Biology for Life

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Note to the teacher

Experiments involving the use of micro-organisms, the drawing of blood, or where the pupil acts as a subject, may be potentially hazardous. Such experiments should be carried out under close supervision. Detailed advice is given in the Association for Science Education booklet entitled *Safeguards in the School Laboratory*. Copies are available from:

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Preface

For most people, O-level or CSE is the last biology course they will ever do, and naturally one hopes that it may be of some use to them afterwards. With this in mind I have written a book for 13 – 16 year olds in which the topics taught in O-level and CSE courses are related to everyday life: hence the title *Biology for Life*. Much of the human physiology is related to medicine and health, and the various organisms which are dealt with are looked at from the point of view of their application to man.

In the last few years a number of surveys have been carried out which suggest that many science text books at this level present students with serious reading difficulties. I have therefore endeavoured to make *Biology for Life* easy to read. This has meant keeping the language and sentence construction as simple as possible. I hope this will make the book equally usable by O-level and CSE pupils, and will help to bridge the gap between these two traditionally separated groups.

Writing a text book which is readable and yet sufficiently rigorous academically has not been easy. If I have had any success in solving the readability problem it is largely because of the help I have received from Drs Nikolas and Justine Coupland of the University of Wales Institute of Science and Technology. Specialists in English, the Couplands have made a special study of the linguistic aspects of communication in science teaching. They kindly read the entire manuscript of *Biology for Life* and made many valuable suggestions as to how the text might be simplified and its clarity improved. I am most grateful to them for their shrewd counsel.

On the question of the language, I obtained much useful information from a trial which was carried out in a selection of schools during 1978. The schools were deliberately chosen for the widely differing ability ranges of their pupils. They are listed below, and I would like to record here my thanks to the heads of the biology departments and their colleagues for their help and cooperation.

The book is divided up into a large number of short topics. Most of the topics are self-contained so that, within reason, they can be studied in any order. I hope this will enable the individual teacher to weave the topics together in a sequence which suits his or her particular course.

Each topic is normally followed by one or more investigations and about six homework assignments. Some of the investigations can be carried out by students, either individually or in groups; others are best done as demonstrations by the teacher. I have deliberately not incorporated the instructions into the text because this would have interrupted the flow and made it difficult to see the overall picture.

The assignments are all questions of the kind which occur in O-level or CSE examinations. They are of graded difficulty with simple ones coming first and more difficult ones later. The simple ones involve mainly factual recall, whereas the harder ones test more advanced skills such as formulating hypotheses and designing experiments.

Many people, in addition to those involved in the trial, have assisted in the production of this book. I am particularly grateful to Dr James Parkyn and my father, Dr Llywelyn Roberts, for advising me on medical matters; to Mrs Gill Williams for her advice on topics relating to health education; to Mr Malcolm Ashby for help with the dental section; to Mr David Alford for his constructive comments on the first draft; and to Dr James Parkyn for obtaining some of the more specialised medical photographs. In addition I would like to thank Mr John Barker, Mr Peter Fry and Dr John Land for their useful comments. Despite the help which I have received, the book is bound to contain some errors. These are entirely my fault and I hope that teachers and students will not hesitate to point them out to me as they use the book.

Biology for Life was written while I was holding a Research Associateship at Chelsea College, University of London. I would like to thank Professor Paul Black, Director of the Centre for Science Education, for providing me with facilities, and Professor Peter Kelly for his continual help and encouragement. I am also grateful to Miss Pat Stevens who typed the manuscript with patience and good humour.

Finally I must thank my publishers, Thomas Nelson and Sons Ltd. It was they who first suggested that I should write this book, and their support has been a constant source of encouragement. I owe particular thanks to Mrs Donna Evans for her unfailing patience and efficiency, and to all those who have been involved with the design and production of the book.

M. B. V. Roberts
Kensington, August 1980

Schools which took part in the trial.

Rydens School, Walton-on-Thames, Surrey.
Isleworth Grammar School, Isleworth, Middlesex.
Hounslow Manor School, Middlesex.
Willesden High School, London, N.W.10.
Woodberry Down School, London, N4.
Kidbrooke School, London, S.E.3.
Marlborough College, Marlborough, Wiltshire.
Winchester College, Winchester, Hampshire.
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Theale Green School, Theale, Berkshire.
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North Bromsgrove High School, Bromsgrove, Hereford and Worcester.
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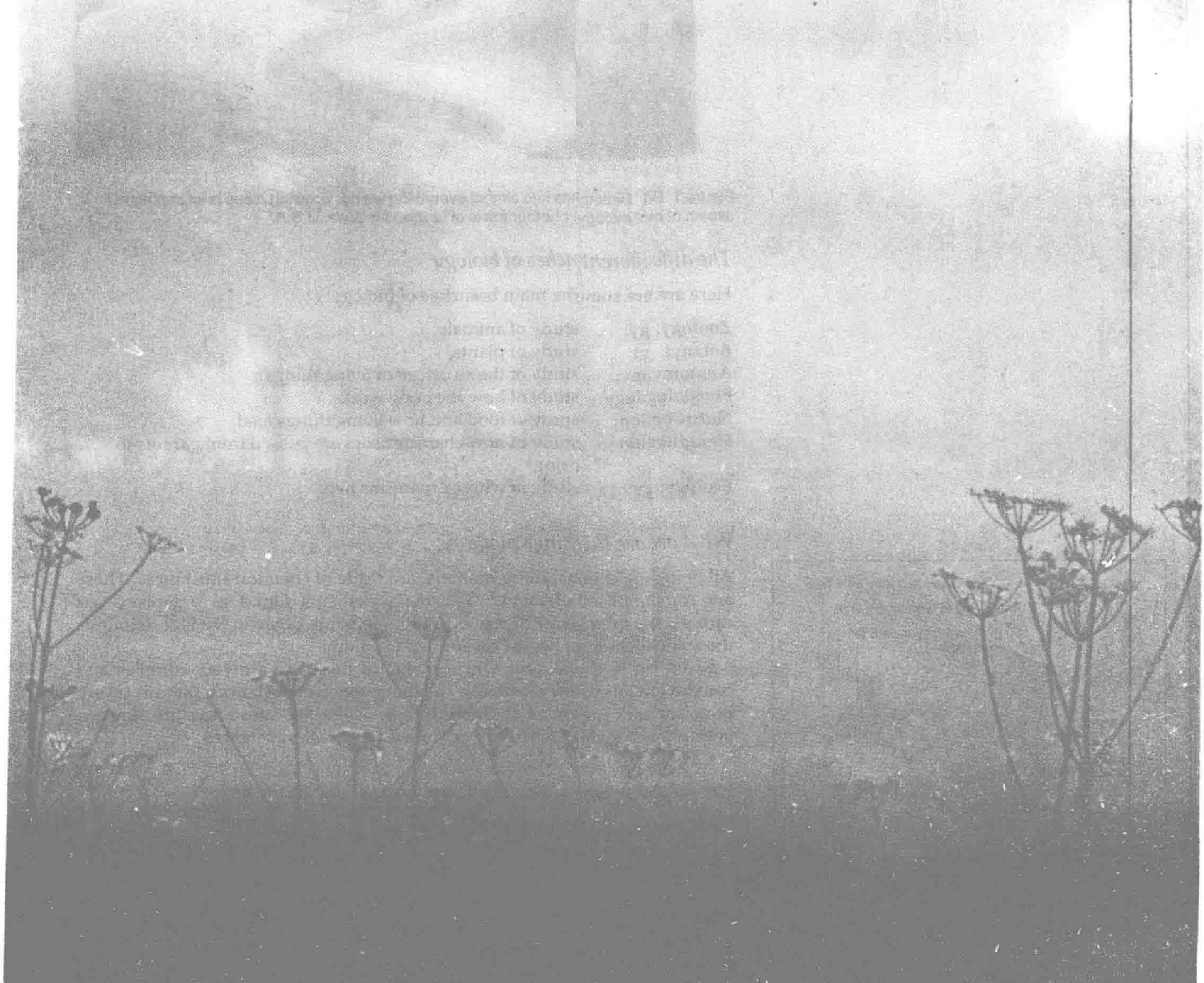
Lucton County Boys' School, Loughton, Essex.
Exmouth School, Devon.
Mayfield School, Putney, London S.W.15.

Contents

Some basic principles

Biology is the study of life and living things. In the first few Topics we shall introduce the subject and look at some of its basic principles.



Introducing biology

Biology is the study of life and living things. We call living things organisms. One of the most complicated organisms is the human being, and studying man is an important part of biology.

Figure 1 Biology comes into almost everything we do. Growing crops is an important aspect of biology. The photograph is of farmland in Iowa, U.S.A.

The different branches of biology

Here are some of the main branches of biology:

Zoology: the study of animals
Botany: the study of plants
Anatomy: the study of the structure of living things
Physiology: the study of how the body works
Nutrition: the study of food and how living things feed
Heredity: the study of how characteristics are passed from parents to offspring
Ecology: the study of where organisms live

What are living things made of?

All living things, including humans, are made of chemical substances. These are composed of **elements**. The main elements found in organisms are carbon, hydrogen and nitrogen. Other elements occur in smaller amounts: these include phosphorus, calcium and sodium.

Some of the substances which make up the body are very complex and contain lots of carbon atoms. We call them **organic substances**; they are a very important ingredient of all living things. The other substances are simpler, and usually lack carbon. They are called **inorganic substances**.

Here is a summary of the main substances found in the body:

Organic substances: Carbohydrates
Fats
Proteins
Inorganic substances: Salts
Water

Each of these substances has certain jobs to do. These are their main jobs:

Carbohydrates give us energy; one of the best known carbohydrates is sugar.
Fats also give us energy; there is a lot of fat under the skin, it helps to keep us warm.
Proteins help to build the body; they form important structures like bones and muscles.

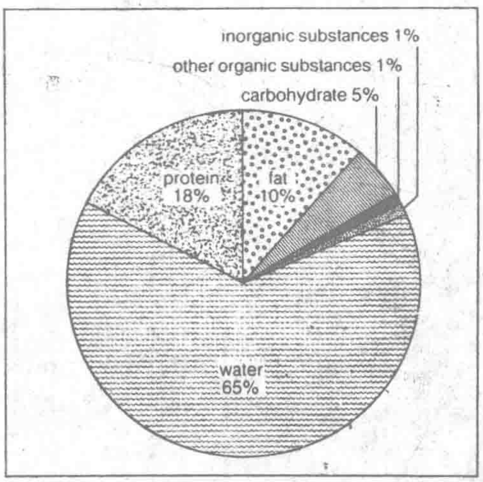


Figure 2 This diagram, called a pie chart, shows the relative amounts of the main substances which make up the human body. There is much variation between different individuals – these are average figures. The 'other organic substances' include a number of important substances derived from vitamins. These and all the other substances in this chart come from the food we eat.

Salts help to make the various structures in the body work properly.

Water provides a liquid in which other substances can be moved about inside the body.

Figure 2 shows the proportions of each of these substances in the human body. You may be surprised to see that our bodies contain far more water than any other substance. The fact is that we are really very wet.

All these substances are made up of **molecules**. The molecules, in turn, are composed of **atoms**. Take water, for example. A molecule of water consists of two hydrogen atoms and one oxygen atom. We usually represent it as H_2O. This is its **chemical formula**.

Water is one of the simplest substances found in living things. A more complicated substance is glucose which is a type of sugar. Its formula is $C_6H_{12}O_6$: this shows that a molecule of it contains six carbon atoms, twelve hydrogen, and six oxygen atoms.

Chemical reactions in organisms

All manner of chemical reactions take place inside living organisms. These reactions are essential for life. If they stop, the organism dies.

We call these reactions **metabolism**. Some of the reactions build things up: they make important substances which the organism needs. These reactions require energy. Other reactions break things down: they give out energy, mainly in the form of heat. The difference between these two kinds of chemical reactions is illustrated in Figure 3.

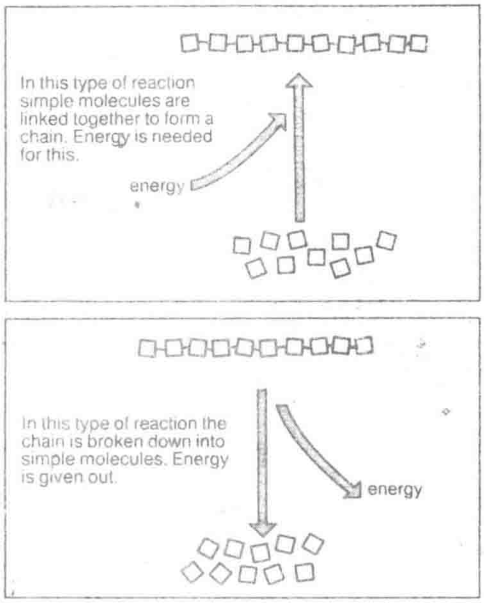


Figure 3 This diagram illustrates the two main types of chemical reactions which take place in living organisms.

Naming living things

Every organism is given two names. The first is the name of the **genus** to which the organism belongs. It shares this name with a number of other closely related organisms. We can liken the genus name to a person's surname. The organism shares this name with other members of its genus, just as we share our surname with other members of our family.

The organism's second name is the name of the **species** to which it belongs. This name is possessed by only one kind of organism: it does not share it with any other organisms in the genus.

It is customary to start the genus name with a capital letter, and the species name with a small letter, and to print both names in *italics*.

Now for an example. The domestic cat's full name is *Felis catus*: *Felis* is the genus name, and *catus* is its species name. This name applies to the family pet which spends so much of its time curled up on the hearth-rug. However, the genus *Felis* also includes several animals which would be less welcome in our houses, the lion and tiger for example (Figure 4). The lion's proper name is *Felis leo*, and the tiger's is *Felis tigris*. Other wild cats include the leopard, jaguar and cheetah.

This system of naming organisms was developed by the 18th Century naturalist Carl Linnaeus (1707 – 78). Because it involves giving organisms *two* names, it is known as the **binomial system**.

The names just described are called **proper names**. They are usually Latin names, or have Latin endings. The trouble is that they are often long and difficult to remember. For example, there is a certain kind of worm which is called *Haploscoloplos bustorus*! To make things easier we often call animals and plants by simpler **common names:** cat, lion, tiger, and so on. These common names may be likened to a person's nickname.

People sometimes ask why we bother with proper names. Why don't we just use common names? The reason is that common names are often not precise enough. An organism may have several different common names, and sometimes the same one is used for several different organisms. Common names can therefore be confusing.

Figure 4 This is a lion. It belongs to the genus *Felis*.

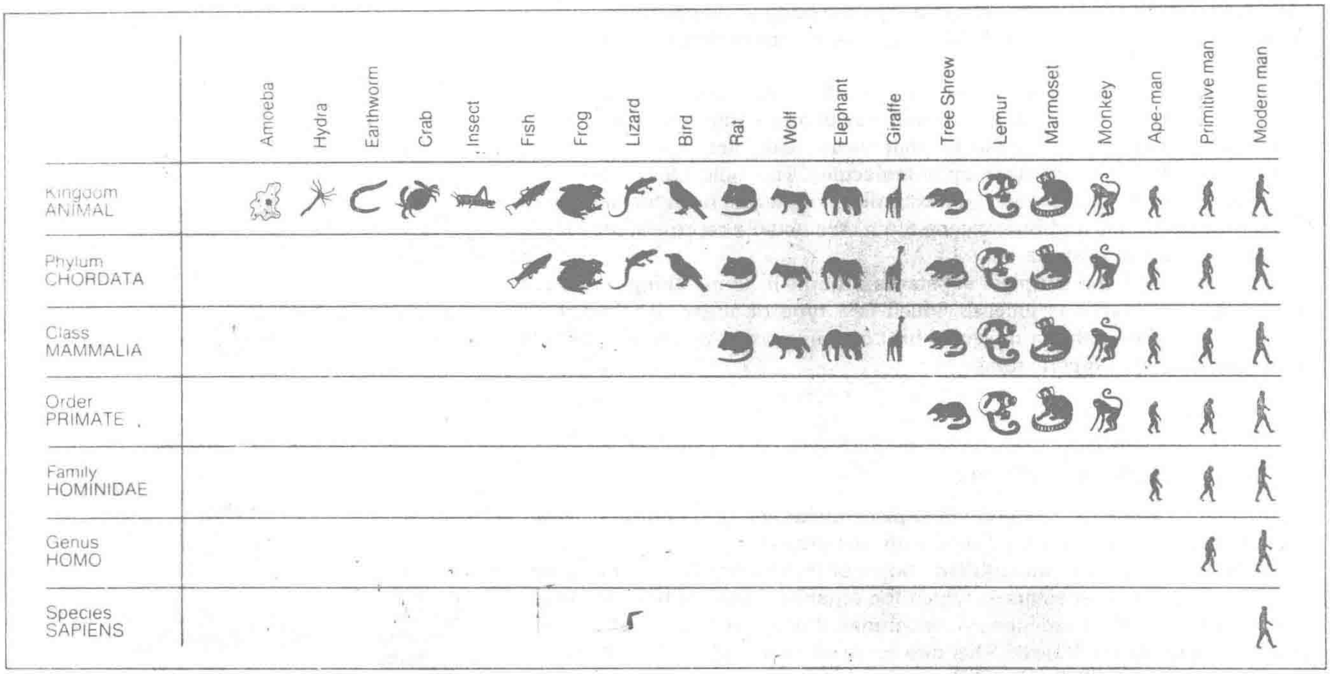


Figure 5 This picture shows how man is classified. As we go downwards from top to bottom the number of organisms in each group decreases and the similarities between them increases. Ape-man and primitive man are, of course, extinct and are known only from their fossil remains.

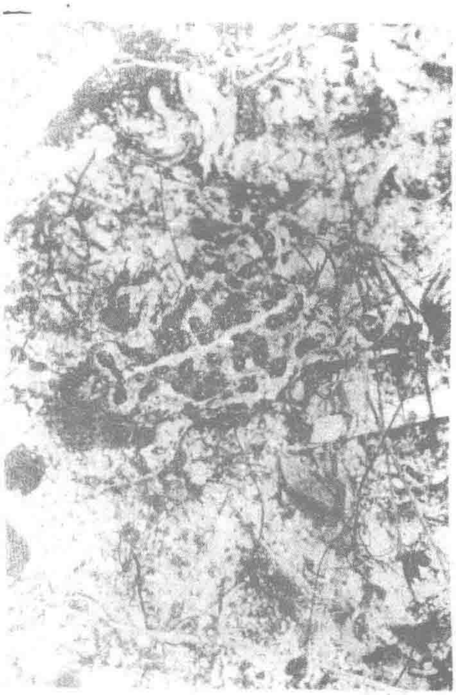


Figure 6 There is an animal here. Can you see it? What kind of animal is it?

How do we classify living things?

Scientists have described about one and a half million kinds of organisms and new ones are constantly being discovered. With so many organisms in existence, we must have some way of classifying them. This is done by arranging them into groups. Each group is then split into smaller groups, and these groups into even smaller groups and so on. The members of each group have certain features in common which distinguish them from other groups.

Living things are first split into **kingdoms**, such as the animal and plant kingdoms. These kingdoms are then split up into a large number of smaller groups called **phyla** (singular: phylum). All the members of a phylum have certain things in common. Each phylum is broken down into **classes**, classes into **orders**, orders into **families**, families into **genera** (singular: genus), and genera into **species**. Each of these groups contain progressively fewer and fewer kinds of organisms. Thus a phylum contains a wide variety of organisms: they all have certain basic features in common, but there are a lot of differences between them. However, the organisms belonging to a genus are all very similar. This is illustrated in Figure 5, which shows how man is classified.

Where do organisms live?

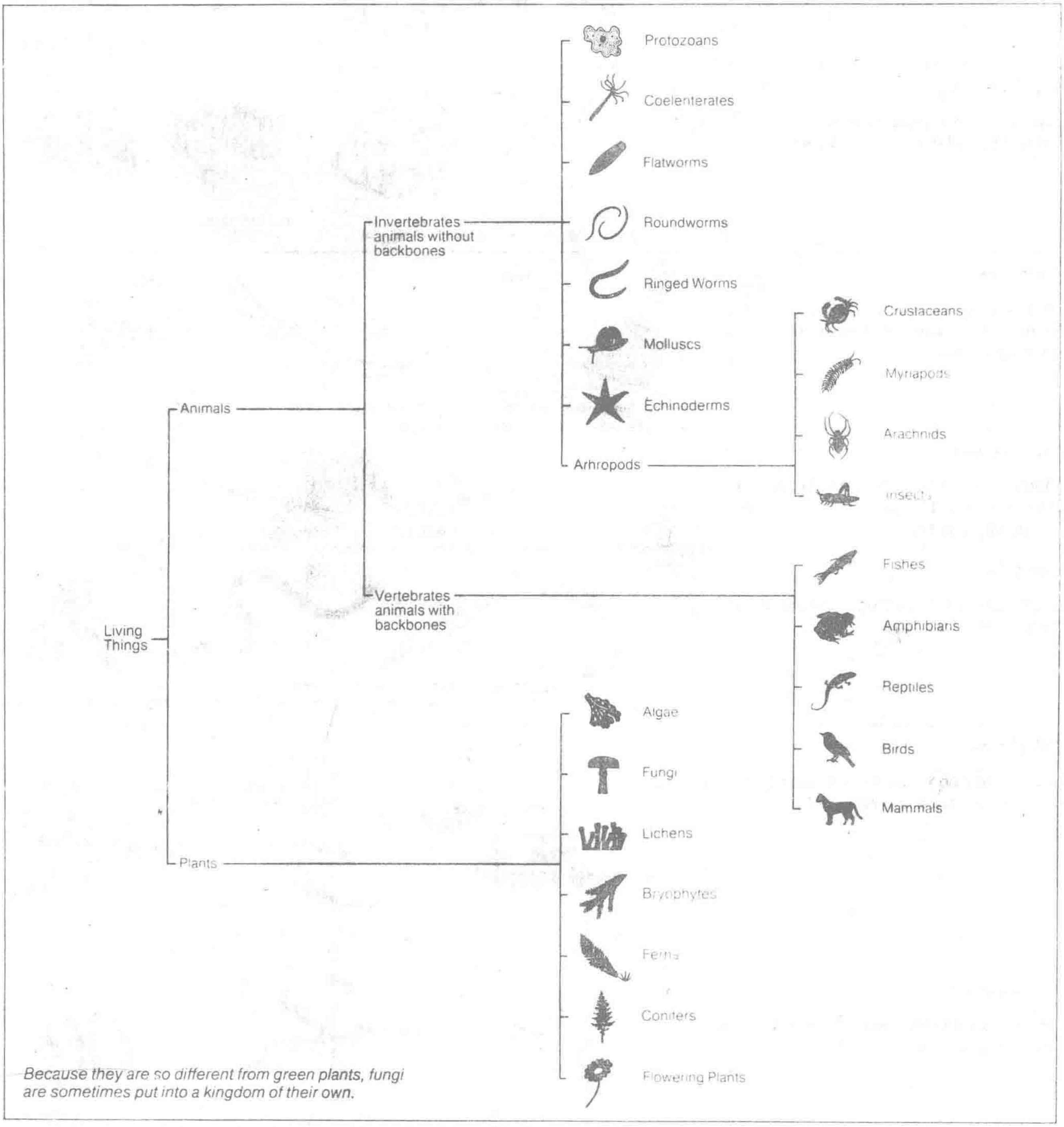
Living things are found almost everywhere in the world: on land and in the air, in water and underground. You find them in the most unlikely places, such as hot dry deserts and the freezing cold polar regions. You even find them in salt lakes and hot springs where the water is almost boiling. Many organisms live on or in the bodies of other organisms.

The place where an organism lives is called its **habitat**. The conditions which exist in its habitat make up the **environment**. Every organism is suited, or **adapted**, to live in its particular habitat. For example, some animals are wonderfully camouflaged so they cannot be seen by their enemies (Figure 6). Organisms can survive only if they are suitably adapted. This is one of the most important principles in biology and we will meet it frequently in later Topics.

The world of living things

We will now look at the main groups of living things. This will give you a glimpse of the variety that's found amongst animals and plants. Before getting down to details, look at Figure 7. This shows at a glance the main groups into which living things are divided. This is not the only way of splitting them up, but it is one that is commonly used. On the next three pages we will look briefly at each of the groups of living things shown in Figure 7.

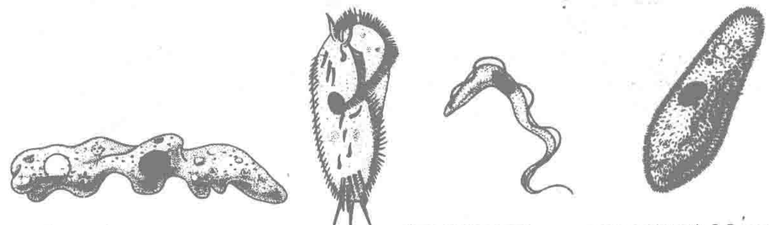
Figure 7 The main groups of living things at a glance. (Viruses and bacteria are not included in this classification. They are put into separate kingdoms of their own.)



Animals without backbones (invertebrates)

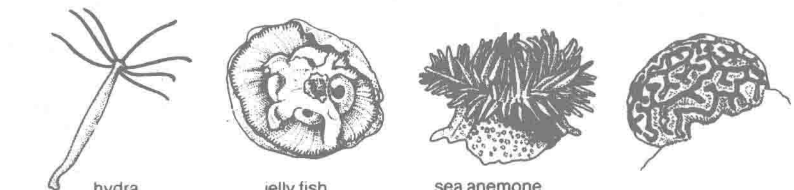
Protozoans

Microscopic animals whose body consists of only one cell. Live in water, or as parasites inside other organisms.



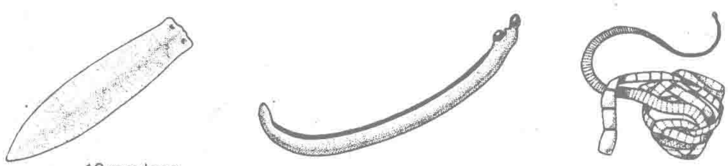
Coelenterates

Many-celled animals with tentacles and sting cells. Most of them live in the sea.



Flatworms

Body elongated and flat. Some of them live in ponds and streams, but most are parasites causing diseases.

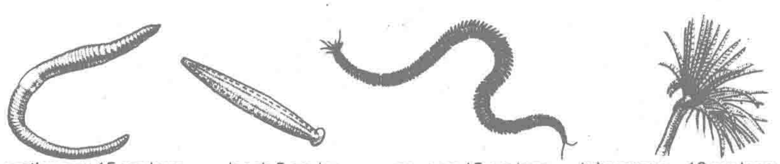


Roundworms

Body elongated and thread-like, round in cross-section. This group includes some harmful parasites.

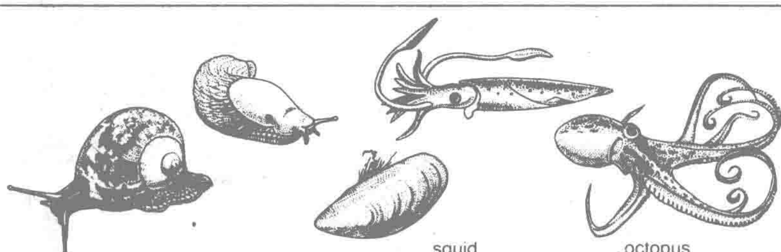
Annelids

Body divided up by rings into a series of segments.



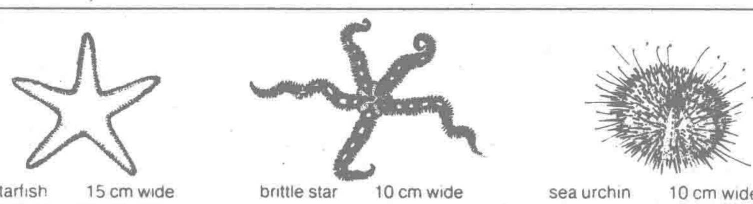
Molluscs

Have a soft body usually protected by a shell. In some the shell is greatly reduced.



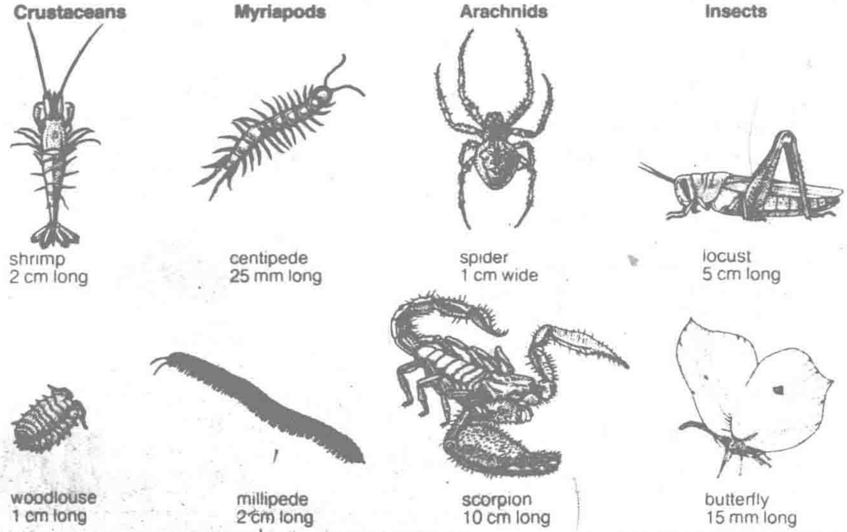
Echinoderms

Have a tough spiny skin. Most of them are star-shaped. They all live in the sea.



Arthropods

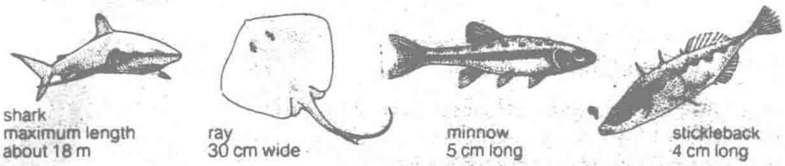
Have a hard cuticle and jointed limbs. Divided into four groups mainly on the basis of the number of legs.



Animals with backbones (vertebrates)

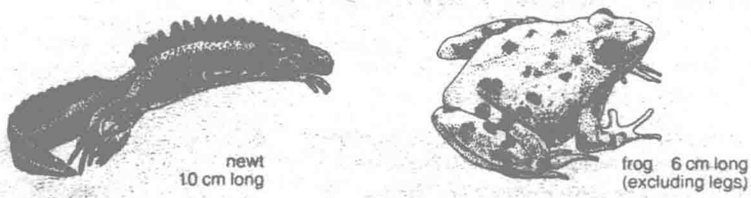
Fishes

Live in water. Have gills for breathing, scales on their skin, and fins for movement.



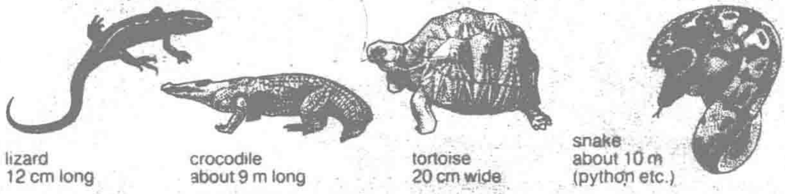
Amphibians

Have moist skin without scales. Live on land but lay eggs in water. Have fish-like tadpole larva which changes into the adult.



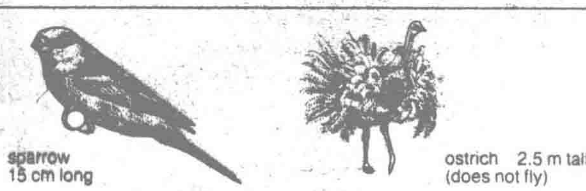
Reptiles

Have dry waterproof skin with scales. Eggs have a leathery shell and are laid on land.



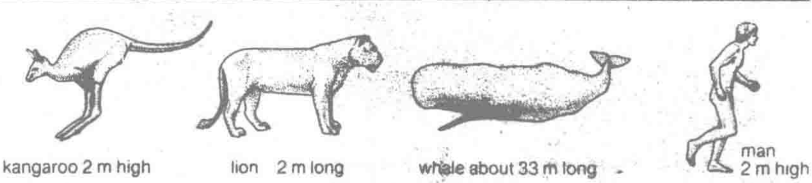
Birds

Have feathers. Eggs have hard shells. Wings for flying, and a beak for feeding.



Mammals

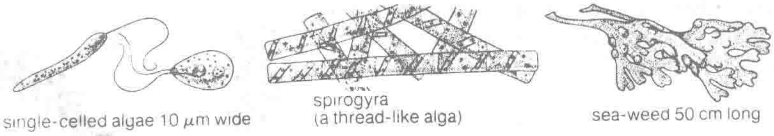
Have hair. The young develop inside the mother and after birth are fed on her milk.



Plants

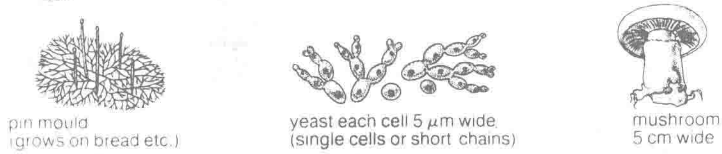
Algae

Simple plants which do not have roots, stems and leaves. Usually green, but sometimes brown or red. Live in water.



Fungi

Simple non-green plants which do not photosynthesise. Some are parasites and cause serious diseases of plants.



Lichens

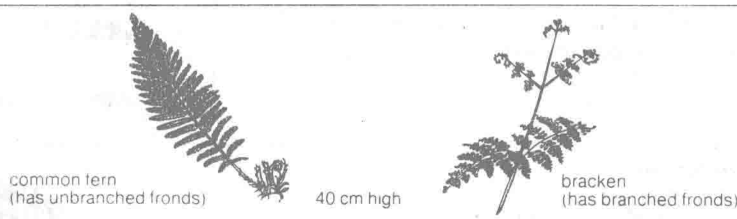
Consist of an alga and fungus combined together. Grow on rocks and tree trunks. Very hardy.

Bryophytes

Have simple leaves or leaf-like form. Found mainly in damp places.

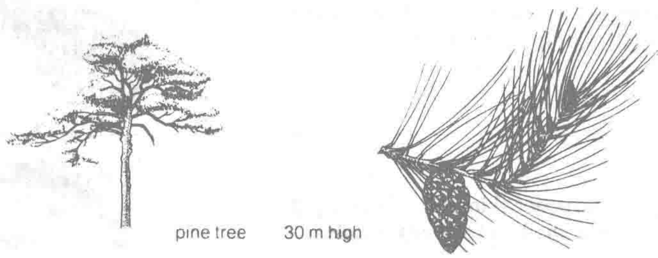
Ferns (Pteridophytes)

Have proper roots and stems, and frond-like leaves. Found mainly in damp places. Reproductive spores can be seen on the undersides of the fronds in the autumn.



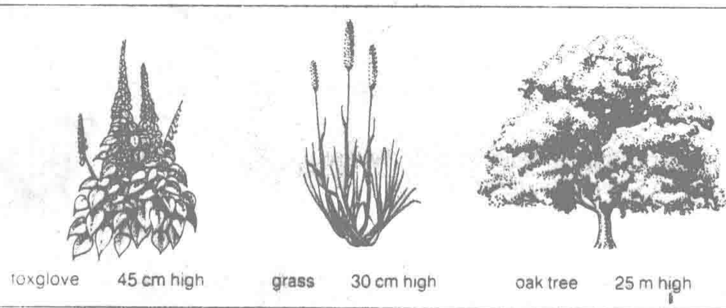
Conifers (Gymnosperms)

Large plants with cones for reproduction. Good at surviving in dry or cold climates. Most of them keep their leaves through the winter.



Flowering plants (Angiosperms)

Wide range of plants with flowers for reproduction. Range from small herbs to massive trees. Many of them drop their leaves in the winter.



Note Fungi are sometimes put in a separate kingdom of their own

Investigation 1

What are you made of and how much are you worth?

1 Weigh yourself.

2 Write down your mass in kilograms.

3 Study Figure 2. This tells you the percentage of different substances in an average human being.

4 Assuming that you contain these substances in the same proportions, work out the mass of each substance in your body.

5 Find out the cost of each of the substances in the shops. Assume that all the carbohydrate is sugar, all the protein is meat, and the salts are all common table salt. Ignore the 'other organic substances'.

6 Work out the value of your body in pounds and pence.

Do you think this is a valid way of expressing the value of a human being?

Investigation 2

Putting some familiar animals and plants into groups

1 Examine various organisms, or pictures of organisms, provided by your teacher. All of them are featured in the classification on pages 6–8.

2 Write down the name of the group to which each organism belongs. Use the classification on pages 6–8 to help you.

3 Look carefully at each organism.

From its structure, what can you say about the sort of place where it lives, and the kind of life it leads?

Investigation 3

Putting some unfamiliar animals and plants into groups

1 Examine various organisms which are *not* illustrated in the classification on pages 6–8.

2 Write down the name of the group to which you think each organism belongs. Do this by relating the characteristics of the organism to the information given on pages 6–8.

3 Which specific animal or plant illustrated on pages 6–8 does each organism resemble most closely?

Assignments

1 Which branch or branches of biology listed at the begining of this Topic must each of the following people know about:

a farmer, a gardener, a nurse, a family doctor, a game warden, a person who breeds dogs, a PE teacher, a forester, a surgeon, a keeper in a zoo.

2 Which chemical substances mentioned in this Topic play the most important part in:

a) helping us to run fast,
b) making us strong,
c) keeping us warm,
d) making our blood 'runny',
e) mending a broken leg?

3 What is the connection between each of the following pairs:

a) carbohydrates and fat,
b) insect and crustacean,
c) genus and species,
d) leopard and cheetah,
e) molecules and atoms?

4 What group does each of these organisms belong to: moss, jelly fish, tortoise, tapeworm, whale, mushroom, mould, tube worm, sea weed, newt?

5 What would be the easiest way of telling the difference between:

a) an arthropod and a vertebrate,
b) an insect and an arachnid,
c) an amphibian and a reptile,
d) an alga and a fungus,
e) a conifer and a flowering plant?

6 From books, try to find out the largest member of each of the following plant groups: Algae, Ferns, Conifers, Flowering plants.

In each case give the proper name and common names of the organism, and state its approximate size.

7 Give the name of an animal which:

a) is shaped like an umbrella and has sting cells,
b) lays eggs with a leathery shell,
c) has a pouch in which the young develop,
d) is shaped like a star,
e) has two pairs of wings,
f) consists of only one cell,
g) lives on land but lays its eggs in water,
h) has a long flat body,
i) has tentacles and belongs to the same group as snails,
j) has four pairs of legs.

8 Give the name of a plant which:

a) reproduces by means of flowers,
b) has frond-like leaves,
c) consists of only one cell and is coloured green,
d) causes a disease,
e) has no chlorophyll.

The characteristics of living things

If we examine the things organisms do, and the processes which take place inside them, we find certain features that are common to them all.

Figure 1 This gymnast is showing one of the basic properties of life: movement.

Living things move

This is obvious in the case of a human being (Figure 1). We move our arms and legs by means of muscles. Most animals can move in this kind of way, at least at some period of their lives.

However movement is not so obvious in a plant. To see movement in a plant you must look inside it, under a microscope. Then you may see things moving about, though it is not always easy (Investigation 1).

Living things respond to stimuli

If you sit on a drawing pin, you jump up quickly. The pricking of your bottom is called the **stimulus** (plural: stimuli). Your jumping is called the **response**.

Living things respond to different kinds of stimuli. The main ones are touch, chemicals, heat, light and sound. For example, when we see something we are responding to light entering our eyes, and when we taste things we are responding to chemicals in the mouth.

At first sight you might think that plants are an exception to the rule that all organisms respond to stimuli. After all, if you hit a tree, it doesn't move away. However, plants *do* respond to certain stimuli, but much more slowly than animals. They do not have muscles. Instead they respond by *growing* in a particular direction. For example, most plants grow towards light (Figure 2).

There are a few plants which respond quickly to touch, like animals do. For example, the leaves of the mimosa plant close up when you touch them (Investigation 2). However, there are no sense organs, nerves or muscles in the leaves: the response is brought about in a quite different way.

Living things grow

As an animal or plant develops, it gets larger and heavier. In other words, it **grows**.

Growth takes place by substances being taken into the organism from outside. These substances are then built up into the structures of the body: they become part of the organism.

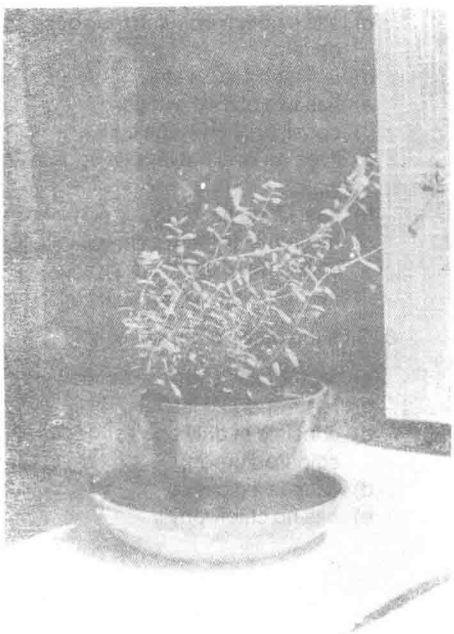


Figure 2 This plant is growing towards the light.

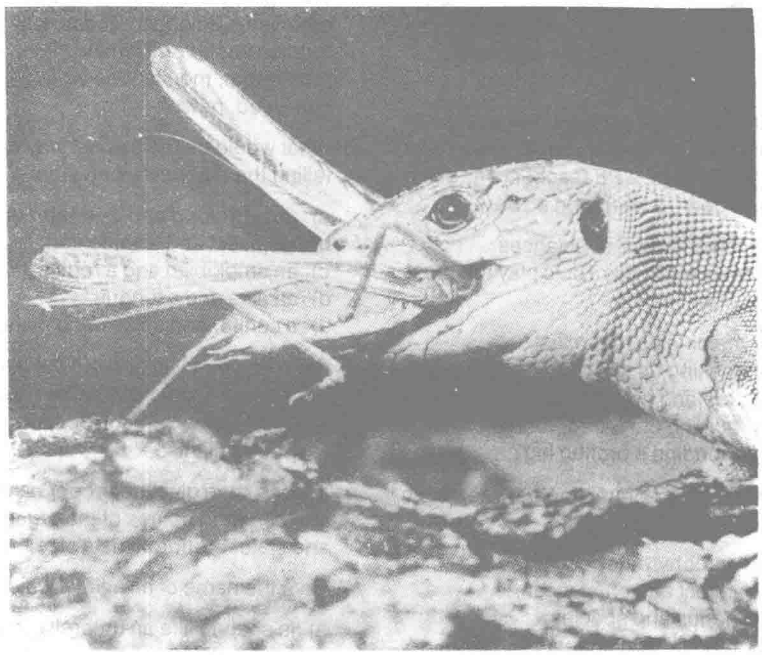


Figure 3 All organisms feed. This lizard is eating a cricket.

A plant, such as a tree, goes on growing throughout its life. Animals usually stop growing when they reach a certain age. For example, humans stop growing at about the age of eighteen.

Even when growth stops, the materials of the body are constantly replaced by new substances coming in from outside. This process of renewal goes on throughout life. It has been worked out that in about seven years all the chemicals in the human body are replaced by new ones.

Living things feed

We have just seen that in order to grow an organism must take substances into its body. This is achieved by **feeding (nutrition)**. All organisms need food.

Animals and plants feed in quite different ways. Animals feed on complex organic substances which are often in solid form (Figure 3). In man the food is taken into the mouth. It is then broken down into a liquid: this process is called **digestion** and it is carried out in the gut.

Any food which cannot be digested passes out of the body through the anus. Meanwhile the digested food is absorbed and used.

In contrast to animals, plants make their own food. They take in simple things like carbon dioxide and water and build them up into complex organic substances. Energy is needed for this: it comes from **sunlight**. The green pigment **chlorophyll** enables the plant to use sunlight in this way: this is why plants are usually green. The process by which plants make food is called **photosynthesis** (Figure 4).

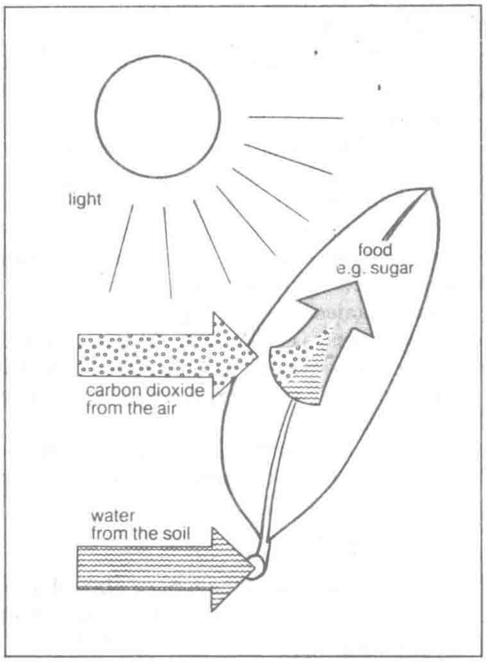


Figure 4 Plants feed by photosynthesis. The plant takes up carbon dioxide and water and turns them into complex food substances such as sugar. This process is carried out mainly in the leaves.

Living things produce energy

Living things need energy to move, grow, replace worn-out structures, and so on. They obtain this energy by burning food. The food is not really burned, but it comes to the same thing chemically: the food is broken down into carbon dioxide gas and water. This process is called **respiration**.

Respiration normally requires oxygen. Organisms get this vital gas from the air or water around them. We call this process **breathing**. For example, in man air is sucked into a pair of lungs (Figure 5). In fishes water flows over the surface of gills. As well as taking up oxygen into the body, lungs and gills get rid of carbon dioxide.

Not all organisms have lungs or gills. Some just let oxygen 'seep' into the body across the surface. This is called diffusion. It's a slow process, but it's good enough for small or inactive organisms which don't need much energy.

Many animals are able to carry oxygen quickly round the body. In man this job is done by the **blood system**: the blood is pumped by the heart through a system of blood vessels. The blood system is also used for transporting dissolved food substances.

Figure 5 An athlete breathing heavily after a race. His muscles have done a lot of work and they need plenty of oxygen.

Living things get rid of poisonous waste

In many ways an organism is like a chemical factory. Substances are constantly being broken down to produce energy, or built up to make structures, such as bones and muscles.

Some of the by-products of metabolism are poisonous. They must not be allowed to pile up in the body, or they will kill the organism. So the body must get rid of them. This is called **excretion**.

In animals one of the most poisonous waste substances is **ammonia**. Ammonia contains nitrogen. It is so poisonous that most animals quickly turn it into a less poisonous substance. This is then expelled from the body, along with water in the form of a liquid called **urine**.

Plants get rid of waste substances in a different way. They turn them into harmless crystals which they store within their bodies out of harm's way.