension question

Q7. Why was the emulsion test not carried out on the milk? (*Hint: what does milk look like?*)

A7. Milk is an emulsion of lipid in an aqueous solution containing other constituents, like protein. The cloudy appearance of this emulsion is similar to that of the emulsion formed in Lipid Activity 1.

Tests for Proteins

Protein Activity 1 Biuret Test for Proteins

Questions

Q1. What do you observe in well A1 after adding the copper sulphate solution?
A1. The solution becomes blue in colour.

Q2. What do you observe in well A3 after adding the copper sulphate solution?
A2. A blue ring appears at the surface of the solution.

Q3. What happens to the solution in well A3 when it is mixed with the copper sulphate?
A3. It becomes purple in colour.

Q4. How can one test for the presence of proteins in food?
A4. An alkaline solution of the food is mixed with a dilute solution of copper sulphate. If protein is present, the solution changes to a purple or mauve colour. If not, the solution remains blue.

Protein Activity 2 Does the Food we Eat contain Protein?

Questions

Q1. Prepare a table like Table 1 below in your workbooks. Record your results with the different foods tested.

Table 1

WELL	FOOD SOLUTION	COLOUR WITH COPPER SULPHATE
A1	potato	purple
A3	apple	blue
A5	carrot	blue/orange
A7	white rice	blue
A9	white mealie meal	blue

Q2. What is the answer to the focus question?
A2. Potatoes contain protein. Carrots, apples, white rice and white mealie meal do not.

Q3. What does the colour of the potato solution tell you about the type of proteins present in potato?
A3. The purple colour indicates that potatoes contain the higher proteins i.e. those with many peptide bonds.

Extension question

Q4. It is often stated that rice and mealie meal contain protein. Mealie meal is a staple food in many African countries. How can the results obtained in this experiment help to explain the high incidence of Kwashiorkor (an illness related to a lack of protein in the diet) in Africa?

A4. The results of the Biuret test with white rice and white mealie meal shows that these foods do not contain protein. People who eat a diet consisting mainly of mealie meal are not being provided with sufficient protein, explaining the incidence of Kwashiorkor. (Brown or unpolished rice and yellow, unrefined mealie meal contain protein. The refining process therefore removes the protein.)

PART 2

CHAPTER 3

PHOTO-SYNTHESIS

NOTES TO THE TEACHER

PHOTOSYNTHESIS

INFORMATION

During photosynthesis, glucose is synthesised by green plants. This process occurs only in parts of plants which contain chlorophyll and mainly in the leaves. Glucose is used by all plant parts during respiration. Some excess glucose is converted to storage products, mainly starch, in the leaves. Stored food may take the form of a number of different food substances like starch, sucrose, oils and certain proteins. Glucose may also be converted to cellulose, a component of the cell wall.

Formulae of some organic compounds

Glucose $C_6H_{12}O_6$ Sucrose $C_{12}H_{22}O_{11}$
Starch $(C_6H_{10}O_5)_n$ [where n = several thousands of units]

Starch is the most common food storage product of plants, so if the leaves of a plant contain starch, we can assume that the plant has performed photosynthesis recently. Likewise, if the leaves of a plant do not contain starch, we can assume that the plant has not performed photosynthesis recently. In the following investigations, we examine plants under different conditions and test the leaves for the presence of starch. We use the information we obtain to find out what conditions are needed for photosynthesis to take place.

Notes to the Teacher

Destarching Leaves

It is standard practice to "destarch" a leaf or the leaves on a plant by keeping the plant in a dark cupboard for several hours before commencing any of the investigations which are used to determine which factors are needed for photosynthesis (i.e. chlorophyll, light, carbon dioxide). This practice is a problem because we are making the *assumption* that without light, photosynthesis will not occur. Students should be made aware of this issue. Although these activities do not destarch the leaves by placing plants in dark cupboards, the same effect is achieved by conducting the tests early in the morning i.e. after a period of natural darkness.

Controls

Controls are frequently used in biological investigations. Doing a "control" investigation is similar to holding variables constant. For instance, if we want to find out if chlorophyll is needed for photosynthesis, we test leaves **with** and **without** chlorophyll and test and compare these. Students are frequently puzzled when asked which set-up is the "experiment" and which is the "control".

Help students by phrasing the aim of the investigation very carefully.

Use the following example:

Aim of Investigation: To find out whether chlorophyll is needed for photosynthesis.

The **control** is the part of the leaf **without** chlorophyll because that is the set-up where the factor being tested has been removed.

SERIES OF INVESTIGATIONS :
FACTORS NECESSARY FOR PHOTOSYNTHESIS

1 CHEMICALS

Note that the chemicals required per activity can be found in the RADMASTE Biology Chemicals Kit. If you have your own supply of chemicals, the following instructions will assist you in preparing the necessary solutions for the photosynthesis activities.

.1 Iodine solution (I_2/ KI solution)

This is a solution of iodine crystals in aqueous potassium iodide. It is sometimes called Lugol's Solution.

To prepare the solution:
Dissolve 1.0 g iodine crystals and 2.0 g potassium iodide in 300 ml distilled water.

.2 Alcohol

For the extraction of chlorophyll, use an alcohol such as 70% ethanol. If possible, keep the chlorophyll extracts in a cool place. They can be used in later investigations for chromatographic separation of chlorophyll pigments.

.3 Soda Lime

Soda lime absorbs carbon dioxide by reacting with it.

.4 Methylene blue

This substance is used to indicate the presence of oxygen. Prepare a solution by mixing 0.1 g methylene blue, 0.6 g sodium chloride and 100 ml distilled water. Use a few drops of the solution in water so that the water just turns blue. If too much methylene blue is used, the colour change will not be noticeable.

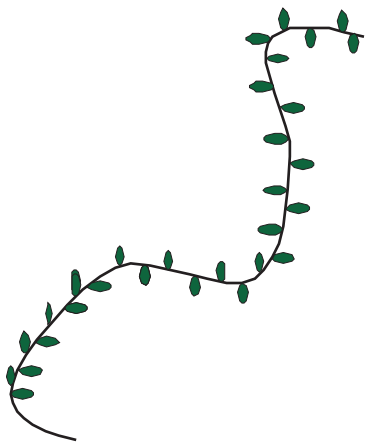
2 EQUIPMENT:

All the equipment you need is listed under the Requirements for each investigation. Most of this equipment can be found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

.1 Plant material

Land plants (plants in the garden or in a pot)

Try to use geranium leaves for the investigations, because they are the easiest to decolour. Use the soft, quite hairy varieties, NOT the thick fleshy ones. Ivy and periwinkle are adequate but it takes a long time to soften and decolour these. Leaves from certain other plants are also suitable but it is suggested that the teacher tries these out prior to using them.



Water Plants

The Canadian pond-weed, **Elodea**, is very suitable for the investigations. However, use what is available in your area. Try to obtain a long, thin type of water plant with many leaves. See the figure alongside.

3 PROCEDURES

Extraction of Chlorophyll

.1 Using a water bath

Use the plastic lunch box as a water bath in the following way.

- Pour about 200 ml or 1 cup full of tap water into the lunch box.
- Slowly add hot water, stirring occasionally. For extraction of chlorophyll, very hot water is needed.

We add the tap water first because certain plastics become distorted if we add very hot water directly to the dish.

- Float the comboplate® on the water bath without allowing it to sink and become submerged.

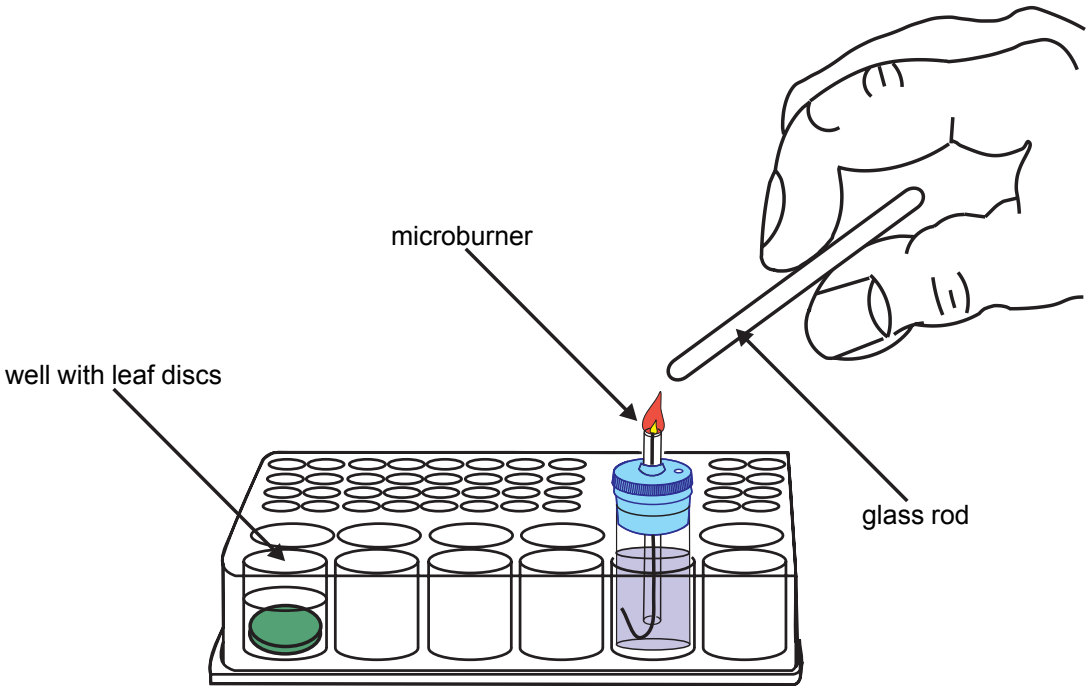
.2 Using a glass rod for heating

In addition to the apparatus listed, you will need

- ♣ glass rod
- ♣ microburner filled with methylated spirits

Once the leaf discs have been heated and softened, place them in the larger wells of the comboplate® and:

1 Set up the apparatus as shown.
2 Pass the glass rod across the flame to heat it and dip the heated end into the well with the discs in alcohol. The discs will decolour quite quickly.



NOTES TO THE TEACHER

PHOTOSYNTHESIS

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE PHOTOSYNTHESIS ACTIVITIES

Activity 1: Testing a Leaf for Starch

Questions

1 What is the colour of the alcohol after 10 minutes?
A Greenish.

2 What is the colour of the leaf after 10 minutes?
A Whitish.

3 What has the alcohol done to the leaf?
A It has removed the chlorophyll.

4 What colour did the leaf discs turn after the iodine was added?
A Blackish.

5 What does this colour change tell you about the storage product in these leaves?
A The leaves of these plants store starch.

Activity 2: Is Chlorophyll Necessary for Photosynthesis?

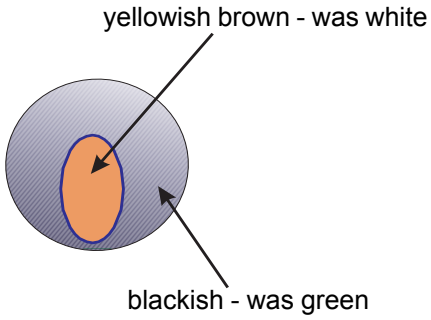
Questions

1 What was the final colour of the leaf discs which were originally green and white?
A The green parts were blackish and the white parts were brownish.

2 Make a drawing of a leaf disc which was originally both green and white.

Note to the Teacher
Such a drawing could look something like the figure shown.

Leaf Disc after Iodine Test



1 What do your results suggest about the role of chlorophyll in photosynthesis?
A Chlorophyll is necessary for photosynthesis to occur.

2 The white parts of the leaf discs had no starch. This means that there is no food for the plant in the white parts of the plant. The white parts of the leaf must get food, otherwise they would die. How do you suppose these parts get their food?

Note to the Teacher

Allow some discussion here. It is not likely that all students will be able to work out all the details immediately. In the green parts of the leaf, glucose is formed during photosynthesis. Some of this glucose is used by the green parts and some is transported to the white parts as required. Glucose which is not used immediately is stored as starch. When required, the starch is converted back to glucose.

SOMETHING TO THINK ABOUT

A Epsom Salts is another name for magnesium sulphate. A magnesium atom is part of the chlorophyll molecule. Without magnesium, plants cannot manufacture chlorophyll. A symptom of magnesium deficiency in plants is yellowing between the veins of the leaves.

Activity 3: Is Light Needed for Photosynthesis ?

Table to show Results of Iodine Test on Leaf after One Day

Part of Leaf	Colour after Testing with Iodine Solution	Conclusion
Covered	yellowish	no starch present
Uncovered	blackish	starch present

Questions

1 What did the foil or black paper do?
A It excluded light from a part of the leaf

2 What do you suppose is the link between light and photosynthesis?
A Light is needed for photosynthesis

3 What does the word "photosynthesis" mean?
A Making or synthesising something with the energy of light.

Note to the Teacher

Many students confuse a number of issues here.

- *Light is needed for photosynthesis because the chlorophyll molecule is activated by light during the light-dependent phase of the process.*
- *However, light is also needed for the formation of chlorophyll. This fact is demonstrated for example when a patch of grass is kept covered and becomes yellow or white after a while.*

It is essential that students are clear on all these points.

Activity 4: Is Carbon Dioxide Needed for Photosynthesis ?

Table to show Results of Iodine Test on Leaf Discs after One Day

Leaf	Colour after Testing with Iodine Solution	Conclusion
Enclosed i.e. no CO_2 available	yellowish	no starch present
Open to atmosphere i.e. CO_2 available	blackish	starch present

Questions

1 Did the leaf discs which did not receive carbon dioxide have any stored starch?
A No they did not.

2 Did the leaf discs which did receive carbon dioxide have any stored starch?
A Yes.

3 What do these results suggest to you?
A Carbon dioxide is needed for photosynthesis.

4 What elements are present in carbon dioxide?
A Carbon and oxygen.

5 What elements are present in glucose and in starch?
A Carbon, oxygen and hydrogen.

6 Where does the additional element come from?

Note to the Teacher

Answers will depend on what students already know and how they have been taught. If they are familiar with the theory of photosynthesis, they may remember that the hydrogen is derived from water. If they are not familiar with the theory, they may make some suggestions. Guide them by asking questions like:

"*What compound is very plentiful on this planet?*"

"*What compounds do you know which contain hydrogen?*"

If it is not possible to conduct this investigation, it could be used as a "thought" experiment. The same or similar questions to those above should be asked.

Activity 5: Is Oxygen Released During Photosynthesis ?

Questions

1 Note what you observe in each of the tubes.

A **Tube A**

At first, bubbles were formed near the plant and they floated in the water. Later in the week, the blue colour of the solution in tube A became darker.

Tube B

No such changes took place.

2 What can you deduce from your observations?

A **The bubbles show that a gas was released. Methylene blue solution turns blue in the presence of oxygen so the gas must have been oxygen.**

3 Why did we add sodium hydrogencarbonate ($NaHCO_3$) to the water?

A **The sodium hydrogencarbonate dissolves in the water, and is a source of carbon dioxide for the plant which it uses during photosynthesis.**

4 What happened to the solution in tube B?

A **There was no colour change, showing that the blue colouration was due to the plant and not to any other factor.**

PART 2

CHAPTER 4

RESPIRATION

NOTES TO THE TEACHER

RESPIRATION

EQUIPMENT

Most of the equipment for the Respiration activities is available in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit.

CHEMICALS

The chemicals required per activity can be found in the RADMASTE Biology Chemicals Kit.

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE RESPIRATION ACTIVITIES

Activity 1: The Products of Combustion

INTRODUCTION

There are similarities and differences between respiration and combustion. In this investigation we demonstrate the products of combustion (by a burning candle).

BACKGROUND INFORMATION FOR THE TEACHER

We compare respiration with combustion because in terms of reactants and products, there are many similarities. One of the most important differences, however, is the **rate** of the reactions.

Observations

Hold your hand over the flame. What do you notice?
The air above the flame is warm.

Hold a glass vial over the flame for a few seconds. Remove the vial and examine the surface. What do you notice?
There are droplets of liquid on the surface of the vial.

Dip a strip of cobalt chloride paper into a droplet on the vial. What do you notice? What does this observation suggest to you?
The paper turns pink. The substance on the vial is water.

Use the hanging drop technique with clear lime water and hold the drop near the flame of the butter candle for a few moments. What changes occur in the lime water? What does your observation suggest to you?
The lime water turns milky. Carbon dioxide is produced.

Questions

1 What substances were produced during the combustion of the butter candle?
A Carbon dioxide and water

2 What else happened?
A The air around the flame became warm. Energy was released / transferred to the surroundings.

3 What happened to the butter candle?
A It became smaller. It was used.

Activity 2: Is Carbon Dioxide Released During Respiration in Germinating Seeds ?

Questions

1 What do you observe?

A **a.** **Experiment**

The seeds in well F1 continue to grow. The roots and shoots are visible. After about two days, bubbles appear at the outlet tube in the lime water of well F2. After another day or so, the lime water becomes cloudy. (The time taken depends on the type of seeds used.)

b. **Control**

The seeds in well F1 do not grow.
There are no bubbles in well F2 and the lime water remains clear or goes very slightly cloudy.

2 Why do you suppose the lime water turned milky?

A **A gas passed into the well containing the lime water. The lime water became milky after some time. Therefore the gas is carbon dioxide.**

3 Living organisms require fuel as a respiratory substrate. What did the seeds use as a substrate?

A **They used the stored food in the cotyledons, which was converted to glucose which was then used as the respiratory substrate.**

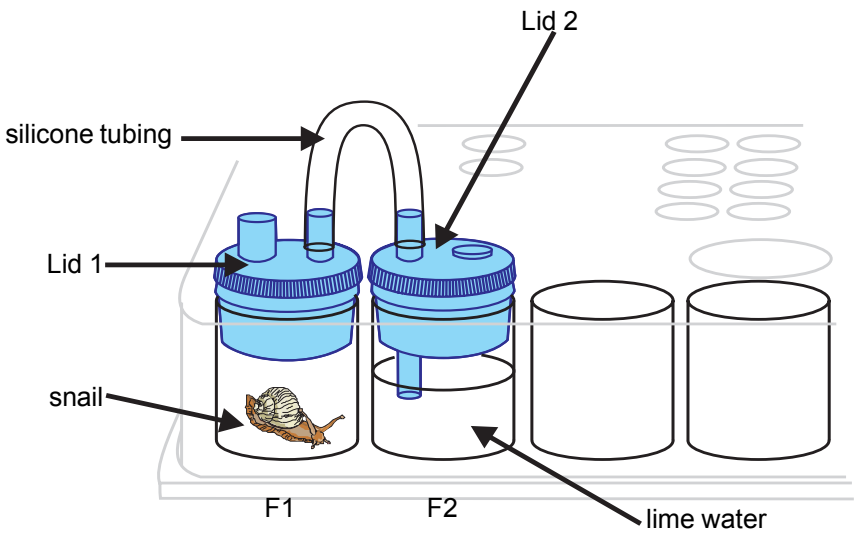
4 What will the seeds use as a substrate after the stored food is used up?

A **They will produce their own food during photosynthesis. Some of this food will be used during respiration.**

5 Design, without carrying out, an investigation to determine whether or not animals release carbon dioxide during respiration.

Note to the Teacher

Ask the students to draw or to construct, using a model animal, the experimental set-up for such an investigation. SEE FIGURE BELOW.



In theory, the snail will respire and produce carbon dioxide which turns the lime water milky. In practice, however, small animals do not make good subjects as they do not thrive under these conditions. However, it is useful for students to grasp the principles of the investigation. A control would not have an animal.

Their experimental design can be assessed according to some or all of the following criteria:

- formulating plan of action
- communicating plan of action
- using a control
- using knowledge to inform actions
- working with others
- gathering relevant information
- making predictions about what will occur
- generating innovative ways of modifying the investigation
- making a decision as to which method is best under the circumstances

As it is a controversial issue, allow the students to debate the topic of using animals in biological research.

Activity 3: What Substances are Formed during Fermentation ?

BACKGROUND INFORMATION FOR THE TEACHER

Yeasts are a group of single-celled fungi belonging to the division Ascomycota. Individual yeast cells measure only 0.003–0.01 mm across, and are just too small to be seen by the unaided eye. Most wild yeasts are found on the surface of flowers and fruits – a "bloom" of yeast can be seen on the skin of grapes, for example.

Yeasts are of enormous economic importance because they can convert sugar into alcohol and carbon dioxide anaerobically. This process, which is called **fermentation**, is exploited by the brewing industry to make alcoholic drinks and by bakers to make bread rise. The Yeast species most often used this way is *Saccharomyces cerevisiae*.

Alcoholic Fermentation

Alcoholic fermentation occurs in plants, yeast, and some types of bacteria. The end products are the toxin ethanol ("alcohol") and carbon dioxide. In plants, fermentation occurs infrequently – roots in waterlogged soils, for example, can respire anaerobically for a short time if deprived of oxygen. The process cannot continue for long, however, as the increasing alcohol concentration poisons the plant.

Commercially, the fermentation of sugar, starch and other carbohydrates by yeast is used to produce ethanol. It is used in drinks and as a solvent and preservative; medicinally, it is used externally as a disinfectant, and internally as a pain reliever and sedative. It is also known as ethyl alcohol, grain alcohol, rectified spirit, wine spirit.

Lactic Acid Fermentation

Lactic acid fermentation occurs in animals and in some types of bacteria, and produces the end-product lactic acid. Unlike alcoholic fermentation, this end-product can be converted back into a compound suitable for aerobic respiration when there is sufficient oxygen again.

The sharp taste of sour milk and yogurt is due to lactic acid produced by anaerobic bacteria converting lactose (milk sugar) to lactic acid during lactic acid fermentation. Tooth decay is caused by the lactic acid produced by fermentation of bacteria in the mouth.

Questions

1 What do you observe?

A **Experiment**

In well F1, the yeast suspension becomes frothy or bubbly.

In well F2, bubbles appear at the outlet tube in the lime water. After a few minutes the lime water becomes cloudy,

Control

No such changes were noted.

2 Why do you suppose the yeast suspension became frothy?

A **A gas (carbon dioxide) was formed.**

3 How can you identify the gas?

A **The gas passed into the well containing the lime water. The lime water became milky after some time.**

4 What do you suppose would happen if there were no sugar in the yeast mixture?

A No breakdown of sugars would occur. Living organisms need a fuel - this fuel is usually a sugar.

Note to the Teacher

Ask the students to conduct such an investigation. Their work can be assessed according to some or all of the following criteria:

- formulate plan of action
- conduct investigation
- make observations
- collect data
- analyse data
- communicate findings
- use knowledge to inform actions
- work with others

5 Lift the lid of well F1 and smell the contents. What substance can you smell?

A There is a slight smell of alcohol (i.e. ethanol).

Some students will recognise the smell as similar to beer or wine.

6 What is the formula of this compound?

A CH_3CH_2OH

This compound is produced when glucose is acted on by the enzymes in yeast and in certain other organisms.

We say that yeast is a ***facultative anaerobe***. This means that when oxygen is present it respires using oxygen, but is able to perform fermentation when necessary, i.e. when there is insufficient oxygen present.

Activity 4: Is Oxygen used During Respiration ?

Questions

1 What do you observe?

A In well F1, the methylene blue becomes colourless.
In well F3, the methylene blue remains blue.

2 What do your results suggest to you?

A In well F1 methylene blue solution became colourless because oxygen was used.
In well F2 methylene blue solution remained blue because no oxygen was used.

3 In this investigation, which set-up was the control?

A The control was the set-up with the dry seeds.

Activity 5: Is Energy Released during Respiration ?

Note to the Teacher

Students should find that the thermometer in the well with germinating (i.e. living, respiring) seeds indicates a slightly higher temperature (between 1 ^{0}C and 3 ^{0}C) than the other thermometer. In order to ensure good results, try a variety of seeds (radish, lentils, popcorn mealies all work well).

If students would like to try organisms other than seeds, try using a handful of soil from a compost heap for the "respiring" setup and sterilised soil as the control.

What do your findings suggest to you?
Energy is released during respiration.

Questions

1 Which setup was the control in this investigation?
A The setup with the dry seeds.

2 What else could be used as a control?
A Nothing, stones, boiled seeds, poisoned seeds . . .

3 Why do you suppose that it is necessary to keep the setups away from the sun and artificial heaters?
A We are trying to avoid these other factors increasing the temperature of the seeds and their surroundings.

4 Give another example of a temperature rise due to respiration.
A Students may make a number of suggestions. One example is that of a person feeling very hot, possibly sweating, after exercise or hard physical work. During such times, the respiration rate increases and so does the temperature.

PART 2

CHAPTER 5

TROPISMS

NOTES TO THE TEACHER

SERIES OF ACTIVITIES: TROPISMS IN PLANTS

CHEMICAL AND OTHER REQUIREMENTS

1 CHEMICALS

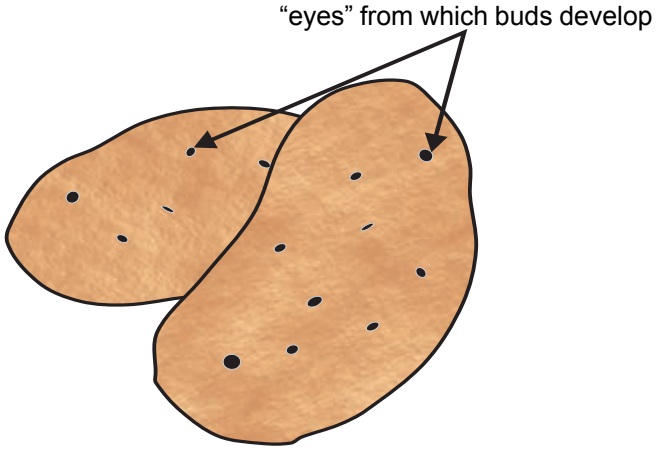
No special chemicals needed.

.1 Seeds

Bean seeds are readily available but must be quite small (about 7 mm in length). Small white beans are ideal. Speckled sugar beans are adequate but do not germinate very well in the comboplate. Other seeds like radish and lentils are also recommended. Certain varieties of maize (like popcorn) can also be used, but are sensitive to temperature, germinating most sucessfully in Spring.

.2 Sprouting Potatoes

Allow one or more potatoes to sprout (send out buds and then shoots from the "*eyes*"). Some greengrocers will give these away at a small charge.



2 EQUIPMENT

All the equipment you need is listed in the table of requirements for each investigation. Most of these items are found in the RADMASTE Microscale Biology Kit and accompanying RADMASTE Biology Teacher Resource Kit. If small plant pots or seedling trays are not available, the seeds can be germinated on moist vermiculite or soil on a saucer or petri dish.

NOTES TO THE TEACHER

TROPISMS IN PLANTS

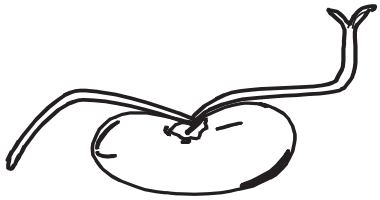
MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE TROPISMS ACTIVITIES

Activity 1: Do the Radicles of Seeds always Grow Downwards?

Questions

1 Write down what you observe when the seeds germinate.

A **The radicles of all of the seeds grew downwards. For example, seed C grew in the way shown below.**



2 What happened to the plumules (young shoots) of the seedlings?

A **The plumules all grew upward - away from the ground and towards the light.**

3 Use what you have learned about tropisms to complete the following sentence about the behaviour of roots and shoots.

A **Roots are positively geotropic and negatively phototropic; shoots are positively phototropic and negatively geotropic.**

4 What is the advantage of tropism to the species?
[HINT]: Think of the ways in which seeds fall to the ground when they are scattered.

A **Whichever way the seeds fall on the ground, they can still germinate. It is not only those which fall in the right direction.**

Activity 2: In which Direction do Young Shoots Grow ?

Questions

1 Note your observations.

A The shoots grow towards the opening. Some of them grow through the opening in the box.

2 What does your observation tell you about the behaviour of the shoots?

A The shoots are positively phototropic.

3 What other evidence of this phenomenon do we see in our everyday lives?

A We see that the leaves of indoor plants grow to the light if they are placed near a window.

PART 2

CHAPTER 6

PLANTS & WATER

NOTES TO THE TEACHER

SERIES OF ACTIVITIES: PLANTS AND WATER

Plants transport substances dissolved in water through vascular bundles. These consist of xylem, which carries water and minerals up from the roots; and phloem, which carries carbohydrates from leaves to the rest of the plants. The cell membrane of a plant cell is selectively permeable, and controls the movement of substances between the cell and its surroundings. Several processes are responsible for the movement of water in plants, including:

Diffusion

Solutes (substances dissolved in water) move from regions of high concentration to regions of low concentration of the solute.

Osmosis

Where two solutions are separated by a selectively permeable membrane (like a cell membrane), water flows from the less concentrated or hypotonic solution towards the more concentrated or hypertonic solution.

Transpiration

Xylem sap flows upwards and evaporates from the leaves and other aerial parts by transpiration. Unless the lost water is replaced, the leaves wilt and eventually die.

Capillarity

This is movement of liquids up or down narrow tubes, or capillaries. The movement is due to unbalanced molecular attraction at the boundary between the liquid and the tube. In the case of transport up the xylem, when a water molecule evaporates from a leaf, another molecule is pulled up from a xylem vessel, and so on down the water column to the roots. The explanation for this movement is called the cohesion-tension mechanism. Cohesion is the force of attraction caused by hydrogen bonding between one water molecule and another.

REQUIREMENTS

1 CHEMICALS:

Please inform students of the following potential hazards. The reagents are perfectly safe if due care is taken. Keep all chemicals out of the reach of children.

Ammonia solution [1]

Copper sulphate [1]

Potassium permanganate [2]

Concentrated hydrochloric acid [3]

1 toxic - do not ingest or inhale

2 stains skin and clothing

3 corrosive

Note that the chemicals listed above can be found in the RADMASTE Biology Chemicals Kit.

PREPARATION OF REAGENTS
As directed.

2 EQUIPMENT:

All the equipment you need is listed under the Requirements for each investigation. Most of these items are available as part of the RADMASTE Microscale Biology Kit and RADMASTE Biology Teacher Resource Kit.

NOTES TO THE TEACHER

PLANTS AND WATER

GROUP OF ACTIVITIES - OBSERVING DIFFUSION

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE DIFFUSION ACTIVITIES

Notes to the Teacher

Ask students if they can taste whether or not a drink like tea or coffee has had any sugar added to it. Explain that the sugar can be tasted because sugar molecules have diffused throughout the tea. The sugar molecules move from where there are lots of them to where there are a few of them per volume. In tea, diffusion of sugar is not visible. The following activities illustrate in a colourful way how diffusion can take place in gases, liquids and solids.

Activity 1: Diffusion in a Gas

Questions

1. What colour was the universal indicator paper when it was placed in the straw?

A **Yellow.**

2. What happens to the indicator paper when ammonia solution is dropped onto the cotton wool?

A **It becomes dark green after a short while.**

3. What caused the colour of the universal indicator paper to change?

A **Some of the ammonia solution on the cotton wool evaporated inside the tube. Ammonia molecules then moved through the air inside the tube. The molecules came into contact with the indicator paper where a reaction took place and caused the colour to change to dark green.**

4. Do you think that an air current through the tube could be responsible for the change which occurred to the universal indicator paper?

A **No, the tube is closed off with cotton wool and air is not likely to blow through the tube. The only movement taking place in the tube is the movement of molecules from areas of high concentration to areas of low concentration.**

Activity 2: More Diffusion in a Gas

Questions

1. What happened in the glass tube?

A **A small whitish cloud formed in the glass tube.**

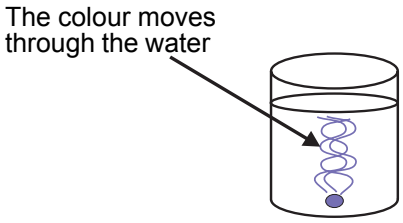
2. What are the tiny white spots which have formed on the glass tube?

A **They are solid ammonium chloride particles.**

3. How did these white spots appear?

A **Some of the ammonia solution and some of the hydrochloric acid evaporated from the cotton wool at each end . Ammonia molecules diffused from the one side of the glass tube and hydrochloric acid molecules diffused from the other side of the glass tube. The molecules collided with each other and reacted to form solid ammonium chloride.**

Activity 3: Diffusion in a Liquid



F5

Questions

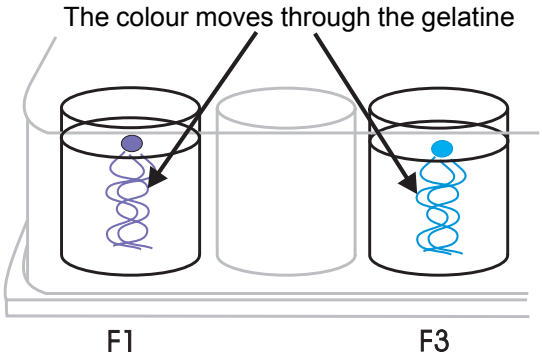
1. What happened when the crystal of potassium permanganate was dropped into the water?

A **The crystal dropped into the bottom of the well. Then the purple colour slowly moved upwards in the water.**

2. Explain your observation:

A **The crystal slowly dissolved forming a concentrated solution of potassium permanganate at the bottom. By diffusion the potassium permanganate molecules spread throughout the water. In this way, the purple colour was evenly distributed (ie. the same everywhere).**

Activity 4: Diffusion in a Solid



Questions

1. What did you observe in F1?

A **A bright purple colour moved downwards in the gelatine.**

2. What did you observe in F3?

A **A pale blue colour moved downwards in the gelatine.**

3. Why did the colours move downwards in well F1 and F3?

A **The potassium permanganate molecules and the copper sulphate molecules moved from the top of the well where there were many per volume (highly concentrated) to where there were a few or none (less concentrated).**

4. If you leave these wells to stand for another day what would happen?

A **The gelatine in well F1 would become entirely red and the gelatine in F3 would become entirely blue indicating that the molecules have become evenly distributed and have reached dynamic equilibrium.**

EXTENSION QUESTION

Repeat the entire procedure. This time, wait for half an hour then invert (turn upside down) the comboplate® after step 5. Discuss your findings with other members of the class.

Note to the Teacher

This extension exercise is necessary to enable students to undestand that the particles (molecules) do not just "fall down" into the gel, but that there is movement that is not caused by gravity.

NOTES TO THE TEACHER

PLANTS AND WATER

GROUP OF ACTIVITIES - FINDING OUT ABOUT OSMOSIS

REQUIREMENTS

1 CHEMICALS:

Note that the chemicals required per activity can be found in the RADMASTE Biology Chemicals Kit.

2 EQUIPMENT:

All the equipment you need is listed under the Requirements for each investigation. Most of these items are available as part of the RADMASTE Microscale Biology Kit and RADMASTE Biology Teacher Resource Kit.

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE OSMOSIS ACTIVITIES

Notes to the Teacher

When two solutions are separated by a selectively permeable membrane (such as a cell membrane), water flows from the less concentrated solution towards the more concentrated solution. This passive movement of water is called osmosis. Living tissues gain and lose water by osmosis, among other processes.

One can simulate the movement of water through cells by using a selectively permeable membrane such as dialysis tubing. Various solutions may be prepared to show how water will move through such a membrane under a variety of conditions.

Pupils can work in groups, each group using a different solution. Examples of solutions include concentrated sucrose solution, orange juice, syrup, treacle and so on. Use the findings of the groups to compare the process of osmosis under different conditions.

Activity 1: Observing Osmosis using Dialysis Tubing

Time (minutes)	Height of Solution (mm)
15	0
30	3
45	5
60	8,5

Questions

1. What did you observe about the level of the water in the propette?

A. The level of the solution in the stem of the propette has risen.

2. Why did the level in the stem rise?

A. Water molecules have passed through the selectively permeable membrane of the dialysis tubing and caused the solution in the propette to rise in the stem of the propette.

3. Is the dialysis tubing totally permeable, selectively permeable or impermeable?

A. Dialysis tubing is selectively permeable.

4. Do you think that the sugar molecules are able to move through the dialysis tubing? Give a reason for your answer by referring to the structure of the membrane.

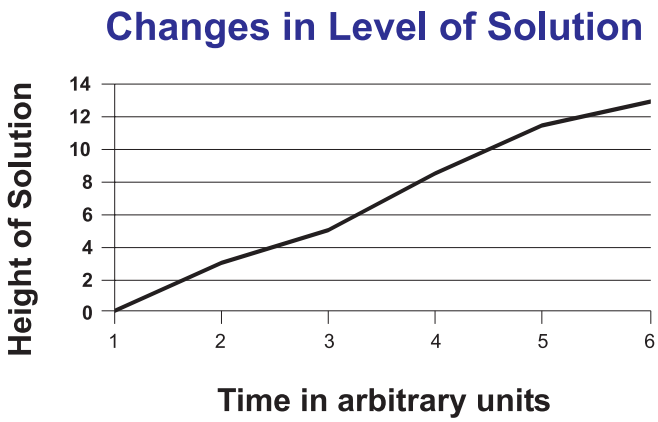
A. No. The "pores" of the membrane are not large enough to allow the sucrose molecules to freely move out onto the other side. Therefore we say that the membrane is selectively permeable.

5. The water molecules can / cannot move through the dialysis tubing. Which is correct?

A. The water molecules can move through the dialysis tubing. Water moves from the less concentrated solution (water) to the more concentrated solution (sucrose solution or alternative).

6. Draw a graph to show how the level of the solution in the stem of the propette changes with time.

A



Activity 2: How Does Osmosis occur in Living Tissue?

Potato or other Vegetable Piece		What it Felt Like		Length in mm
F1	(tap water)	Before:	**Quite Firm**	**10**
		After:	**Firm**	**10**
F2	(tap water)	Before:	**Quite Firm**	**10**
		After:	**Very Firm**	**11**
F3	(10% sucrose solution)	Before:	**Quite Firm**	**10**
		After:	**Same**	**10**
F4	(10% sucrose solution)	Before:	**Quite Firm**	**10**
		After:	**About the Same**	**10**
F5	(30% sucrose solution)	Before:	**Firm**	**10**
		After:	**Soft**	**8**
F6	(30% sucrose solution)	Before:	**Firm**	**10**
		After:	**Soft**	**8.5**

Note to the Teacher
The results in the table above are examples of what is likely to be found. Compare your findings with those of other groups.

Questions

1. In general, what happened to the potato or other vegetable pieces in the tap water?

A. The potato or other vegetable pieces in the tap water became swollen and larger.

2. In general, what happened to the potato or other vegetable pieces in the 10 % sucrose solution?

A. The potato or other vegetable pieces in the 10 % sucrose solution did not change in size or texture.

3. In general what happened to the potato or other vegetable pieces in the 30 % sucrose solution?

A. The potato or other vegetable pieces in the 30 % sucrose solution became shrunken and soft to the touch (flaccid).

4. Try to give reasons for your findings in each case

A. Tap water is hypotonic to cell sap so the potato or other vegetable pieces in the tap water absorbed water by osmosis and became swollen.

10% sucrose solution is isotonic with cell sap so overall, the number of water molecules moving into the potato or other vegetable pieces equalled the number of water molecules moving out of the potato or other vegetable pieces. In other words, there was no net movement of water molecules into or out of the potato or other vegetable pieces. The potato or other vegetable pieces remained the same size.

30% sucrose solution is hypertonic to cell sap so water molecules moved out of the potato or other vegetable pieces into the solution. The potato or other vegetable pieces became shrunken due to water loss.

Water moves through selectively permeable membranes from regions of high water potential to regions of low water potential.

NOTES TO THE TEACHER

PLANTS AND WATER

GROUP OF ACTIVITIES - PATH OF WATER THROUGH THE PLANT

REQUIREMENTS

1 CHEMICALS:

Note that the chemicals required per activity can be found in the RADMASTE Biology Chemicals Kit. Food colouring is not part of the kit and should be purchased from a grocery store.

2 EQUIPMENT:

All the equipment you need is listed under the Requirements for each investigation. Most of these items are available as part of the RADMASTE Microscale Biology Kit and RADMASTE Biology Teacher Resource Kit.

MODEL ANSWERS TO OBSERVATIONS AND QUESTIONS IN THE 'PATH OF WATER THROUGH THE PLANT' ACTIVITIES

Activity 1: Path of Water Through the Plant

Questions

1 In what tissue did you observe the red food colouring?

A The red dye (food colouring) stained the xylem.

2 What can you conclude from this observation?

A Water travels in the xylem of plants, from the roots through the stems and to the other aerial parts of the plant.

Extension Activities

1 Repeat the procedure with other plants which have variegated (for example, green and white) leaves and observe the leaf veins after a few hours.

A The leaf veins will become stained with the food colouring.

2 Repeat the procedure with pale-coloured flowers and observe changes which occur in the petals.

A The veins of the petals will be stained with the food colouring.

Activity 2: Does the Root System of a Plant Push Water up the Stem?

Questions

1 Why do you suppose we placed oil over the water in the tube?
A The oil prevents evaporation of water in the tube.

2 What did you observe about the level of water in the tube above the stem?
A The level of water rose.

3 Where did this water come from?
A It came from the conducting tissue (xylem) of the plant.

4 Do you think the water level rose because of transpiration?
A Transpiration is not taking place (little or no aerial parts of the plant). Therefore some other factor is responsible for the movement of water through the plant.

5 What system of the plant caused the water level to rise?
A **The roots are intact. Therefore the roots (or the water in the root system) exert a force upwards.**

Activity 3: Is Water Lost Through the Aerial Parts of A Plant?

Questions

1 What was the purpose of the oil on the surface of the water?
A The oil prevents evaporation from the surface.

2 Which plant part lost the most, second most and least liquid?
A The leafy twig lost the most, then the flower and the leafless twig lost the least liquid.

3 What happened to the blue cobalt chloride paper when you used it to test the liquids in each of the plastic bags?
A The paper turned pink.

4 What liquid did the plant parts lose?
A The plant parts lost water.

5 Summarise all your findings in a single sentence
A The aerial parts of plants lose water (vapour) into the atmosphere. The leaves of plants generally lose more water than the other parts.

Activity 4: Investigating How the Leaves of Plants Lose Water

Note to the Teacher

Sometimes it is possible to see minute pink dots, indicating the positions of the stomata. Usually, however, the blue cobalt chloride paper is streaked with pink.

Questions

1. Was there any change in the colour of the cobalt chloride paper on any side of the leaves?

A **Yes. The blue cobalt chloride paper became pink in parts.**

2. What does this observation suggest?

A **Plants lose water (vapour) through the surfaces of their leaves.**

3 Do leaves lose water from both surfaces, from the upper surface, from the lower surface?

A **Different leaves show different results. Some leaves lose more water from the upper surface than the lower surface, some leaves lose water equally from both surfaces.**

Note to the Teacher

Most leaves are dorsiventral; i.e. there are unequal numbers of stomata on the upper and lower surfaces. Some leaves, however, notably those of monocotyledons, are isobilateral; i.e. having equal numbers of stomata on the upper and lower surfaces.

Activity 5: Loss of Liquid Water From Plants

Questions

1 What can be seen along the margins of the leaves?

A **Droplets of water are observed.**

2 What process has taken place?

A **Guttation has taken place.**

3 Under which environmental conditions would this process take place in plants?

A **Under humid conditions.**

4 Why would guttation occur under these conditions?

A **The humid atmosphere cannot hold any more water vapour. The water lost from the plant is therefore released in liquid form.**

Note to the Teacher

It is possible that not all of the seedlings will lose water to the same extent. Use the findings to discuss variation between organisms.

Activity 6: Loss of Water from Plants under Various Environmental Conditions

Questions

1 Which plant or plants lost the most water?
A Those in hot, dry, windy areas.

2 Which plant or plants lost the least water?
A Those in cool, shady, still and humid areas.

3 Was any water lost from the control setups?
A (Sometimes) Very little.

Note to the Teacher

In this investigation, we are comparing directly the loss of water from plants with the loss of water from a similar set-up with no plant. Indirectly, we make comparisons between plants (and between set-ups) under different conditions. We are not comparing directly the loss of water in a single plant under various conditions. We can only ***assume*** *how a single plant would behave under a range of conditions, and we* ***cannot make generalisations****.*

The UNESCO-associated Centre
for Microscience Experiments
RADMASTE Centre
University of the Witwatersrand

19th Floor, University Corner
Corner Jorissen and Bertha Street
Braamfontein, Johannesburg
South Africa

Private Bag 3
WITS 2050

Tel: (+) 27 11 717 4802
Fax: (+) 27 11 403 8733

email: UNESCO@radmaste.wits.ac.za
website: www.microsci.org.za