Classification

Unit 5

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5.1 Principles of classification

By the end of this section you should be able to:

- Explain the need for classification.
- Define species as a group of individuals able to breed successfully with one another.
- Describe the system of binomial nomenclature developed by Linnaeus.
- Explain how organisms are given scientific names.
- Write scientific names properly and give examples.
- Classify some common plants and animals, including humans, using their scientific names.

On Earth today there are many types of living things. This great variety of life is called diversity or biodiversity.

To help us understand the great diversity of living things we put them into groups. This grouping of similar living things is known as classification.

Biologists classify living things for the following reasons:

1. To simplify their study.
2. To bring order out of chaos or confusion.
3. To try to understand how life originated.

Figure 5.1 *In countries like Ethiopia alone, the number of living organisms is enormous. A system of classification is important to help us understand the different types of living things there are.*

What is a species?

Classifying living organisms is central to understanding the variety of life on Earth. Scientists group organisms together in different ways, as you will see shortly. But the most important unit of classification is the **species**. Species are defined in many different ways, but the most common and widely used definition of a species is: *A group of organisms that can breed successfully with one another to produce fertile offspring*. So, for example, horses and donkeys look similar, but the offspring produced from a horse and a donkey is a mule, which is sterile. So horses and donkeys are not the same species. But the offspring produced between a Borena and a British Friesian will be fertile – the different cattle breeds are variants of the same species.

In the 21st century scientists make decisions about which organisms belong in the same species in a number of ways.

How are living things classified?

Living things are classified according to how similar they are. We use similarities on or in their bodies to group them. One example is animals that are put in a group together because their limbs are built on the same basic plan. The limbs of a bat, horse, bird, human and whale all have the same basic pattern though they are used in different ways.

The front limbs of a bat are adapted as wings and used for flying and climbing, whereas the limbs of a horse are used for galloping. The front limbs of a bird are also used for flying, whereas human front limbs are for using tools. In a whale, the front limbs are used for swimming. Each of these animals looks very different – yet if we look at their skeletons the bones in their front limbs are all recognisably the same. These limbs are called homologous structures. They have the **pentadactyl** limb pattern or five-digit plan and this has been very useful both for classifying the organisms and for tracing back their ancestors through ancient history.

Many other features, from the numbers of hairs on the leg of an insect to the numbers of petals on the flower of a plant or the chemistry of the blood are also used for classification. These are known as the characteristics of the organism. Classification began centuries ago with the careful observations of scientists and anyone interested in natural history. Now, in the 21st century, we use technology to allow us to look at the genetic make-up of living organisms so that we can be sure that they are related to each other – or not!

KEY WORDS

species *a group of organisms that can breed successfully with one another to produce fertile offspring*

pentadactyl *having five fingers or toes*

Originally scientists just looked closely at the outer (and sometimes inner) appearance or **morphology** of the organism. Classification was based on the degree of difference or similarity in the way they looked. Different features – for example, the number of hairs on the leg of an insect, the arrangement of fins and scales on a fish – were used to group them into species, genus and so on. In many cases you can tell just by looking at an organism what it is – you would never mistake a lion for a cheetah, for example. However, the appearance of an organism can be affected by many different things, and there can be a huge amount of variation within a group of closely related organisms.

Today there are more sophisticated ways of comparing organisms. The fundamental chemicals of life – such as DNA, RNA and proteins – are found in almost all organisms. However, while these chemicals are broadly similar across all species, we can find differences when the molecules are broken down to their constituent parts. Sometimes scientists use these differences to decide which species an organism belongs to.

Figure 5.2 *British Friesian (top) and Borena cattle do not look very similar – but they are the same species and will produce fertile offspring.*

The classification system

The process of classifying living organisms is known as **taxonomy**, and the system we use groups living things into categories called **taxa**. The main taxonomic categories are kingdom, phylum (or for plants, division), class, order, family, genus and species.

The largest groups into which living organisms are divided are the kingdoms. Kingdoms are subdivided into phyla, each phylum into classes, each class into orders, each order into families, each family into genera and each genus into species. The species is the smallest unit of classification. There will be many different types of organisms in a phylum, all of which have a few characteristics in common. There will be far fewer organisms in a genus – but they will all have a lot of features in common. A species only contains one type of organism, which have all their main features in common!

KEY WORDS

morphology *appearance of an organism*

taxonomy *process of classifying living organisms*

taxa *category in classification*

Naming living things

The many varieties of living organisms means there are even more names! People in different areas of Africa speak many different languages. In Ethiopia alone we have 85 living languages – and at least 11 of those have over a million native speakers! And many of us speak more than one language, often including English! All of the different languages will have different names for the same animal or plant. For example, the Ethiopian wolf is also known as the Abyssinian wolf, Simien fox, Ethiopian jackal, red jackal and Simien jackal in English, as *Qey kebero* in Amharic and *jedala dima* in Afan Oromo and *Keyih Wukaria* in Tigrigna. It is also named differently in different other Ethiopian languages. Around the world you also have to add languages such as English, French, Russian and Chinese into the mixture. It becomes impossible for one scientist to know what organism another scientist is talking about!

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The problem is solved because every organism that is classified is given a scientific name.

Taxonomy began with the work of Aristotle, a philosopher who lived in Ancient Greece from 384–322 BC. He tried to create a classification system for the living world, and grouped animals by similarities such as 'animals that live on land' and 'animals that live in water'. He thought that some animals were higher up the order of nature than others, with human beings at the very top. He even tried to give everything a scientific name with two parts to it – he called humans 'rational animals'. However, his system was never finished.

Taxonomy became a serious science with the work of Carl Linnaeus in the 18th century. Linnaeus loved to collect plants. He qualified as a doctor, but then went back to study plants. He developed the binomial system of nomenclature for organisms, which he published in a book called *The System of Nature*. He suggested a way of organising living organisms from the kingdoms downwards, with a binomial system of naming them that is still used today. **Binomial** means two names. The two names of an organism are in Latin. Even in the time of Linnaeus, Latin was no longer spoken anywhere in the world. However, it was the language of scholars everywhere. This meant no one was offended because their language was not chosen to identify animals and plants – yet most people could understand the names. So, for example, the wolf with so many names in Ethiopia is known to all scientists as *Canis simensis* – so no one gets confused.

KEY WORD

binomial *having two names*

Simple rules for writing scientific names

1. The first name is the name of the genus to which the organism belongs. It is written with a capital letter. Sometimes the name of the genus is reduced to just the capital letter, e.g. *H. sapiens*, *C. simensis*.
2. The second name is the name of a species to which the organism belongs. It is written with a small letter.
3. The two names are underlined when handwritten or in italics when printed.

Table 5.1 *Examples of scientific names of some common organisms*

Common name	Scientific name
Human beings	*Homo sapiens*
A dog	*Canis familiaris*
A housefly	*Musca domestica*
Domestic cat	*Felis domesticus*
Maize	*Zea mays*
Bean	*Phaseolus vulgaris*
Lion	*Panthera leo*

To summarise, living things are classified and named for the following main reasons:

1. To create an internationally accepted way of referring to a particular living thing.
2. To avoid confusion created by different languages.
3. To help in simplifying classification and study of living things.

The names we use for organisms are their binomial names – but to reach those names, the organism needs to be completely classified from the kingdom downwards. Here are some examples:

Table 5.2 *Hierarchy of groups*

	Human	**Honeybee**	**Teff**	**Mushroom**
Kingdom	Animalia	Animalia	Plantae	Fungi
Phylum	Chordata	Arthropoda	Angiospermophyta	Basidiomycot
Class	Mammalia	Insecta	Liliopsida	Basidiomycetes
Order	Primates	Hymenoptera	Cyperales	Agaricales
Family	Hominidae	Apidae	Poaceae	Agaricaceae
Genus	Homo	Apis	Eragrostis	Agaris
Species	sapiens	mellifera	teff	campestris

Classifying living organisms

You may have come across organisms that you did not recognise and could not classify. How did you solve this problem? You may have used their common names or searched for their pictures in books. As you have seen, we classify living organisms by looking at the things that are similar between them, and also the things that are different. When you find a strange organism, how do you know which group it fits into?

In this section of the book, you are going to learn how to put organisms into groups and how to use – and build up – a classification key.

To make it as easy as possible to sort organisms out – particularly when you are out in the field – biologists have developed a special method known as a biological key or identification key.

The simplest type of identification key is the **dichotomous key** (*di* means two and *chotomous* means branching). Therefore, a dichotomous key is a type of key that is based on making successive choices between two statements or alternatives.

The statements are descriptions of the external features of specimens. In this section you are going to look at how dichotomous keys are constructed and how they are used to identify unknown specimens. The easiest way to understand how these keys work is to use one that is very straightforward.

KEY WORDS

dichotomous key *a type of key based on making choices between two statements or alternatives*

The example you have here involves some very well-known living organisms to help you understand the process.

As you use these keys, you can see how important it is to have the right questions. You must be able to answer 'Yes' or 'No' to the questions, and the questions asked must separate and identify the animals clearly. For example, in the key below, it is the fact that the cheetah has patterned fur that is not striped that is important – you don't need to ask if it has spots!

Activity 5.1 Identifying organisms using a simple key

In figure 5.3 you can see five big cats. Even if you know the names of these animals, use the keys to identify them fully and write down the correct identification. Add the names in your own language as well!

1. Animal with patterned fur: go to 2.
   Animal with plain fur: go to 3.
2. Animal with stripes: *Panthera tigris* (tiger).
   Animal without stripes: go to 4.
3. Animal is black: *Panthera onca* (black panther).
   Animal is not black: *Panthera Leo* (Lion).
4. Animal has a very short tail: *Lynx lynx* (lynx).
   Animal does not have a very short tail: *Acinonyx jubatus* (cheetah).

Figure 5.3 *Identification using a simple key*

Activity 5.2: Using classification keys to identify common organisms

Materials

Collect five different organisms locally – these might be plant leaves, such as sweet potato, teff, rose, cassava or maize, and some animals, such as a grasshopper or spider. Make a classification key to identify these organisms as accurately as you can. You may need a hand lens to help you look for small features.

Summary

In this section you have learnt that:

- Scientists classify organisms to make the living world easier to understand.
- A species is a group of living organisms that are able to breed successfully with one another and produce fertile offspring.
- Taxonomy involves dividing living organisms into smaller and smaller groups based on features they have in common.
- The binomial system of nomenclature was developed by Carl Linnaeus.
- You can classify living organisms using simple keys.

Review questions

Select the correct answer from A to D.

1. Which of these statements is not a reason why biologists classify the living world?
   A to simplify their study
   B to bring order out of chaos or confusion
   C to try to understand how life originated
   D to make things sound complicated
2. Which of the following great biologists developed the system of naming organisms that we use today?
   A Aklilu Lemma
   B Charles Darwin
   C Carl Linnaeus
   D Tilahun Yilma
3. *Homo sapiens* is the scientific name of which animal?
   A honey bee
   B human being
   C teff
   D lion

KEY WORDS

prokaryotic cells *single-celled organisms without a separate nucleus*

eukaryotic cells *single-celled organisms with a nucleus*

dinoflagellates *microscopic single-celled organisms that cause bioluminescence in the sea when they produce a green light*

5.2 The five kingdoms

By the end of this section you should be able to:

- Explain the five-kingdom classification system.
- Describe the kingdoms of the Monera, Protista and Fungi and give examples of organisms from each one.
- Describe the kingdom Plantae and explain its major divisions, giving examples.
- Classify angiospermes into monocots and dicots and explain the differences between them.
- Describe the kingdom Animalia and explain its major phyla, giving examples.
- Group animals into vertebrates and invertebrates and explain the differences between them.
- Classify the vertebrates into five classes and give examples of each.

As you learnt in section 5.1, the system that scientists use for classifying living things is known as the natural classification system. Living things are put into groups called taxa based on their similarities and differences. The main taxa are kingdom, phylum (division for plants), class, order, family, genus and species. You are going to look at some of these taxonomic groups in more detail and learn the main characteristics of our classification system.

What is a kingdom?

A kingdom is the largest taxon and consists of all the other taxa. In the modern classification, there are five kingdoms namely:

1. Monera (bacteria)
2. Protista (also known as the protoctista)
3. Fungi
4. Plantae
5. Animalia

This system of classification is known as the five-kingdom system. For several centuries scientists worked with a two-kingdom classification (Animalia and Plantae) and a three-kingdom classification (animals, plants and others). There were always a lot of problems with classifying organisms such as bacteria, *Euglena* and fungi. As biologists have discovered more and more organisms, and understand much more about the internal structures of their cells, most of them agree that a classification system with five kingdoms makes the most sense.

Viruses are not classified in any of the above kingdoms. They are grouped separately, as you will see. This is because viruses do not have all the seven characteristics of life, although most scientists now classify them as living organisms.

Kingdom Monera

The Monera include all of the bacteria, as well as the blue-green algae. The members of the kingdom are all single-celled organisms that do not have a separate nucleus (they are **prokaryotic**). They are all microscopic and they reproduce by simply splitting in two. Some of them can make their own food by photosynthesis, but many of them are heterotrophic – they rely on other organisms to provide their food.

Examples include *Mycobacterium tuberculosis*, the bacterium that causes tuberculosis, and *Haemophilus ducreyi*, the bacterium that causes chancroid, as well as all the other bacteria that act as pathogens. Bacteria that do good include those in the soil and in your gut, and those which are involved in the carbon and the nitrogen cycle and in all the processes of decay.

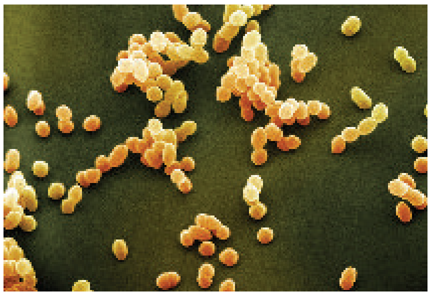

Figure 5.4 *Colour-enhanced scanning electron micrograph of* Staphylococcus aureus. *These are bacteria commonly carried on the skin or in the nose of healthy people and one of the most common causes of skin infections.*

Kingdom Protista

The protista are all microscopic single-celled organisms that do have a nucleus – they are **eukaryotic cells**. They can be quite complex in their shapes. They include plant-like organisms that can move around and animal-like organisms that cannot move. Protista make up much of the plankton found in the oceans and are the basis of the food supply for all the organisms in the sea. Some protista cause serious disease in human beings.

Examples of harmful protista include *Plasmodium falciparum*, which causes malaria, *Entamoeba histolyca*, which causes amoebic dysentery, and *Trypanosoma*, the blood parasite that causes sleeping sickness. **Dinoflagellates** are protista that cause bioluminescence in the seas and oceans when they produce a greenish light.

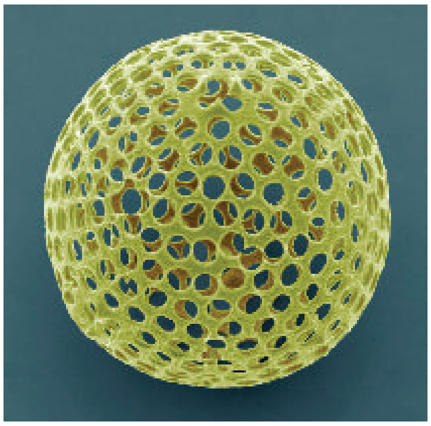

Figure 5.5 *Protista like this radiolarian have complex silica shells and are part of the plankton in the oceans.*

Activity 5.3: Looking at protista under the microscope

You will need:

- microscope
- prepared slides of protista or
- pond water
- microscope slides
- cover slips

Method

Use your microscope with care, as you learnt in unit 2.

Either use prepared slides to look at different protista and draw them, or make a slide from a drop of pond water and look for protista such as amoeba moving about.

Activity 5.4: Looking at fungi

You are going to look at and draw several different types of fungus. Some of them may be quite big, but you may want to use a microscope to look at some of them. If necessary you can grow your own fungi on a little damp injera or by letting a piece of fruit go rotten. You can collect lichen from the trees to examine and draw as well.

KEY WORDS

saprotrophs *organisms that feed off dead material*

mutualists *organisms that live in close association with each other and both benefit from this association*

mycorrhizae *organic association between a fungus and the roots of a plant*

bryophyta *plant division consisting of mosses and liverworts*

liverworts *small, green nonvascular plant growing in wet places*

Figure 5.6 *Fungi are very important – they do a lot of good but can also cause harm.*

Kingdom Fungi

For many years the fungi were classified as a sort of plant. However, fungi cannot make food by photosynthesis so they do not really fit in the plant kingdom. Now the great differences between fungi and true plants are recognised, the fungi have a kingdom of their own. The fungi are a large and very successful group – there are around 80 000 species. They vary in size from single-celled yeasts to enormous puffballs.

Fungi are eukaryotic and usually multicellular. They are heterotrophic, either absorbing nutrients directly from their food or secreting enzymes to digest their food outside the fungus and then absorbing the nutrients. Many fungi are **saprotrophs**, which means they feed on dead material. Saprophytic fungi usually produce huge numbers of spores, which float on the wind to other dead material. They play a vital role within ecosystems as decomposers. Examples of this type of fungus are *Rhizopus* (bread mould), *Mucor* and *Penicillium* (the fungus that produces the antibiotic penicillin).

Fungi can be parasites, feeding on living organisms. They attack plants more than animals, although some fungi, such as *Candida albicans* (thrush) and *Tinea pedis* (athlete's foot) affect people and other animals. Fungal parasites such as the mildews cause enormous damage to plants. Some fungi are **mutualists**. This means they live in close association with another organism and both benefit. Examples are lichens, which are a combination of a fungus and green algae or blue-green bacteria, and **mycorrhizae**, an association between a fungus and the roots of a plant. Yeast, which makes injera rise and allows us to make alcohol, is one of the few single-celled fungi.

Activity 5.5: The first three kingdoms

Develop a table that simplifies and summarises the first three kingdoms as follows. Copy the example shown here and fill it in.

Kingdom	Characteristics	Examples
Monera		
Protista		
Fungi		

Kingdom Plantae

The kingdom Plantae – the plants – includes a great variety of organisms, which range from tiny mosses to giant trees. So far botanists have identified around 300 000 living plant species, and over 80% of these are flowering plants.

Plants are enormously important – they are the source of the fossil fuel coal and through photosynthesis they provide food and oxygen for all other living organisms. We human beings use plants to provide us with food, building materials, clothing, medicines and many other things.

The main characteristics of all plants include:

- They have eukaryotic cells.
- They are multicellular organisms.
- They contain chlorophyll and carry out photosynthesis.
- They are predominantly land dwelling.
- Most have a waxy cuticle that helps to prevent drying out.

The kingdom Plantae consists of non-flowering plants and flowering plants. The kingdom is split into a number of divisions. Plant divisions are the same as animal phyla. The four most important divisions are:

Bryophyta – the **mosses** and **liverworts**

Pteridophyta (also known as the Filicinophyta) – the **ferns**

Gymnospermae (also known as the Coniferophyta) – the **conifers**

Angiospermae (also known as the Angiospermophyta) – the true flowering plants

Division Bryophyta (mosses and liverworts)

Bryophytes are the simplest land plants. They do not have a true root system so they cannot reach water under the soil or anchor themselves very firmly to the ground. They are non-vascular (do not have xylem and phloem) and so cannot transport food or water around the body of the plant. They are small – the largest species is less than 60 cm tall – and are found in damp places. A large percentage of bryophytes live in tropical rainforests.

The best examples of bryophytes are mosses like *Etodon concinnus*, found in the Bale Mountains, and *Funaria* spp. A moss plant has a simple, slender stem. They also have thin simple leaves, which are only one cell thick (and therefore useful for looking at under a microscope). Mosses also have simple root-like structures called **rhizoids** that have slender filaments and attach the mosses to the soil but without any strength. The other example is the liverworts, which only grow in very wet places. Bryophytes are commonly found in rainforests and at high altitudes on mountains.

KEY WORDS

mosses *nonvascular plants with a single stem and leaves of only one cell thickness*

pteridophyta *plant division consisting of ferns*

ferns *plants of damp shady places*

gymnospermae *plant division of conifers*

conifers *evergreen plants with needle-shaped leaves whose reproductive structures are found in cones*

angiospermae *true flowering plants*

rhizoids *simple root-like structure of mosses*

Figure 5.7 *Our forests have an amazing variety of plant life.*

Figure 5.8 *Mosses like this can be found in damp places in Ethiopia.*

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Activity 5.6: Looking at mosses

You will need:

- mosses, e.g. *Funaria*
- microscope
- hand lens
- scalpel blade
- forceps
- microscope slide and cover slip

Method

1. In groups, search around the school for moss plants around damp walls, rocks, tree bark or damp verandas. Carry your collected specimen into the laboratory for detailed study.
2. With the help of a hand lens, examine the specimen carefully and identify the parts.
3. Draw and label your specimen.
4. Carefully detach one leaf from the moss plant and mount on a clean glass slide. Examine under low power and observe the arrangement of the cells.
5. Mount the rhizoids on a slide and view under low power and observe the arrangement of the cells.
6. Using forceps or a needle, remove a capsule if you can see one, mount it on a slide and view under low power. Draw what you see.
   - What does a capsule contain?
   - In what respects is a moss plant more complex than an alga or fungus?

Figure 5.9 *Ferns can transport water and food around their bodies, which means they can grow in a much wider range of places than mosses can, but many of them still prefer damp and shade.*

Division Pteridophyta

In this division the plants have true leaves, stems and roots. Fern stems have **rhizomes**, which grow horizontally just below the surface of the soil. Their stems contain vascular tissue similar to that found in flowering plants, and so do their roots. They produce spore-forming bodies on the underside of the fronds. The spores are dispersed by wind. However, they still rely on water for reproduction, which limits where they can live.

Most ferns live in damp, shady places – they are very common in tropical rainforests where conditions are ideal for their growth. However, some ferns – such as *Pteridium* spp (commonly known as bracken) – are an exception because they can grow and do well in full sunlight.

Another example of a pteridophyte is the fern *Dryopteris* spp. There are a number of different *Dryopteris* ferns in Ethiopia, and *Dryopteris concolor* is a recently discovered one.

The next two divisions of the plants that you are going to look at are the seed-bearing plants or **spermatophytes**. These are the most successful of all land plants. They form the most common plants on earth. Spermatophytes are the most successful because of the following characteristic features that they possess:

- They have well-developed roots, stem and leaves.
- They have well-developed vascular tissues.
- The male gametes are contained within pollen grains and the female gamete is contained within the embryo sac.

Activity 5.7: Examining a fern

You will need:

- a common fern
- hand lens
- scalpel
- clean slide
- cover slip
- microscope

Method

1. In groups, search for a fern along rivers/stream banks, shady areas beneath trees and fences.
2. Examine your specimens and identify as many structures as you can.
3. Draw and label your specimen.
4. Observe the lower surface of the leaves (fronds).
5. Draw the lower surface of the specimen showing the arrangement of the spore-forming bodies (sori) if there are any there.
6. Use a scalpel to transfer some of the sori onto a slide and examine them under low power and draw.

- The product of fertilisation in sexual reproduction is a seed that may or may not be enclosed in a fruit.

The spermatophyta are divided into two divisions, namely, gymnospermae and angiospermae.

KEY WORDS

rhizome *root which grows horizontally just below the surface of the soil*

spermatophytes *seed-bearing plants*

Division Gymnospermae

These are more commonly known as the conifers or 'naked seed plants'. Pine trees, spruces and cedars are just some of the more common conifers. They grow around the world – about one third of the world's forests are coniferous – and are often cultivated for timber as some of them are relatively fast growing. They are usually the dominant vegetation in cold and mountainous regions. Some conifers have developed relatively fleshy tissue around their seeds (e.g. juniper and yew), but the majority produce bare cones. The main characteristics of the gymnospermae are:

- Their seeds are not enclosed in fruits.
- They have small needle-shaped leaves with a thick waxy cuticle that reduces water loss and minimises damage by excess heat or cold.
- They are evergreen so they can photosynthesize all year long.
- The reproductive structures are found in cones.

Figure 5.10 *Gymnosperms have very typical leaves and cones with naked, exposed seeds.*

A conifer tree produces two different types of cone. The male cone forms huge numbers of pollen grains that are blown by wind to a female cone. Fertilisation results in a small winged seed.

The genus *Pinus* (for example, *Pinus sylvestris*, *Pinus resinosa*, *Pinus radiata*) is a good example of a conifer. Members of this genus grow all around the world. They are evergreen – they maintain their leaves throughout the year, even in temperate climates. This means they shed and replace a few leaves all the time rather than spending part of the year leafless and dormant.

Activity 5.8: Examining conifers

You will need:

- conifer leaves and cones

Method

1. Obtain some conifer leaves and cones.
2. Observe them carefully.
3. Make large well-labelled drawings of the leaves of the conifer.
4. Examine some conifer cones. Note the seeds attached to the cone. Carefully remove one seed from the cone of the conifer and draw it.

Conifers have been imported and planted in East Africa because of their importance as a source of timber and for ornamental purposes. Look for some conifers around homes, schools, hotel compounds and other places where trees are commonly found.

Division Angiospermae

The flowering plants are the biggest group of land plants on the Earth. Their reproductive structures are carried in flowers. The biggest flowers in the world belong to *Rafflesia arnoldii* and they can be as much as a metre across. The smallest belong to *Wolffia globosa* and they are less than 2 mm across. Whatever the size of the flowers, they carry the reproductive parts of the plant. The main characteristics of the angiosperms are:

- They have flowers as reproductive organs.
- They have their seeds enclosed in a fruit.
- They have well-developed **xylem** and **phloem** tissue.

Subdivisions of angiosperms

Angiosperms are subdivided into two main classes according to the number of cotyledons they have in their seeds. These classes are **monocotyledons** and **dicotyledons**.

Class Monocotyledons (monocots)

The monocotyledons (monocots) are a group of enormous importance because the cereal plants that form the staple diet of most of the world's population are monocotyledons. So are the grasses that feed domestic herbivores, which supply so many cultures with meat and milk. The grasses also feed many of the large wild herbivores such as zebra, wildebeest and the many different types of antelope that live in Ethiopia and beyond. The main characteristics of the monocotyledons are:

- The embryo has a single seed leaf (cotyledon).
- Leaves are generally long and thin with parallel veins.
- The stem contains scattered vascular bundles.
- In general, monocots do not reach great sizes (palms are the exception to this).
- They are often wind pollinated.

Common examples of monocot plants include the grasses, orchids and maize. Maize (*Zea mays*) has been used for food and animal fodder by people for centuries. Teff is another example of a monocotyledonous plant.

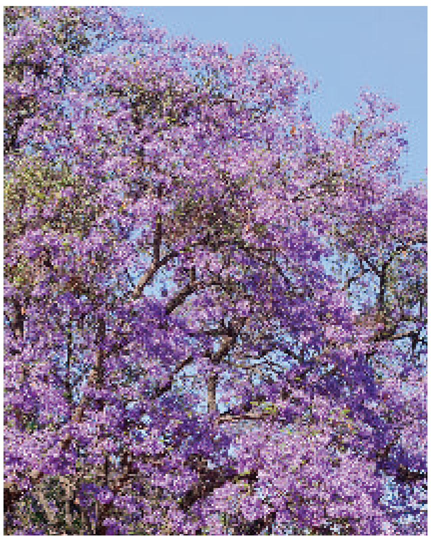

Figure 5.11 *Flowering plants are all around us. They are the most successful plants.*

KEY WORDS

xylem *dead transport tissue in plants, moving water and minerals*

phloem *living transport tissue in plants that transports food around*

Class Dicotyledons (dicots)

The dicotyledoneae (dicots) make up most of the trees with which we are familiar, as well as many vegetable plants in our gardens and almost all of the coloured flowering plants in the world. The main characteristics of the dicotyledons are:

- The embryo has two seed leaves (cotyledons).
- The leaves are often relatively broad and have a network of veins.
- The stem contains a ring of vascular tissue.
- Some dicots reach great sizes.
- They are often insect pollinated.

Some common examples of dicots include sunflowers, peas, roses and beans. Most trees, such as *Jacaranda*, *Eucalyptus*, *Cassia* and mangos are dicotyledons. Shrubs include *Hibiscus*, *Lantana camara*, *Bauhinia* and oranges.

Figure 5.12 *Close-up of a chard leaf, showing the network of veins.*

Activity 5.9: Examining a dicotyledonous plant and a monocotyledonous plant

You will need:

- bean plant with flowers and bean seed
- maize plant with flowers and maize grain (or any other specimens available in the locality)
- hand lens

Method

1. Obtain a bean plant and a maize plant (or any other specimens available in the locality).
2. Compare their roots, stems, leaves, flowers and seeds.
3. Make a table of differences between the bean plant and the maize plant.
4. Draw well-labelled diagrams of the bean plant and the maize plant.
5. Make a collection of plants around your school. Identify them and then classify them according to whether they are monocotyledons or dicotyledons.

Activity 5.10: From bryophytes to angiosperms

Develop a table that simplifies and summarises the divisions from mosses to flowering plants as follows. Copy the example shown here and fill it in.

Division	Characteristics	Examples
Bryophyta		
Pteridophyta		
Gymnospermae		
Angiospermae (including monocots and dicots)		

KEY WORDS

monocotyledons *any flowering plant having a single cotyledon (leaf) in the seeds*

dicotyledons *flowering plants with two embryonic seed leaves*

Kingdom Animalia

This kingdom includes the animals. There are at least two million species of animals alive today. Animals are multicellular and heterotrophic – they feed on other organisms. They differ from the members of the other four kingdoms in that they exhibit locomotion, that is, can move their bodies from one place to another, and their cells do not have cell walls. They have nervous systems so they are sensitive to their surroundings. There are 33 animal phyla, but here we shall only consider the main ones.

- **Porifera** (sponges)
- **Coelenterata** (cidaria)
- **Platyhelminthes** (flatworms)
- **Nematoda** (roundworms or nemathelminthes)
- **Annelida** (segmented worms)
- **Mollusca** (soft-bodied animals)
- **Echinodermata** (spiny-skinned animals)
- **Arthropoda** (joint-footed animals)
- **Chordata**

The first eight phyla are also called invertebrates. This means they do not have a backbone. The phylum Chordata includes the vertebrates – all the animals which have a spinal cord enclosed in a backbone of vertebrae. We shall consider the main features of each of these phyla.

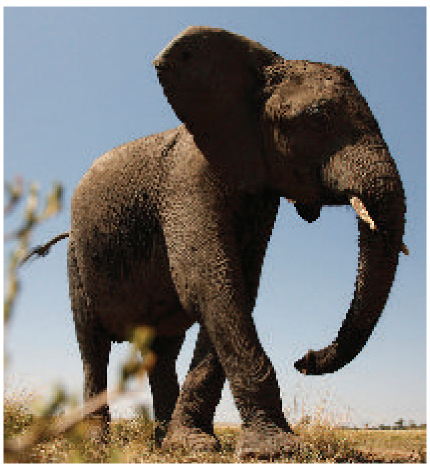

Figure 5.13 *Animals come in many different shapes and forms but they are all multicellular heterotrophs.*

Figure 5.14 *Sponges do not look much like animals, but that is what they are.*

Phylum Porifera – the sponges

The sponges are the simplest invertebrates. Only the young move about – the adults are permanently attached to a surface on the sea bed. They are hollow filter feeders, and the body cavity is connected to its external environment by pores. There is little co-ordination or control. They range in size from a few millimetres to two metres and are supported by a series of calcareous spicules. As far as is known, the sponges are an evolutionary dead end and have no other close living relatives.

Phylum Coelenterata

The coelenterates include some exceptionally beautiful creatures and also some very poisonous ones. Sea anemones, hydra, jelly fish and coral are among the members of this phylum. They have soft bodies with a ring of tentacles for capturing prey. They have stinging cells on their tentacles for poisoning or immobilising prey and predators. Coelenterates have two layers of cells in their bodies that surround a central cavity. They have only one opening, the mouth, and their bodies have radial symmetry.

Figure 5.15 *Coelenterates range from tiny coral polyps and hydra to enormous jelly fish.*

Phylum Platyhelminthes – flatworms

The flatworms show a relatively high level of organisation. They range from 1 mm to 30 cm in length. They possess a front end where the mouth, major sense organs and the main integrating region of the nervous system is sited. They have flattened bodies with a mouth but no anus. They have no body cavity and rely on diffusion for everything. They are hermaphrodites – they contain both male and female sex organs. They live in other animals as parasites or are free-living in fresh water.

Examples of platyhelminthes include *Planaria* spp, which live in fresh water, tapeworms and liver flukes like *Fasciola hepatica*.

Figure 5.16 *Like* Taenia, *which you met in unit 4, the liver fluke* Fasciola hepatica *can cause problems both for livestock and humans.*

Activity 5.11: Looking at porifera, coelenterata and platyhelminthes

You will need:

- preserved or fresh specimens of porifera, coelenterata and platyhelminthes
- hand lens

Method

Observe, draw and label specimens of these invertebrate phyla.

Phylum Nematoda (nemathelminthes) – roundworms

Roundworms are thought to be the most numerous animals in the world. It has been estimated that there are around 5 billion roundworms in the top 7 cm of an acre of soil. They are found in almost all environments, from the deepest ocean floor to the Antarctic! Nematodes have narrow, thread-like bodies, which are pointed at both ends and bilaterally symmetrical. Their bodies are not segmented and are round in cross-section, which is how they get their name. They don't have a circulatory system but they do have a complete digestive system with both mouth and anus.

The phylum contains many important parasites, such as *Ascaris*, which infects the guts of both humans and pigs, and the family Filariidae, which cause elephantiasis affecting the lives of up to 1.2 billion people in Africa and Asia. Nematodes are also a very important part of a healthy soil.

Activity 5.12: Looking at nematodes

You will need:

- sample of moist soil or water from the bottom of a pond
- hand lens

Method

Observe and then measure, if possible, draw and label specimens of nematode worms.

Figure 5.17 *Nematodes or roundworms are vital for healthy habitats, yet they cause diseases of many plants and animals as well.*

KEY WORDS

chaetae *bristle-like structures that help segmented worms to move*

tube feet *used by echinoderms to move around*

Figure 5.18 *Earthworms are one of the best-known examples of the annelid worms all over the world.*

Activity 5.13: Looking at annelida

You will need:

- sample of moist soil or compost from a compost heap
- hand lens

Method

Observe and then measure, if possible, draw and label specimens of annelid worms.

Figure 5.19 *Molluscs are a very varied group of animals. This giant East African land snail carries its protective shell on its back.*

Phylum Annelida

The annelid or segmented worms have a body divided into regular segments with structures and organs repeated along the body. They have a closed blood circulatory system. They are hermaphrodites, with male and female reproductive organs and they have bristle-like structures called **chaetae** to help them move. They are found in moist soil and water and most are free-living. The common earthworm, *Lumbricus terrestris*, is a good example. Earthworms are very important because they increase the fertility of the soil. *Hirudo* spp, the medicinal leech, is another example of an annelid worm.

Phylum Mollusca

The molluscs have a wide range of lifestyles and include the most intelligent of the invertebrate species. Octopi and squid have well-developed brains. They may have shells or be shell-less, live in the sea, or in fresh water or on land. The main features of the molluscs include a soft muscular foot with a soft body, which is often protected by the shell. Their bodies are divided into head, foot and visceral mass and they are not segmented. They breathe through gills. Examples of molluscs include slugs and snails like the giant East African land snail (*Achatina fulica*), bivalves like *Mytilis* spp, the marine mussel and octopuses and squids.

Activity 5.14: Looking at mollusca

You will need:

- molluscs, e.g. *Achatina fulica*, any other local slug or snail
- hand lens
- glass beaker

Method

Observe and then measure, if possible, draw and label specimens of molluscs.

Observe carefully how the animal moves. Putting it in a glass beaker allows you to see the underneath of the muscular foot and watch the waves of muscle contraction as it moves along.

Phylum Echinodermata

The sea urchins, starfish and brittle stars make up this phylum of invertebrates. The skin contains many spines. Although they appear very simple they have a mouth (on the lower side), a gut and an anus (on the upper side). They are all marine animals, and move around using **tube feet**. The adults have five arms, but the larval stages do not. Examples include *Asteris*, the common starfish, *Echinus*, the common sea urchin and *Paracucumana tricolor*, a brightly coloured sea cucumber known as a sea apple.

Phylum Arthropoda

This phylum gets its name from two Greek words, *arthron* – joint, and *podos* – foot. The arthropods are the most varied animals on the Earth, with around a million different species. They have made use of a wide range of available ecological niches. However, they cannot grow very large. They have an external exoskeleton made of chitin that prevents excessive water loss but also limits their growth. Arthropods are animals with segmented bodies and jointed limbs. They have a well-developed nervous system and a complete gut from the mouth to anus.

The phylum Arthropoda is divided into a number of classes according to the number of limbs, presence and number of antennae and number of body parts. These include **insecta**, **crustacea**, **arachnida**, **diplopoda** and **chilopoda**.

The insecta live almost everywhere, although most are land-based. They have a body divided into three body parts; head, thorax and abdomen. They have three pairs of jointed legs on the thorax along with one or two pairs of wings. On their head they have a pair of antennae and one pair of compound eyes. Insects include flies, butterflies and moths, beetles, wasps and bees and many other common groups.

The crustacea are mainly aquatic. They vary in size from very small, for example water fleas, to quite large, for example lobsters and crabs. The body is made up of two parts – a cephalothorax (head fused with thorax) and abdomen. The body is often protected by a tough covering called a carapace. They have more than four pairs of jointed legs, two pairs of antennae and simple eyes. In some members, the eyes are on stalks. Crustaceans include *Daphnia*, crab, prawn, shrimp, barnacle, water flea, lobsters, woodlice and crayfish.

The chilopoda – the centipedes – and the diplopoda – the millipedes – are often confused. In fact some scientists put them all in one group. They both have long bodies with many segments and lots of legs! Table 5.3 summarises the differences between them.

Table 5.3 *Differences between centipedes and millipedes*

Centipedes	Millipedes
Have flattened bodies	Cylindrical bodies
Have brightly coloured bodies	Dull-coloured bodies
Have few or less segments	Have more segments
Have one pair of limbs per segment	Have two pairs of limbs per segment
Carnivorous (feed on other animals)	Herbivorous
Have poisonous claws for paralysing their prey	Have claws for biting and chewing plant material

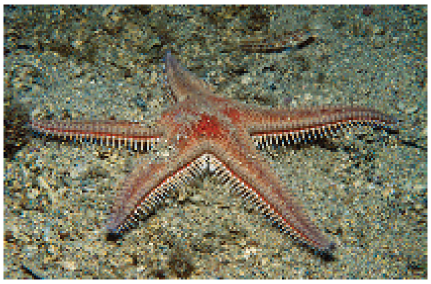

Figure 5.20 *Echinoderms are a relatively small specialised phylum of marine animals.*

KEY WORDS

insecta *insects*

crustacea *aquatic creatures with bodies made up of a cephalothorax and abdomen, four pairs of legs, two pairs of antennae and simple eyes*

arachnida *spiders*

diplopoda *millipedes*

chilopoda *centipedes*

Figure 5.21 *Insects are the best known of all the arthropods, and they come in many shapes and sizes.*

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The arachnida (the spiders) are mainly terrestrial although some are aquatic. They have two body parts – a cephalothorax (fused head and thorax) and the abdomen – with no antennae. They have eight legs in four pairs. Arachnids have simple eyes but often up to eight of them. Spiders spin silken webs. Examples of arachnids include spiders, ticks, scorpions and mites.

Activity 5.15: Collecting and examining arthropods

You will need:

- representative specimens of each class, e.g. grasshopper, crab, spider, a tick, a centipede, a millipede, in suitable containers
- a hand lens

Method

1. Obtain representatives of the class of arthropods. You may be given dead specimens or capture live ones. Treat living organisms with respect. You may need to use nets to catch some of the organisms. Make sure that they have access to air and do not get too hot while you have them in the lab.

   Take care handling any organisms which may sting or bite, or may carry disease.
2. What features do your specimens have in common?
3. Examine their characteristic features, i.e. number of limbs, presence and number of antennae and number of body parts, presence and number of wings.
4. Make a table of characteristic features like table 5.4.
5. Make large well-labelled drawings of each of your specimens.

***Table 5.4** Characteristic features of arthropods*

Specimen (examples have been filled in – use the actual examples you find)	**Number of body parts**	**Number of limbs**	**Antennae**	**Wings**
Grasshopper				
Crab				
Spider				
Centipede				
Millipede				

KEY WORD

notochord *flexible rod-like structure of cartilage running along the dorsal side of the body*

Phylum Chordata

The term chordata is derived from the term notochord. A **notochord** is a flexible rod-like structure, made of cartilage, which runs along the dorsal side of the body. It provides support to the body.

Animals in the phylum Chordata have the following three features in common:

- They have a notochord at some stage of their lifecycle.
- They have a hollow nerve cord, which is a group of nerves forming a hollow tube. This is located above the notochord.
- They have gill slits during early stages of development that are later replaced by lungs and gills.

Vertebrates

The invertebrates make up more than 99.9% of the animals alive on earth today. However, if you ask people to name ten animals, most of them would chose ten from the remaining 0.1% – the **chordates**, the best known of which are the **vertebrates**. As the name suggests, vertebrate animals have a vertebral column/backbone. In addition, they also have the following features:

1. An internal skeleton (endoskeleton) made of bone or cartilage.
2. A closed blood circulatory system consisting of blood vessels.
3. A well-developed nervous system.
4. Two pairs of limbs.
5. Kidneys as excretory organs.

Vertebrate animals form the largest group of the phylum Chordata and they are divided into five classes:

- Pisces – the fish
- Amphibia – the amphibians
- Reptilia – the reptiles
- Aves – the birds
- Mammalia – the mammals

KEY WORDS

chordates *creatures characterised by a notochord, nerve chord and gill slits*

vertebrates *creatures with a vertebral column/ backbone*

teleosts *bony fish*

elasmobranchs *cartilaginous fish*

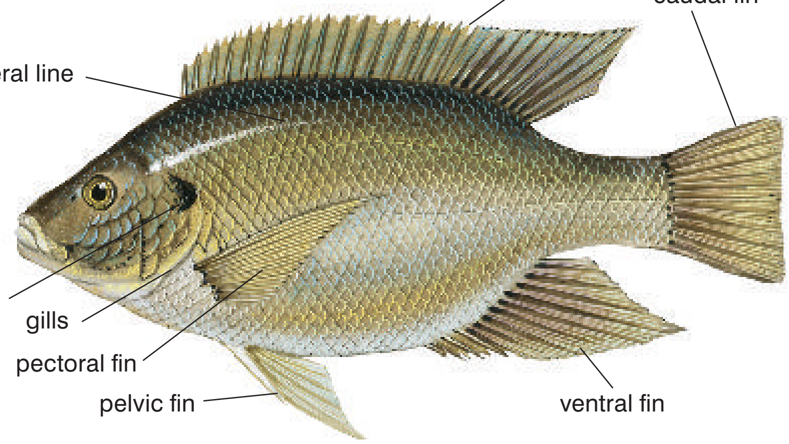

Figure 5.22 *An illustration of a typical bony fish*

Class Pisces

These are the fishes. They are aquatic, i.e. they live in water, except the mudskipper and lung fish, which can spend short periods breathing in air. They have streamlined bodies with scales on their skin. They use gills for gaseous exchange and have fins for swimming. They have a lateral line system for hearing and most fish are dark on the dorsal (back) side and lighter on the ventral side. Fish are ectothermic – they rely on heat from their environment to regulate their body temperature. Fish are important to people the world over as a source of food.

The class Pisces is divided into two subclasses:

- Bony fish (**teleosts**) – examples include *Tilapia*, Nile perch, cod, mackerel and catfish.
- Cartilaginous fish (**elasmobranchs**) – examples include sharks, skates and rays.

The main differences between the two groups are summarised in table 5.5.

Table 5.5 *Differences between bony fish and cartilaginous fish*

Bony fish	Cartilaginous fish
Have bony skeleton	Have cartilaginous skeleton
Have round-shaped scales	Have scales that are not round shaped
Have opercula (gill covers) covering their gills	Have no opercula (gill covers) but have gill slits
Have homocercal tails (even size fins)	Have heterocercal tails (one part is larger than the other)
Are usually smaller in size	Are usually larger in size

Activity 5.16: Examining a bony fish

You will need:

- freshly killed bony fish, e.g. *Tilapia*, Nile perch
- dissecting board
- dissecting kit

Method

1. In groups of five, examine the external features of the bony fish.
2. Using figure 5.22 as a guide, identify the following parts:

   dorsal fin, caudal fin, ventral fin, pectoral fin, pelvic fin, lateral line, scales, operculum
3. Make a large and well-labelled drawing of the bony fish as seen from the side. Label all the structures you have identified.

KEY WORD

amphibian *creatures who spend part of their lives in water and part of it on land*

Class Amphibia

This class includes the amphibians (frogs, toads, newts and salamanders). The word **amphibian** comes from two Greek words *amphi*, which means both, and *bios*, which means life. This means that amphibians spend part of their lives (as larvae or tadpoles) in water and part of it (as adults) on land.

The amphibians were the first vertebrates to colonise the land. They have simple sac-like lungs (which are not very efficient) and smooth, moist skin, which is also used as a respiratory surface. Their lifecycle includes metamorphosis, and they need water for successful reproduction as fertilisation is external and the larval form (tadpole) is aquatic. Gills are only present in the larval forms. Amphibians are ectothermic – they rely on heat from their environment to regulate their body temperature. Worldwide there are many concerns about the survival of the amphibian class, because a pathogenic fungus has emerged that is killing them in their millions, driving species to extinction particularly in the Americas and Australia. Combined with the loss of habitat that is also occurring and the pollution, which is becoming a problem all over the world, scientists are very worried about the future of amphibians. There is a genus of toads containing two species known as Ethiopian toads (*Altiphrynoides*), which are found mainly in the mountains in the south and centre of our country.

Figure 5.23 *The Ethiopian banana frog,* Afrixalus enseticola, *is tiny and, like many amphibians, vulnerable to extinction.*

Activity 5.17: Examining the external features of a frog or toad

You will need:

- a live or freshly killed toad or frog (The live toad/frog should be kept in a transparent container or cage.)
- a pair of forceps
- a pair of gloves

Method

1. Examine the head and trunk regions of the toad. Note and identify the following characteristic features:
   - Mouth – has a wide gape. With the help of forceps, open the mouth and note the long sticky tongue, which is used to capture insects, and homodont teeth, i.e. same-sized teeth (dead specimen only).
   - Nostrils – two small holes situated above the mouth to enable breathing while partly submerged in water.
   - Eyes – large and bulging; move the eyelids with your forceps. Are both eyelids movable and opaque? (Dead specimen only.)
   - Ears – are dark, round patches behind the eyes; there is no external ear.
   - Poison glands (toads) – elongated swellings behind the ears, which secrete a detestable milky substance when the toad is attacked.
   - Trunk – in toad note the dark, rough and dry skin on the dorsal side and lighter and less rough skin on the ventral side of the trunk; in frog: smooth moist skin.
   - Limbs – these are found on the trunk; note that the hindlimbs are longer and thicker than the forelimbs. The hindlimbs are used for leaping, whereas the short stout forelimbs help to absorb the shock on landing. The webbed digits give additional thrust during swimming. Which of these limbs are webbed?
   - Does your toad/frog have a tail?
2. Make a large well-labelled drawing of the toad/frog as seen from the side.

Table 5.6 will help you discover which features to look for if you have a toad or a frog – many people are confused about the differences between them.

KEY WORD

reptiles *cold-blooded, usually egg-laying, vertebrates*

***Table 5.6** Differences between a frog and a toad*

Frog	Toad
Has a smooth skin	Has a rough skin
Has a moist skin	Has a dry skin
Has more webbed feet	Has less webbed feet
Has a brightly coloured body	Has a dull-coloured body
Has a more streamlined body	Has a less streamlined body
Has extra-long hind legs	Has hind legs that are not extra long

Class Reptilia

The **reptiles** are mainly terrestrial animals that were for many millions of years the dominant group of animals on the Earth. They have dry skin with scales and their gas exchange takes place exclusively in the lungs. They have developed internal fertilisation

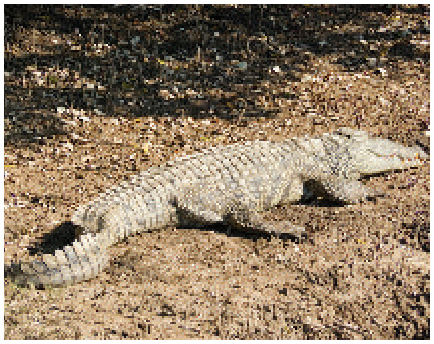

Figure 5.24 The Ethiopian crocodile is one of the larger reptiles and it shows all the typical features of the group. Many other types of reptile are much smaller!

and they lay eggs on land in a leathery shell. Some reptiles even keep the eggs within their body and give birth to fully developed young. These reproductive developments freed the reptiles from the need to return to the water to breed and so have enabled them to colonise dry and hot environments. As a result, reptiles are found in many areas of the world. The gill slits that are a chordate feature are seen only in embryonic development in the reptiles, and reptiles have no external ears. Reptiles are ectothermic – they rely on heat from their environment to regulate their body temperature. Examples include snakes, crocodiles, such as the Ethiopian crocodile, a subspecies of the Nile crocodile known as *Crocodyus niloticus niloticus*, and lizards, for example, the East African spiny-tailed lizard, *Cordylus tropidosternum*.

KEY WORDS

wings *forelimbs of birds adapted for flying*

endothermic *creatures who use heat produced by their own metabolism to regulate their body temperature*

mammals *creatures who produce milk for their young, have a high internal body temperature and regulate their own body temperature*

Class Aves

These are the birds. Birds have feathers over most of their body, and scales on their legs. The forelimbs are adapted as **wings**, which most birds use to fly. The sternum or breastbone has been enlarged into a big keel shape for the attachment of the wing muscles, particularly in those birds that fly. This forms the tasty meat that is so good to eat! The jaws are toothless and are covered by a horny beak. Birds reproduce using well-developed eggs with a hard shell and in many cases the parent birds spend a lot of time and effort raising their young. Birds have light skeletons, which makes it easier for them to fly. They are also **endothermi**c, which means they use heat produced by their own metabolism to regulate their body temperature. Of the main chordate features, only the hollow nerve cord remains in an adult bird, although the others can be seen at stages during the development of the embryo in the egg. Examples include domestic fowl, the wattled ibis (*Bostrychia carunculata*), white collared pigeon (*Columba albitorques*) and the Ethiopian eagle owl (*Bubo capensis*).

Examine the bird provided in the following activity to discover as many of the characteristics of birds as you can.

Activity 5.18: Examining a bird

You will need:

- a stuffed or preserved specimen of a bird, a live pet bird or domestic fowl or a freshly killed domestic fowl
- dissecting board

Method

1. Carefully examine the domestic fowl provided.
2. Identify as many of the different parts as you can.
3. Make a large well-labelled drawing of the fowl.

Figure 5.25 Birds are the only group of vertebrate animals which can almost all fly. Their bodies are specially adapted to make this possible.

Class Mammalia

Mammals are the best known of all animals. Mammals differ from other chordates in a number of ways. A true mammal produces milk for its young in mammary glands, has a high internal body temperature and regulates its own body temperature. Mammals sweat to help control their body temperature. A mammal has hair on the skin and external ears. Most mammals also produce live young which have developed for a time within the body of the mother in a structure called the uterus. As with the birds, chordate features are only plainly visible in the embryos. The mammals range in size from tiny shrews to elephants and whales. The ways in which they control their body temperature and reproduce inside their bodies have made it possible for them to live almost everywhere on the earth. We human beings are just one example of this most highly developed phylum of animals.

In the following activity you will examine a typical mammal to find out the characteristic features of mammals.

Subdivisions of mammals

Mammals are classified according to the way their young are produced. There are three sub-classes of mammals:

- Egg-laying mammals – lay eggs, e.g. duck-billed platypus.
- **Marsupials** – produce immature young, which are nourished by milk in the pouch, e.g. kangaroo, koala bear, opossum.
- Higher mammals – produce fully developed young, which are nourished by milk from the mammary glands, e.g. rats, cows, elephants, cats, monkeys and humans.

Mammals are a very successful group of animals, which give us the biggest animals in most of the habitats on the Earth. There are even flying mammals, as bats have been adapted to fly through the air on their leathery wings!

Figure 5.26 *The Ethiopian wolf (*Canis simensis *Rüppell) is a beautiful example of a rare mammal found in our country. It has all the features of a typical mammal and survives in tough conditions.*

Activity 5.19: Examining a small mammal

You will need:

- small live mammal in a cage, e.g. a pet dog, or freshly killed small mammal, e.g. a rat or rabbit
- dissecting board
- forceps

Method

1. If the mammal is alive and tame so it can be handled, get it out to look for the different features. If not, look at it in the cage. If it is dead, place the mammal on a dissecting board.
2. Identify and examine the following features: skin, mouth (open the mouth and examine the teeth), external ear.

   If your specimen is a female, look for the mammary glands.
3. Make a large well-labelled drawing of the mammal showing its external features.

KEY WORD

marsupials *mammals who produce immature young which are nourished by milk in the mother's pouch*

Summary

In this section you have learnt:

- The five-kingdom classification of the living world.
- The characteristic features of the kingdom Monera and examples of typical monerans.
- The characteristic features of the kingdom Protista and examples of typical protista.
- The characteristic features of the kingdom Fungi and examples of typical fungi.
- The characteristic features of the main divisions of the kingdom Plantae – Bryophyta, Pteridophyta, Gymnospermae and Angiospermae with typical examples of each.
- That the Angiospermae are divided into monocots and dicots and how to recognise each type of plant.
- The characteristic features of each phylum of the kingdom Animalia – Porifera, Coelenterata, Platyhelminthes, Nemathelminthes, Annelida, Mollusca, Echinodermata, Arthropoda and Chordata with typical examples of each phylum.
- The characteristic features of the main classes of the phylum Chordata – fish, amphibian, reptiles, birds and mammals with typical examples of each.

Review questions

Select the correct answer from A to D.

1. Which of the following is NOT one of the five kingdoms used to classify the living world?
   A Protista
   B Animalia
   C eukaryota
   D Fungi
2. Which of the following is a characteristic of all members of the kingdom Monera?
   A does not have an enclosed nucleus
   B carries out photosynthesis
   C has a bony skeleton
   D breathes through gills

3. In which of the following plant divisions would you find plants that have no transport tissues and no true roots?
   A Pteridophyta
   B Gymnospermae
   C Angiospermae
   D Bryophyta
4. The following statements describe which phylum of animals?

   They have narrow, thread-like bodies that are not segmented, pointed at both ends, bilaterally symmetrical and round in cross-section. They have no circulatory system but they do have a complete digestive system with both mouth and anus.
   A Mollusca
   B Annelida
   C Echinodermata
   D Nematoda
5. Which class of the vertebrata has scaly skin on the legs, lays eggs and can regulate its own body temperature?
   A birds
   B fish
   C mammals
   D reptiles

End of unit questions

1. a) What does classification mean?
   b) Why is classification so important to scientists?
   c) What is taxonomy?
   d) What do scientists look for when classifying organisms?
2. Investigate the life and work of Carl Linnaeus and write a report on his binomial system of naming organisms.
3. a) What is a dichotomous key?
   b) Explain why dichotomous keys are useful to a scientist.
4. a) Name the five kingdoms in the biological classification system.
   b) State the subdivisions into which these kingdoms are all split.
5. State the kingdom and phylum to which each of the following organisms belongs:
   a) jellyfish
   b) mango
   c) scorpion

d) earthworm

e) tapeworm

f) whale

g) mushroom

h) blue-green algae

i) toad

j) bacteria

6. a) What do scientists look for when classifying organisms?

   b) What determines if an animal is called a vertebrate or an invertebrate?

   c) Choose one invertebrate phylum and one vertebrate class. Describe the characteristics of the group and give two clear examples.

7. a) Which group of animals has wings and six legs?

   b) State the class for each of the following animals: snake, toad, termite.

8. A reptile and an amphibian both lay eggs. Explain why they are separated into two different classes.

9. a) How do flatworms, annelid worms and roundworms differ from each other?

   b) How do mosses differ from conifers?

   c) How do fungi differ from plants?

10. This table shows some of the characteristics of animals. Copy it out and fill in the equivalent characteristics of plants.

Animals	Plants
a) Move whole of the body from one place to another	
b) Grow up to a maximum size in life	
c) Have a variety of colours	
d) Respond to stimuli quickly	
e) Show complex behaviour patterns	
f) Feed on other organisms	
g) Give out carbon dioxide all the time	

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Copy this table into your exercise book (or your teacher may give you a photocopy). Draw a pencil line through each of the words in the list below as you find it.

Words go up and down in both directions

M	O	N	E	R	A	P	F	E	R	N
X	O	M	U	I	J	H	T	P	Q	A
P	R	O	K	A	R	Y	O	T	I	C
L	D	D	A	R	G	L	C	A	G	F
A	E	G	R	V	E	U	I	J	N	P
N	R	N	Y	S	A	M	D	N	U	K
T	D	I	O	G	E	N	U	S	F	E
A	Y	K	T	A	X	O	N	O	M	Y
E	A	N	I	M	A	L	I	A	O	M
S	P	E	C	I	E	S	F	I	S	H

Word search: In this table you will find 16 words linked to classification.

They are:

monera	fungi	plantae	animalia
species	taxonomy	dicot	fern
fish	eukaryotic	prokaryotic	phylum
genus	order	kingdom	key

Environment

Unit 6

Contents

6.1 Ecosystems

By the end of this section you should be able to:

- Define an ecosystem.
- Explain the abiotic (physical) components of an ecosystem.
- Explain the biotic (biological) components of an ecosystem.

Think about the world around you. If you live in a town or city, think of the parks and gardens, the drains and the rubbish piles. If you live in the countryside, think of the farms, the forests, the mountainsides and the rivers. Wherever you live, you are surrounded by living organisms, from monerans in the air and water, to plants, insects and worms to birds, dogs, cattle and of course people. All of these living things do not live in a vacuum.

The many different species of living things interact with the physical world of rocks, soil and rivers and these interactions make up the **ecology** of the world.

You are going to study what happens in **ecosystems**. An ecosystem is a life-supporting **environment**. It includes all the living organisms, the nutrients which cycle through the system and the physical and chemical environment in which the organisms are living. Ecosystems are huge – the whole world is an ecosystem – but we break them down to look at smaller ecosystems. So we might study a rainforest, a pond or a tree – each of them is an ecosystem!

An ecosystem is the home or **habitat** of the living organisms within it. They are affected by both the **abiotic components** and the **biotic components** of the ecosystem.

KEY WORDS

ecology *science of the relationship between organisms and their environment*

ecosystem *all the animals and plants that live in an area along with the things that affect them*

environment *an organism's home and its surroundings*

habitat *place where an animal or plant lives*

Abiotic components

The abiotic components or factors are the non-living elements of an ecosystem. The climate and weather produce several important abiotic components. They include the amount of sunlight, and the amount of rainfall. Each of these factors will affect which living organisms can survive there. Temperature is an important abiotic component which often affects whether animals and plants can survive in an ecosystem. Other abiotic factors include the type of soil and rocks, the drainage of the soil and the pH (acidity).

If the environment is water, the levels of oxygen dissolved in the water are an important abiotic factor as many animals cannot survive in low oxygen concentrations. The current is another factor – many animals and plants cannot survive in a strong current as they are swept away. The level of wind is also an important abiotic component of an ecosystem – too much wind can make life very difficult for living organisms.

Figure 6.1 *In Ethiopia we have ecosystems with very tough abiotic factors – hot sun, cold temperatures, little water, rocky soils (top) – but we also have ecosystems with plenty of light, warmth and water, which living organisms take advantage of!*

Biotic components

The biotic components (factors) of an ecosystem are the living organisms within an ecosystem which affect the ability of an organism to survive there. The number of predators in an ecosystem is one biotic component that has a big effect on the numbers of other organisms in the area. A pride of lions in an area will affect the numbers of prey animals that survive, and the number of caterpillars will make a difference to the number of plants that survive and reproduce.

The amount of food available is another important biotic factor, which particularly affects animals. The food might be the number of plants growing as food for a plant-eater or the number of prey animals available for a carnivore to eat. Biotic components of an ecosystem also include the numbers of parasites and diseases. High levels of parasites or a serious disease will reduce the numbers of animals or plants in an ecosystem.

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KEY WORDS

abiotic components *physical factors in a habitat*

biotic components *components linked to the plants and animals in a habitat*

terrestrial habitats *habitats on land*

aquatic habitats *habitats in water*

marine habitats *habitats in salt water oceans*

freshwater habitats *habitats in fresh water of lakes, rivers, ponds and streams*

camouflage *the ability of an animal to blend its colour into its surroundings to avoid detection*

Figure 6.2 *Ethiopian wolves live in an ecosystem that has harsh abiotic and biotic components. The numbers of rats and wolves in the ecosystem is affected by competition for food by both the rats and the wolves.*

Habitats may be on land – when they are known as **terrestrial habitats** or they may be in water, when they are called **aquatic habitats**. In turn there are two main types of aquatic habitat – the **marine habitat**, which is the salt water of the seas and oceans, and the **freshwater habitat** of lakes, ponds, rivers, and streams.

The final biotic component which has a big effect on ecosystems is competition. There can be competition between different species all trying to get the same food, for example, and there is competition between members of the same species for the best mate, the best nest site or the most sunlight, for example.

Animals compete with each other for food, water, territory and mates. Competition for food is very common. Herbivores (animals that eat plants) sometimes feed on many types of plant, and sometimes on only one or two different sorts. Many different species of herbivores will all eat the same plants – think how many types of animals eat grass! The animals which eat a wide range of plants are most likely to be successful. If you are a picky eater you risk dying out if anything happens to your only food source. An animal with wider tastes will just eat something else for a while!

Competition is common among carnivores (animals that eat meat) – they compete for prey. Wildebeest are hunted by several different predators, for example.

Animals often avoid direct competition with members of other species when they can. It is the competition between members of the same species which is most intense!

Prey animals compete with each other too – to be the one that ISN'T caught! Adaptations like **camouflage** colouring, so you don't get seen, and good hearing, so you pick up a predator approaching, are important for success.

Competition for mates can be fierce. In many species the male animal puts a lot of effort into impressing the females, because it is often the female who chooses her mate. The males compete in different ways to win the privilege of mating with her. In some species – like deer and lions – the males fight between themselves and the winner gets the females. Sometimes the fights are mainly 'mock battles' but in some species the fights can be life-threatening.

Many male animals display to the female to get her attention. Some birds have spectacular adaptations to help them stand out – male peacocks and birds of paradise have the most amazing feathers, which they use for displaying to other males (to warn them off) and to females (to attract them).

Plants might look like peaceful organisms, but in fact the world of plants is full of fierce competition – just like animals! Plants compete with each other for light, for water and for nutrients (minerals) from the soil.

They need light for photosynthesis, when they make food using energy from the sun. They need water for photosynthesis and to keep their tissues rigid and supported. And plants need minerals so they can make all the chemicals they need in their cells.

When seeds from different plants land on the soil and start to grow the plants that grow fastest will win the competition against the slower growing plants. Plants are constantly competing against other plants – which are biotic components of the ecosystem. If you have ever tried to grow food in your garden or on a farm, you will know that the competition between the plants you want to grow and weeds can be fierce. We try to get rid of the weeds to remove the competition for water, light and minerals so our crops can grow as well as possible. And we plant our crop plants apart from each other so they are not competing between themselves.

So the biotic components of an ecosystem have a big effect on the populations of living organisms within it.

Summary

In this section you have learnt that:

- An ecosystem is a life-supporting environment which includes all the living organisms, the nutrients which cycle through the system and the physical and chemical environment in which the organisms are living.
- The abiotic components of an ecosystem are the non-living components of the environment. They include the amount of sunlight, the amount of rainfall, temperature, the type of soil and rocks, the drainage of the soil and the pH (acidity), the levels of oxygen dissolved in the water, the current and the levels of wind.
- The biotic components (factors) of an ecosystem are the living organisms within an ecosystem which affect the ability of an organism to survive there. They include disease, predator numbers, food availability and competition for things such as mates, territory, food, light, etc.

Review questions

Select the correct answer from A to D.

1. Which of the following is not an abiotic component of an ecosystem?

   A sunlight
   B rainfall
   C food
   D wind

2. Which of the following is not a biotic components of an ecosystem?

   A predators
   B rocks
   C parasites
   D diseases

KEY WORDS

phototrophs *organisms that feed off light*

producers *plants*

herbivores *animals that eat plants only*

carnivores *animals that feed on other animals only*

omnivores *animals whose diet includes both plants and animals*

heterotrophs *organisms that rely on eating other organisms*

chemotrophs *organisms that get energy from the breakdown of inorganic chemicals*

Figure 6.3 *Plants are phototrophs – they make their own food using energy from the sun.*

6.2 Food relationships

By the end of this section you should be able to:

- Define phototrophs, heterotrophs and chemotrophs.
- Explain food chains using diagrams.
- Explain food webs using diagrams.
- Explain pyramids of biomass using diagrams.
- Explain pyramids of energy using diagrams.

Plants are vitally important in any ecosystem, because they harness the energy of the sun by photosynthesis and make it available to other organisms in the form of food. They make food from simple inorganic molecules – and without them little else could survive for long. Plants are **phototrophs** (light feeders). Because of their role in making carbohydrates, plants are known as the **producers**. What is more, they absorb carbon dioxide and produce oxygen in the process, maintaining the balance of gases in the atmosphere and providing us all with the oxygen which we need to live.

Plants are the main source of food for many thousands of different species of animals, from the aphids which feed on houseplants to the great herds of wildebeest, zebras and elephants of Africa. Animals that eat plants are known as **herbivores**.

Not all animals eat plants. Many of them feed on other animals and they are known as **carnivores**. And some types of animals, ourselves included, eat a diet that contains both plants and animals. These animals are known as **omnivores**. All animals and fungi are **heterotrophs** – they rely on eating other living organisms.

There are a small number of organisms that can get energy from the breakdown of sulphur-containing chemicals. They are known as **chemotrophs**.

Around the world much of the staple diet for human beings comes from plants. Cereal crops, pulses, nuts, fruits and berries are all the products of plant reproduction, whereas other foodstuffs come from stems, roots, leaves and storage organs. And it doesn't stop there. People don't just eat plants – in many cultures people eat meat as well. Meat comes from animals, but many of those animals eat plants. Cows, sheep, pigs, goats, rabbits, chickens, fish – all of these animals eat plants to provide them with the energy and material they need to grow. Sometimes we eat animals that feed on other animals – for example, many of the fish we eat are carnivores and in some parts of the world dogs, cats and other carnivores are eaten. Even then the animals eaten by the carnivores in their turn eat plants.

It is not only human beings that are dependent on plants and the process of photosynthesis. Almost all living organisms depend on plants as the producers of food from the raw materials of carbon dioxide and water. The way in which living things are linked to each other and to plants can be described by looking at food chains.

Food chains

The first stage of the chain involves converting light energy from the sun into stored chemical energy in plants by photosynthesis. This is always done by plants which are known as producers. Then all of the animals that eat plants or other animals are known as **consumers**.

Some of the energy produced by a plant is passed on to the animal which eats it. This will usually be a herbivore, although it could also be an omnivore. The herbivore (or omnivore) is known as a primary consumer, because it eats plants. Some of the energy within the herbivore is, in turn, passed on to the animal which eats it. Again, this will usually be a carnivore but could be an omnivore. The carnivore (or omnivore) is known as a secondary consumer because it eats the plant eater. This naming continues along the chain. At the end of every food chain are the **decomposers** – the bacteria and fungi which break down the remains of animals and plants and return the mineral nutrients to the soil. They are often not shown in food chains.

Wherever you look you will find food chains which demonstrate time after time the reliance of animals on plants.

Within any habitat living organisms depend on plants – the producers – to provide the food on which all of the rest of the organisms depend. The different levels within a food chain – the producers, primary consumers, secondary consumers, etc. are known as the **trophic levels**. Some of the simplest food chains have only two trophic levels. They come from terrestrial habitats and they describe the food we eat ourselves. For example, bananas photosynthesise and then we eat them in a wide variety of dishes. This food chain is very simple: (In food chains the arrow → means 'is eaten by'.)

banana → human

On the other hand, we often eat meat, and this extends the food chain. For example, if you enjoy chicken, the food chain in which you are taking part may have three trophic levels:

corn → chicken → human

But if you prefer beef the chain would be:

grass → cow → human

Not all food chains involve people however – in fact the great majority of food chains have nothing to do with human beings at all. For example, in the seas around the Horn of Africa coral reefs are a major habitat. Tiny plant-like organisms known as algae grow on the coral, photosynthesising and making food. Parrot fish graze on these algae, before they themselves are eaten by predatory fish such as groupers. But the chain doesn't stop there as groupers in turn are eaten by larger carnivores such as the barracuda.

algae → parrot fish → grouper → barracuda

KEY WORDS

consumers *all of the animals that eat other animals or plants*

decomposers *bacteria and fungi that break down the remains of animals and plants, returning the nutrients to the soil*

trophic levels *levels in a food chain to which an organism belongs*

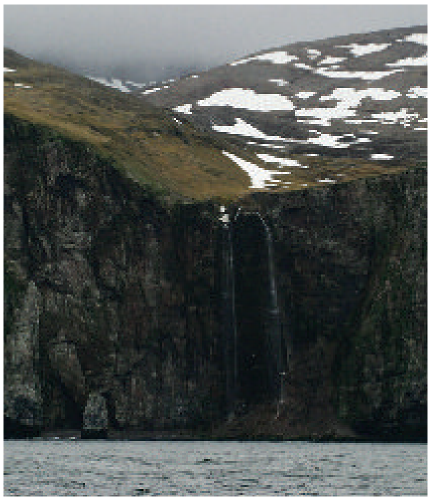

Figure 6.4 *Bear Island is a very stark environment – very unlike Ethiopia! Yet it was here that Charles Elton first observed food chains in action.*

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KEY WORDS

phytoplankton (plant plankton) *microscopic photosynthetic organisms at the beginning of many aquatic food chains*

zooplankton (animal plankton) *microscopic organisms which eat the phytoplankton*

food web *network of food chains*

Figure 6.5 *Coral reefs support a huge variety of life. You can identify many different food chains among the species around a reef!*

Many aquatic food chains start with the microscopic photosynthetic organisms known as **phytoplankton** (**plant plankton**). These tiny organisms are eaten by the equally microscopic **zooplankton** (**animal plankton**) and these two groups of organisms underpin food chains which involve almost every animal in the water, from tiny shrimps to enormous whales.

In Ethiopia we have a wide variety of ecosystems and a rich variety of animals and plants. This gives us some very interesting food chains. Some are simple, some are quite long. Here are some examples:

leaves and flowers → black and white colobus monkeys

leaves → grasshopper → rodent → leopard

grass → zebra → lion

Food chains are a great simplification of the situation in the real world. Very few organisms eat only one type of plant or animal, so many organisms appear in many different food chains. It is possible to draw all these interactions to make a much more complex **food web**.

Activity 6.1: Investigating food chains

Wherever you live or go to school, you will be surrounded by food chains and animals and plants interacting in their habitat. If you look closely in any small area of habitat – it might be a corner of the school field, a garden or a pond – you will find plants and animals linked together in food chains. In this investigation, you are going to see how many you can find.

Remember, you will be capturing and handling living organisms. Treat them with great respect and do not harm them in any way.

You will need:

- trays and containers to store organisms temporarily once you have collected them
- labels for the containers to record where you found the organism and what it is
- hand lens or viewer
- net
- forceps
- pooters (if available) to catch small insects

Method

1. Mark out a small area that you will study (if a land habitat).

2. Collect as many organisms as possible – carefully – and store them in separate containers (to avoid them eating each other). Remember to collect the plants as well – a single leaf or a sketch will do to help you identify them.
3. Observe each organism carefully. Use the hand lens where it will help. Make a sketch of each organism. Identify each one as well as you can and decide if they are herbivores or carnivores.

   Hints: Herbivores are often more slow moving than carnivores.

   Herbivores are often well camouflaged.

   Herbivores are often found on or close to the plants that they feed on.

   Carnivores often have sharper mouthparts than herbivores.
4. Try and build up as many food chains as you can, using the organisms you have found.
5. Then think of several other habitats and try and work out three food chains for each.

Food webs

Food chains are very simple, but in real life things are much more complex. Grass is eaten by insects, by rodents and by many large herbivores. Antelope may be prey for lions, leopards or hyenas. The many interactions between living organisms cannot be shown in simple food chains. So people have developed food webs. In a food web the interactions between many different food chains can be shown. An example based on some of the organisms living on our African savannahs has been prepared for you in figure 6.6.

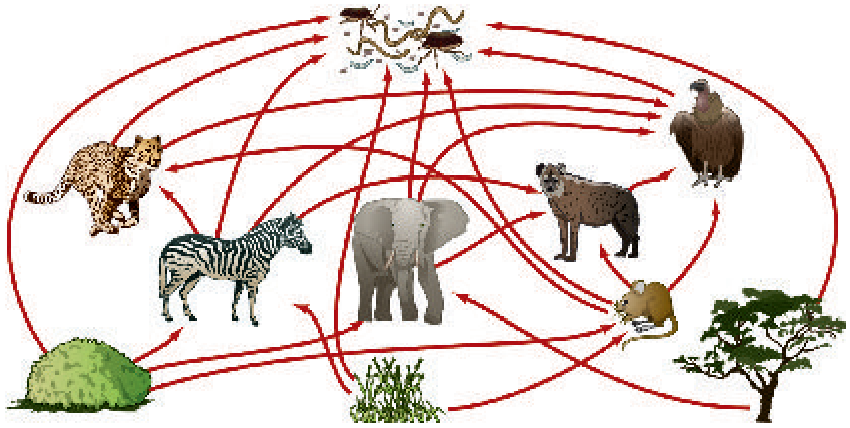

Figure 6.6 *This food web of organisms on the savannah only includes a small number of the organisms that are involved – but already you can see how complicated it is.*

KEY WORD

biomass *all the organic material produced by living organisms*

DID YOU KNOW?

It has been estimated that plants synthesise around 35×10^{15} kg (35 000 000 000 000 000 kg) of NEW biological material each year. That's an awful lot of biomass!

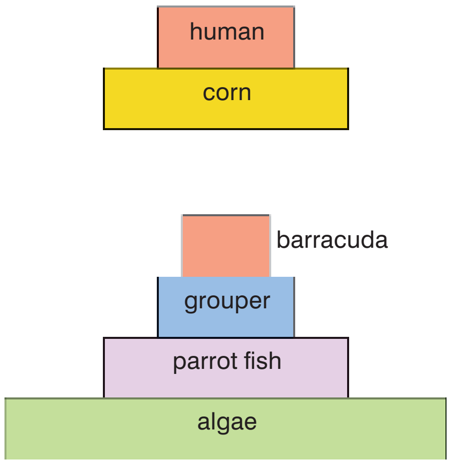

Figure 6.7 *A pyramid of numbers like this seems a sensible way to represent a food chain.*

Energy for life

As you have seen, radiation from the sun is the source of energy for all communities of living organisms. Solar energy pours out continually onto the surface of the earth and a small part of it is captured by the chlorophyll in plants. It is used in photosynthesis and the energy from the sun is stored in the substances which make up the cells of the plant. This new plant material adds to the **biomass**. Biomass is a term that describes all the organic material produced by living organisms. It all comes originally from plants as they photosynthesise at the beginning of all food chains.

This biomass is then passed on through a food chain or web into the animals which eat the plants and then on into the animals which eat other animals. However long the food chain, the original source of all the energy and hence the biomass involved is the sun.

When you look at a food chain, there are usually more producers than primary consumers, and more primary consumers than secondary consumers. This can be shown as a pyramid of numbers.

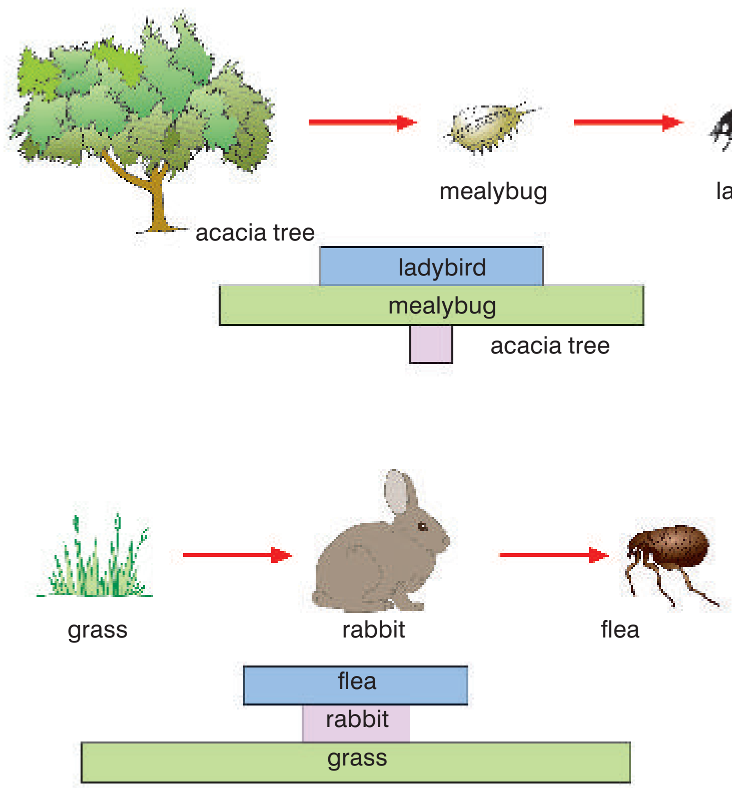

Figure 6.8 *These food chains cannot be accurately represented using a pyramid of numbers.*

However, in many cases a pyramid of numbers does not accurately reflect what is happening. For example, the breadfruit tree can grow to around 20 m tall, yet it can be attacked by mealybugs. They in turn are eaten by ladybirds. However, the pyramid of numbers for this food chain doesn't look like a pyramid at all. And cows eat grass, and people eat cows – and that doesn't make a very good pyramid of numbers either!

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To represent what is happening in food chains more accurately we can use biomass. Biomass is the mass of living material in an animal or plant and ultimately all biomass is built up using energy from the sun. The total amount of biomass in the living organisms at each stage of the food chain can be drawn to scale and shown as a pyramid of biomass.

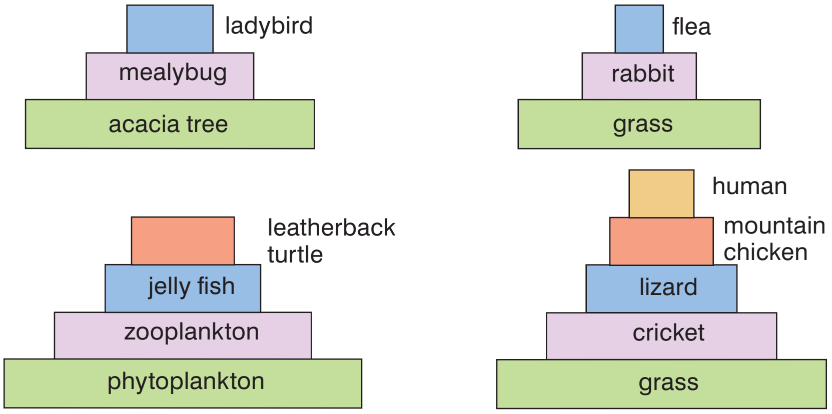

Figure 6.9 *No matter what the numbers of organisms involved in a food chain, when the biomass of the different feeding levels is considered, a pyramid of biomass always results.*

The biomass, and so the energy available at each trophic level of a food chain is less than it was at the previous stage. This is because:

- Not the whole organism at one stage is eaten by the stage above.
- When an herbivore eats a plant, it turns some of the plant material into new herbivore. But much of the biomass from the plant is used by the herbivore to release energy for living and so does not get passed on to the carnivore when the herbivore is eaten.

So at each stage of a food chain the amount of biomass which is passed on is less – a large amount of plant biomass supports a smaller amount of herbivore biomass which in turn supports an even smaller amount of carnivore biomass.

DID YOU KNOW?

Counting the number of living organisms in a food chain can be difficult, but measuring biomass is even harder. If the animals and plants are alive their biomass contains lots of water. Wet biomass is very inaccurate – for example, it is affected by how much water an animal has drunk. Measuring dry biomass is the most accurate measure. Unfortunately to find the dry biomass the organisms have to be killed and dried, which destroys the food chain you are studying!

Figure 6.10 *The amount of biomass in a lion is substantially less than the amount of biomass in the grass which feeds the zebra they prey on. But where does it all go?*

Figure 6.11 *Animals like elephants eat vast amounts of biomass, but they also produce very large quantities of dung containing all the material they cannot digest.*

DID YOU KNOW?

In a food chain, an animal passes on only about 10% of the energy it receives. The amount of available energy decreases at every trophic level, so each level supports fewer individuals than the one before. The longest food chains are found in the seas and oceans, and even then the number of links is usually limited to about five – unless you can think of a longer one!

Energy reduction between trophic levels and pyramids of energy

An animal like a zebra eats grass and other small plants. It takes in a large amount of plant biomass, and converts it into a smaller amount of zebra biomass. What happens to the rest?

Firstly, not all of the plant material can be digested by the animal, so it is passed out of the body in the faeces. Excess protein which is eaten but not needed in the body is broken down and passed out as urea in the urine. The same is true for carnivores, they often cannot digest hooves, claws and teeth, so some of the biomass that is eaten is always lost in their waste.

Part of the biomass which is eaten by an animal is used for cellular respiration. This supplies all the energy needs for the living processes taking place within the body, including movement which uses a great deal of energy. The muscles use energy to contract, and the more an animal moves about, the more energy (and biomass) it uses from its food.

Much of the energy produced in cellular respiration is eventually lost as heat to the surroundings. These losses are particularly large in mammals and birds, because they are warm-blooded. This means their bodies are kept at a constant temperature regardless of the temperature of the surroundings. They use up energy all the time to keep warm when it's cold or to cool down when it's hot. Because of this warm-blooded animals need to eat far more food than cold-blooded animals like fish and reptiles to get the same increase in biomass.

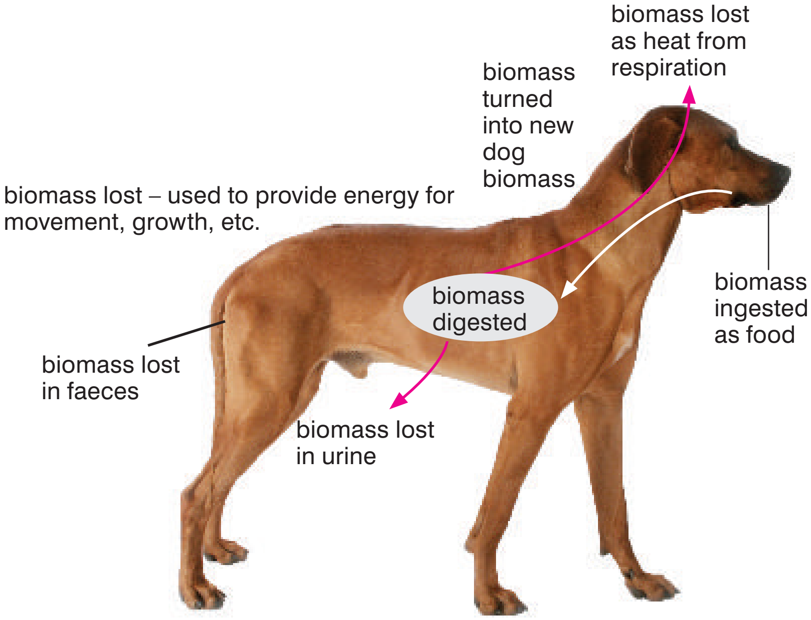

Figure 6.12 *Only between 2 and 10% of the biomass eaten by an animal such as this dog will get turned into new dog biomass, the rest will be used or lost in other ways.*

If we represent the energy held in each trophic level we get the best possible representation of what is happening in a food chain. A pyramid of energy represents the energy in the producers and how much of that energy is passed on at each stage along the food chain. However, pyramids of energy are very difficult to measure so practically we usually use biomass.

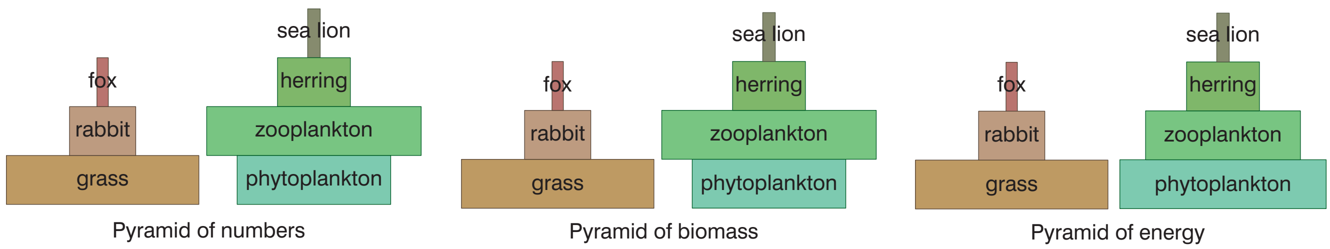

Figure 6.13 *This diagram shows you how pyramids of numbers, biomass and energy compare for two different food chains.*

Summary

In this section you have learnt that:

- Radiation from the sun is the source of energy for all communities of living organisms. It is captured by green plants in photosynthesis. Green plants are known as phototrophs.
- Heterotrophs get their energy by feeding off other organisms and chemotrophs get their energy from chemical reactions which are not related to photosynthesis.
- Food chains and food webs show the feeding relationships between animals and plants.
- The idea of food chains and food webs was developed by Charles Elton in the 1920s from his observations on Bear Island.
- The mass of living material (the biomass) at each stage of a food chain is less than it was at the previous stage because some material is always lost in waste materials and much is used for respiration to supply energy for movement and maintaining the body temperature.
- The biomass at each stage of a food chain can be drawn to scale and shown as a pyramid of biomass.
- Measuring the flow of energy through a system takes place over time. It can be shown in an energy pyramid.

Review questions

1. Why is a pyramid of numbers not always a useful way to represent a food chain?
2. What do pyramids of biomass show about the effect of the number of trophic levels in a food chain on the amount of biomass which is available at the end of the chain?
3. Explain why the biomass from one stage does not all become biomass for the next stage of the pyramid when it is eaten.

6.3 Recycling in nature

By the end of this section you should be able to:

- Describe and illustrate the nitrogen cycle.
- Describe and illustrate the carbon cycle.

Living things are constantly removing materials from the environment. Plants take minerals from the soil and these minerals are then passed on into animals through the food chains and food webs which link all living organisms. If this was a one-way process then the resources of the Earth would have been exhausted long ago. Fortunately the materials are returned to the environment from the waste products of animals and the dead bodies of plants and animals.

The nutrients held in the bodies of dead animals and plants, and in animal droppings, are released back into the soil by the action of a group of organisms known as the decomposers. These are micro-organisms such as bacteria and fungi. They feed on waste droppings and dead organisms. They digest them and use some of the nutrients. They also release waste products, and these are nutrients broken down into a form which plants can use. When we say that things decay they are actually being broken down and digested by these micro-organisms.

The chemical reactions which take place in micro-organisms, like those in most other living things, work faster in warm conditions. But as in other organisms, these reactions are controlled by enzymes, and if the temperature gets too hot, the reactions stop altogether as the enzymes denature. They also stop if conditions are too cold.

Most micro-organisms also grow better in moist conditions which make it easier to dissolve their food and also prevent them from drying out. So the decay of dead plants and animals – and dung – takes place far more rapidly in warm, moist conditions than it does in cold, dry ones.

The majority of decomposers respire like any other organism to release energy to feed and reproduce as rapidly as possible. This means that decay takes place more rapidly when there is plenty of oxygen available.

As people developed an understanding of decomposers they have also developed ways of using them in artificial situations. For example, as the human population has grown, so has the amount of human waste (sewage) produced. Not only is this material unpleasant to live with, it also carries disease. Sewage treatment plants use micro-organisms to break down the sewage and make it harmless enough to be released into rivers or the sea for the breakdown to be completed. They have been designed to provide the bacteria and other micro-organisms with the conditions they

DID YOU KNOW?

Sometimes when an organism dies it freezes rapidly. The decomposers cannot function at these low temperatures and so the organism is preserved with very little decay. Once it begins to warm up, however, the rot will rapidly set in. We have seen mammoths and other prehistoric animals preserved in this way.

Figure 6.14 *Within the natural cycle of life and death in the living world mineral nutrients are cycled between living organisms and the physical environment.*

need, particularly a good supply of oxygen. At the moment we do not treat much of our human waste in Ethiopia.

Another place where the decomposers are useful is in the garden. Many gardeners have a compost heap. This is where they place grass cuttings, sometimes vegetable peelings and bits they cut off plants. Then they leave it to let decomposing micro-organisms break all the plant material down to a fine, rich powdery substance known as compost. The compost produced is full of mineral nutrients released by the decomposers. This compost is then dug into the soil to act as a valuable and completely natural fertiliser.

But it is in the natural world where the role of the decomposers is most important, and where the cycling of resources plays a vital role in maintaining the fertility of our soil and the health of our atmospheres. In a stable community of plants and animals living in an environment, the processes which remove materials from the soil are balanced by processes which return materials. In other words, the materials are constantly cycled through the environment. And by the time the microbes and detritus feeders have broken down the waste products and the dead bodies of organisms in ecosystems, all the energy originally captured by the green plants in photosynthesis has been transferred to other organisms or back into the environment itself as heat or mineral compounds.

The nitrogen cycle

Nitrogen is very important in a wide range of biological molecules. It is a vital part of the structure of amino acids and proteins, and it is also part of the molecules of inheritance, DNA and RNA. Plants can make carbohydrates by photosynthesis – but carbohydrates contain no nitrogen. So where does the nitrogen come from?

Green plants absorb nitrogen in the form of nitrates dissolved in the soil water. They use these nitrates to make proteins, and then this protein is passed along the food chain as herbivores eat plants and are then eaten themselves by carnivores. In this way the nitrogen taken from the soil becomes incorporated into the bodies of all types of living organisms. But almost 80% of the air we breathe is made up of nitrogen – so why don't plants use that? Although it is vital to the formation of proteins and healthy growth, plants cannot use the nitrogen which is in the air around them. It is an inert gas and in that form it is so unreactive that it is no use to them at all.

The nitrates taken out of the soil by plants are returned to it in a number of ways. Urine contains urea, a breakdown product of proteins, and proteins are also passed out in the faeces, so the waste passed out of animals' bodies contains many nitrogen-rich compounds. Similarly when animals and plants die their bodies contain a large proportion of protein. Some of the decomposing or **putrefying** bacteria and fungi which break down the waste products from animals and the bodies of animals and plants act specifically on the proteins. As they break down the protein they form ammonium compounds. These ammonium compounds are

KEY WORD

putrefying *decomposing*

Figure 6.15 *Farmers have been using leguminous plants and the nitrogen-fixing root nodules for centuries to help return fertility to the soil.*

KEY WORDS

nitrogen cycle *cycling of nitrogen compounds between the living and non-living world*

legumes *plants with the ability to fix nitrogen in the soil*

denitrifying bacteria *bacteria that use nitrates as an energy source and breaksthem down again into nitrogen gas*

carbon cycle *cycling of carbon compounds between the living and the non-living world*

then oxidised by nitrifying bacteria which convert them to nitrates which are returned to the soil to be absorbed by plants through their roots again.

Not all of the nitrates in the soil come from the process of decay. Nitrogen-fixing bacteria in the soil can actually convert nitrogen from the soil air into ammonia, which is then converted into nitrates by the nitrifying bacteria of the nitrogen cycle.

There is one group of plants which plays a particularly important role in the **nitrogen cycle**. The **legumes** – that is plants such as peas, beans and clover – have nodules on their roots which are full of nitrogen-fixing bacteria. This is an example of mutualism, where two organisms live together and both benefit. The bacteria get protection and a supply of organic food from the plant, whereas the plant gets ammonia that it can use to form amino acids. The bacteria produce far more ammonia than their host plant needs – and the excess passes into the soil to be used and turned into nitrates by the nitrifying bacteria.

However, not all the bacteria in the soil are helpful in the nitrogen cycle. One group, known as the **denitrifying bacteria**, actually uses nitrates as an energy source and breaks them down again into nitrogen gas. Denitrifying bacteria reduce the amount of nitrates in the soil!

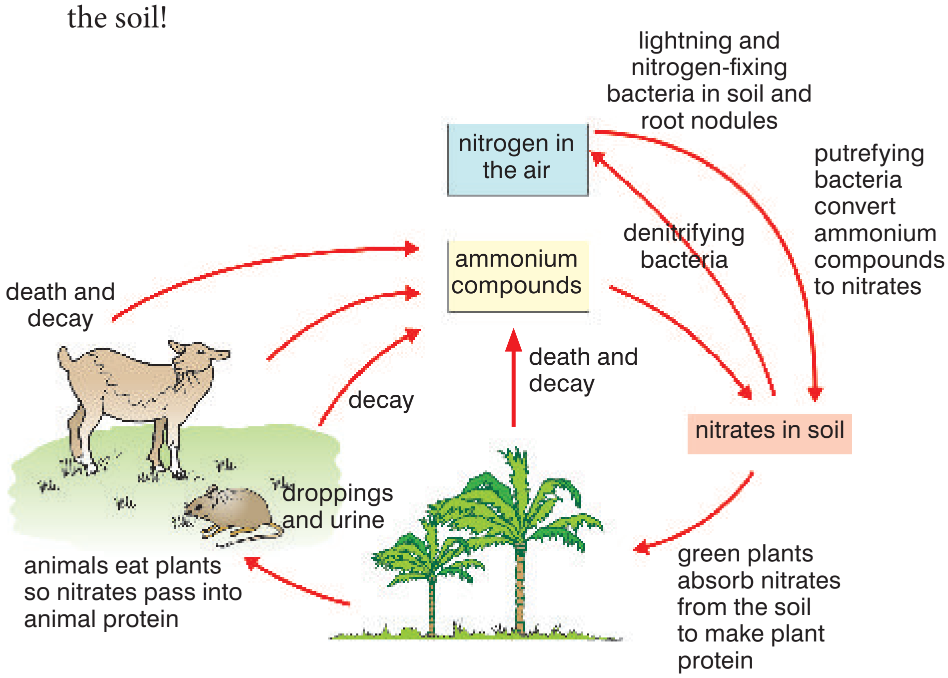

Figure 6.16 *The nitrogen cycle in nature*

The carbon cycle

Another important example of the way minerals are cycled through living organisms and the environment is the **carbon cycle**.

The element carbon is vital for living organisms because all of the main molecules of life are based on carbon atoms. There is a vast pool of carbon in the form of carbon dioxide in the air

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and dissolved in the water of rivers, lakes and seas. At the same time carbon is constantly recycled between living things and the environment. This is known as the carbon cycle.

Carbon dioxide is removed from the air by green plants in the process of photosynthesis. It is used to make the carbohydrates, proteins and fats which make up the body of the plant. Then when the plants are eaten by animals, and those animals are eaten by predators, the carbon is passed on and becomes part of the animal bodies. This is how carbon is taken out of the environment.

When green plants themselves respire, some carbon dioxide is returned to the atmosphere. Similarly when animals respire they release carbon dioxide as a waste product into the air. Finally when both plants and animals die, their bodies are broken down by the action of decomposers and when these microbes respire, they release carbon into the atmosphere as carbon dioxide, ready to be taken up again by plants in photosynthesis.

In addition to all of these processes, when anything which has been living is burnt – whether wood, straw or fossil fuels made from animals and plants which lived millions of years ago – carbon dioxide is also released into the atmosphere in the process of combustion.

This cycling of carbon can be summarised in a diagram (figure 6.17):

DID YOU KNOW?

At the University of Knoxville in the USA forensic research teams are studying the rate at which the decomposers break down the human body under a range of different conditions. People donate their bodies, which are then deposited in the ways that people most often dispose of murder victims. By monitoring the rate of decomposition in these bodies, the team are collecting information which will help solve murder investigations all over the world.

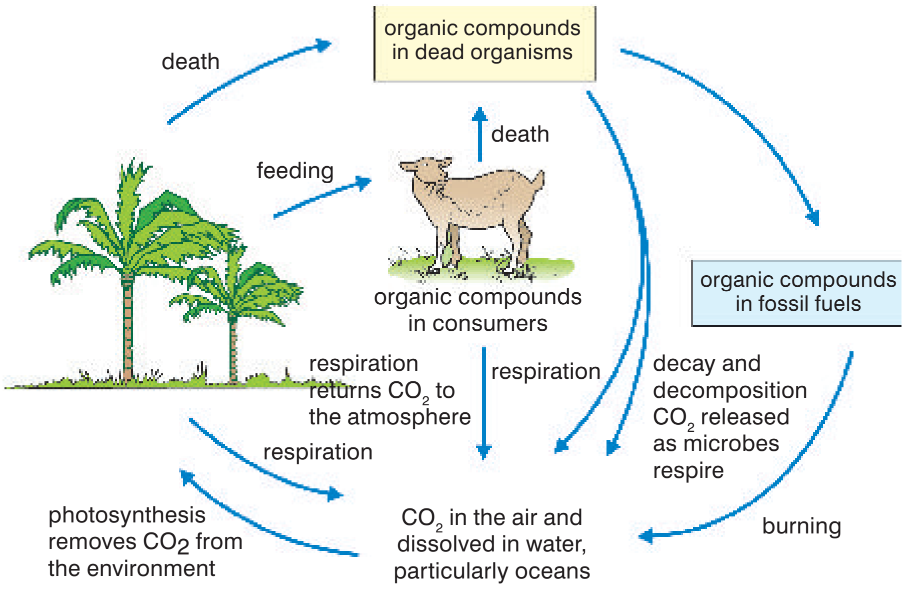

Figure 6.17 *The carbon cycle in nature*

For millions of years the levels of carbon dioxide released by living things into the atmosphere has been matched by the plants taking it out and the gas dissolving in the seas. As a result the level in the air stayed about the same from year to year.

But now the amount of carbon dioxide produced is increasing fast as the result of human activities. We are burning huge amounts of fossil fuels in our cars, our planes and also in power stations to generate electricity. This speed means that the natural sinks cannot cope, and so the levels of carbon dioxide are building up.

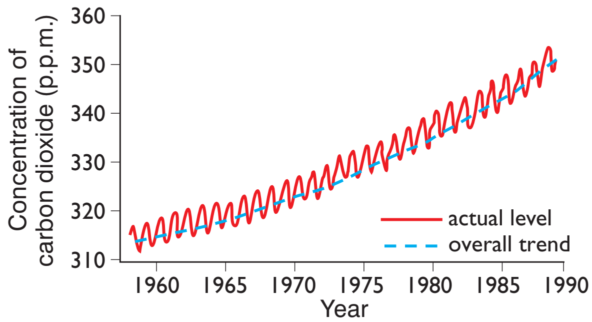

Figure 6.18 *This graph shows how carbon dioxide levels in the air have been steadily increasing. The variations through the year show the difference in the plants taking up carbon dioxide in summer and winter.*

This build-up of carbon dioxide gas in the atmosphere is generally believed to contribute to the **greenhouse effect**, also referred to as **global warming**. Although plants take in carbon dioxide and release oxygen, the release of carbon dioxide from human activities is higher than the plants can process. The situation is made worse because all around the world large-scale **deforestation** is taking place. We are cutting down trees over vast areas of land for timber and to clear the land for farming. In this case, the trees are felled and burned in what is known as 'slash-and-burn' farming. The land produced is only fertile for a short time, after which more forest is destroyed. No trees are planted to replace those cut down.

Deforestation increases the amount of carbon dioxide released into the atmosphere as burning the trees leads to an increase in carbon dioxide levels from combustion. The dead vegetation left behind decays as it is attacked by decomposing micro-organisms which releases more carbon dioxide.

Normally trees and other plants use carbon dioxide in photosynthesis. They take it from the air and it gets locked up in plant material like wood for years. So when we destroy trees we lose a vital carbon dioxide 'sink'. Dead trees don't take carbon dioxide out of the atmosphere.

Methane is another greenhouse gas which causes air pollution and the levels of this gas are rising too. It has two major sources. As rice grows in swampy conditions, known as paddy fields, methane is released. Rice is the staple diet of many countries so as the population of the world has grown so has the farming of rice.

The other source of methane is cattle. Cows produce methane during their digestive processes and release it at regular intervals.

In recent years the number of cattle raised to produce cheap meat for fast food like burgers has grown enormously, and so the levels of methane in the atmosphere are rising. Many of these cattle are raised on farms produced by deforestation.

So as a result of human activities the amount of carbon dioxide (and methane) in the air is continuing to increase. This build-up acts like a blanket and traps heat close to the surface of our earth. This causes the temperature at the surface of the earth to rise. This in turn may have many effects on our climate and health – and it is also thought to contribute to the extreme droughts, strong hurricanes and heavy rains and flooding which are affecting many different parts of the world.

KEY WORDS

greenhouse effect *high levels of greenhouse gases in the atmosphere prevent heat radiating away from Earth's surface and causes the surface temperature to rise*

global warming *another term for greenhouse effect*

deforestation *loss of forests due to the overcutting of trees*

DID YOU KNOW?

Cows produce methane all through the day from both ends! A single cow can release from 100–400 litres of methane per day – that's a lot of greenhouse gas.

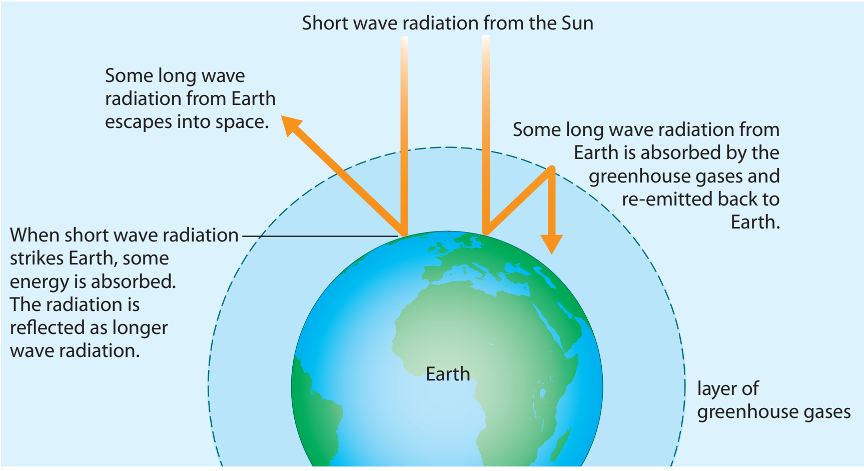

Figure 6.19 *Most scientists believe that global warming is a result of the build-up of air pollutants such as carbon dioxide. The pollution is produced all over the world – but here in Africa we are already feeling the effects.*

We have affected the atmosphere in another way too. Chemicals used as refrigerants in fridges and freezers and in aerosol cans have made the ozone layer around the earth thinner. Over the Antarctic regions there is what is known as an 'ozone hole' where the layer is very thin indeed. **Ozone** protects us from the harmful ultraviolet light in the sun's rays. As the ozone layer thins, more people are getting skin cancers and suffering eye damage from the sun. People need to be very careful with their actions – we can damage our environment without meaning to!

KEY WORD

ozone *layer of the atmosphere that protects the earth from harmful ultraviolet light from the sun*

Summary

In this section you have learnt that:

- Living organisms remove materials from the environment as they grow and return them when they die through the action of the decomposers.
- Dead materials decay because they are broken down by micro-organisms.
- The carbon cycle describes the way carbon is cycled through the environment including plants and animals and carbon sinks.
- The nitrogen cycle describes the way nitrogen is cycled through the environment, including plants and animals and showing how nitrates are returned to the soil.

Review questions

1. Why are the natural recycling processes like the carbon cycle so important for the continuation of life on earth?
2. It can be said that no part of our bodies is truly our own – we have borrowed the materials and at a later date they will be used again elsewhere. How would you explain this statement?

KEY WORD

adaptations *features organisms develop which make it possible for them to survive in particular habitats*

6.4 Adaptations

By the end of this section you should be able to:

- Explain the need for adaptation.
- Describe plant adaptations with examples.
- Describe animal adaptations with examples.

The variety of conditions on the surface of the Earth is huge. Here in our own Ethiopia, altitude can vary from 110 m below sea level to 4620 m above sea level at the highest peak. Rainfall varies from 500 mm to 2800 mm and temperatures in different parts of our country can be as far apart as 35 °C to 0 °C. If you are a living organism, you could find yourself living in the dry heat of a desert or in wastelands of ice and snow. Fortunately living organisms have features (known as **adaptations**) which make it possible for them to survive in their particular habitat – however extreme those conditions might be!

DID YOU KNOW?

Polar bears don't need any camouflage; they don't have any predators on the land – who would dare to attack a polar bear?! They hunt their prey in the sea amongst the ice all year round, so the white colour makes them less visible.

Animals in cold climates

To survive in a cold environment you must be able to keep yourself warm. Arctic animals are adapted to reduce the heat they lose from their bodies as much as possible. Body heat is lost through your body surface (mainly your skin). The amount of heat you lose is closely linked to your surface area:volume (SA/V) ratio. This explains why so many Arctic mammals, such as seals, walruses, whales and polar bears, are relatively large. It keeps their surface area:volume ratio as small as possible and so helps them hold on to their body heat.

Activity 6.2: Calculating surface area:volume ratios

Draw two cubes on a piece of paper. Give one sides of 1 cm, and the other sides of 3 cm.

Calculate the surface area of each cube. Do this by working out the area of one side, and then multiplying your answer by six for the number of sides. Note your answer down beside each cube. The units are cm^2.

Calculate the volume of each cube. Do this by multiplying length x breadth x height. The units are cm^3.

Now work out the surface area to volume ratio for each cube.

What do you notice about the ratio of the larger cube compared to the smaller cube?

Animals in very cold climates have other adaptations as well as a helpful surface area:volume ratio. The surface area of the thin-skinned areas of their bodies – like their ears – is usually very small. This reduces their heat loss. Look at the ears of the polar bear in figure 6.20.

Many Arctic mammals also have plenty of insulation, both inside and out. Blubber – a thick layer of fat that builds up under the skin – and a thick fur coat on the outside will insulate an animal very

Figure 6.20 *The Arctic is a cold and bleak environment. However, the animals that live there are well adapted for survival. Notice the large size, thick fur, small ears and white camouflage of this polar bear.*

effectively. They really reduce the amount of heat lost through the skin.

The fat layer also provides a food supply. Animals often build up their blubber in the summer. Then they can live off their body fat through the winter when there is almost no food.

Camouflage is important both to predators (so their prey doesn't see them coming) and to prey (so they can't be seen). Unfortunately the colours which would camouflage an Arctic animal in summer would stand out against the snow in winter. Many Arctic animals including the Arctic fox, the Arctic hare and the stoat change the greys and browns of their summer coats for pure white in the winter.

Surviving in dry climates

Dry climates are often also hot climates – like deserts! Deserts are very difficult places for animals to live. There is scorching heat during the day followed by bitter cold at night, whilst water is constantly in short supply.

The biggest challenges if you live in a desert are:

- coping with the lack of water
- stopping your body temperature from getting too high

Many desert animals are adapted to need little or no drink – they get the water they need from the food they eat.

Mammals keep their body temperature the same all the time, so as the environment gets hotter they have to find ways of keeping cool. Most mammals rely on sweating to help them cool down, but this means they lose water which is not easy to replace in the desert.

Many animals which live in hot or dry conditions have other adaptations for cooling down. They are often most active in the early morning and late evening, when the temperature is comfortable. During the cold nights and the heat of the day they rest in burrows well below the surface, where the temperature doesn't change much.

Figure 6.21 *Animals like this fennec fox have many adaptations to help them cope with the hot dry conditions, from their large surface area:volume ratio, big ears and thin fur to the way they behave to avoid the heat of the day.*

KEY WORD

stomata *small openings in the leaves of plants*

Figure 6.22 *Not all animals that live in hot, dry climates are small. An elephant is pretty big, but its huge wrinkled skin would cover an animal that was much bigger still. The wrinkles in the skin and the big, thin ears increase the surface area through which heat can be lost.*

DID YOU KNOW?

Animals that live in the deep oceans of the world are adapted to live under enormous pressure, no light and very cold water. But, if these deep water organisms are brought to the surface too quickly, they explode because of the rapid change in pressure.

Many desert animals are quite small, so their surface area is large compared to their volume. This helps them to lose heat through their skin. They often have large, thin ears as well to increase their surface area for losing heat.

Another adaptation of many animals which live in hot areas is that they don't have much fur, and the fur they do have is fine and silky. They also have relatively little body fat stored under the skin. Both of these features make it easier for them to lose heat through the surface of the skin. The animals keep warm during the cold nights by retreating into their burrows.

Plants grow in hot, dry areas around the world – without them there would be no food for the animals. But plants need water both for photosynthesis and to keep their tissues upright – if a plant does not get the water it needs it wilts and eventually dies.

Plants take in water through their roots in the soil. It moves up through the plant and is lost through the leaves in the transpiration stream. Plants lose water all the time through their leaves. There are small openings called **stomata** in the leaves of a plant. These open to allow gases in and out for photosynthesis and respiration. But at the same time water is lost by evaporation. The rate at which a plant loses water is linked to the conditions it is growing in. When it is hot and dry, photosynthesis and respiration take place fast. As a result, plants also lose water very fast. So how do plants that live in dry conditions cope? Most of them either reduce their surface area so they lose less water or they store water in their tissues. Some do both!

Changing surface area

When it comes to stopping water loss through the leaves, the surface area:volume ratio is very important to plants. There are a few desert plants which have broad leaves with a large surface area. These leaves collect the dew which forms in the cold evenings. They then funnel the water towards their shallow roots.

However, most plants that live in dry conditions have reduced the surface area of their leaves. This reduces the area from which water can be lost. They can reduce their surface area in a number of ways. Some desert plants have small fleshy leaves with a thick cuticle to keep water loss down. The cuticle is a waxy covering on the leaf which stops water evaporating away.

Some plants in dry environments have curled leaves; this reduces the surface area of the leaf. It also traps a layer of moist air around the leaf which really cuts back the amount of water they lose by evaporation.

The best-known desert plants are the cacti. Their leaves have been reduced to spines with a very small surface area indeed. This means the cactus only loses a tiny amount of water – and the spines put animals off eating the cactus as well! This adaptation has been very successful. A mature apple tree in England can lose about 100 l of

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water from its leaves every day. A large saguaro cactus in the desert loses less than one glass of water in the same amount of time!

Storing water

The other main way in which plants can cope with dry conditions is to store water in their tissues. When there is plenty of water available after a period of rain, the plant stores it. Plants which store water in their fleshy leaves, stems or roots are known as **succulents**. Cacti don't just rely on their spiny leaves to help them survive in dry conditions. They are succulents as well. The fat green body of a cactus is its stem, which is full of water-storing tissue. All these adaptations make cacti the most successful plants in a hot dry climate.

Figure 6.23 *These dramatic* Lobelia rynchopetalum *may not be small but they have thick leathery leaves to reduce water loss in their mountain habitat.*

KEY WORD

succulents *plants which store water in their fleshy leaves, stems or roots*

Spreading the seeds

As you saw on page 202, animals and plants compete with each other for resources. To compete successfully a plant has to avoid competition with its own seedlings. The most important adaptation for success in most plants is the way they shed their seeds.

Many plants use the wind to help them. Some produce seeds which are so small that they are carried easily by air currents. Many others produce fruits with special adaptations which carry their seeds as far from home as possible. The fluffy parachutes of the dandelion 'clock' and the winged seeds of trees like the sycamore are common examples of flying fruits. Tumbleweeds, found on the plains and deserts of Northern America, use the whole plant to scatter their seeds! When the seeds are ripe, the plants break off at the roots and are blown away, travelling miles across the plains and scattering seeds as they go.

Figure 6.24 *Tumbleweeds travel a long way to make sure their seedlings don't compete with each other! The whole parent plant is sacrificed to scatter the seeds as far as possible across North America!*

Some plants use mini-explosions to spread their seeds – the pods dry out, twist and pop, flinging the seeds out and away. Others, like the coconut palm, rely on water to carry their seeds away.

A wide variety of plants depend on animals to scatter their seeds for them. They have adaptations which encourage the animals to do this. Juicy berries, fruits and nuts are produced by plants to tempt animals into eating them. Once the fruit gets into the animal's gut, the tough seeds travel right through. They are deposited with the

DID YOU KNOW?

Different types of African dung beetles will feed on the same pile of dung. They avoid competition with each other by attacking the pile at different times of day and in different ways. The most active beetles work in the heat of the day and make balls of dung, which they roll away, whereas if they are quieter tunnellers, the beetles actually live in the dung heaps and work as dusk is falling.

waste material in their own little pile of fertiliser, often miles from where they were eaten! There are even fruits which are sticky or covered in hooks which get caught up in the fur or feathers of a passing animal. They are carried around until they fall off or the animal removes them by grooming hours or even days later.

DID YOU KNOW?

Seeds come in an enormous range of sizes, from the tiny seeds of the rattlesnake plantain, which only weigh 0.000 002 g to the giant seeds of the coconut palm, weighing over 20 000 g (20 kg)! But the roots of some desert plants have a deadly adaptation. They produce a chemical that inhibits (prevents) seeds from germinating. They murder the competition before it has a chance to get growing!

Summary

In this section you have learnt that:

- Living organisms have features (known as adaptations) which make it possible for them to survive in their particular habitat.
- Plants have many adaptations including thick waxy cuticles, water storage tissue, stomata in pits, etc. to help them survive in different conditions.
- Animals have many different adaptations to help them survive in different conditions from very hot, dry deserts to very cold and hostile countries.

Review questions

1. List three ways in which Arctic animals keep warm in winter.
2. Why do many Arctic animals change the colour of their coats between summer and winter?
3. Why do plants often reduce the surface area of their leaves to help them prevent water loss?

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6.5 Tree-growing project

By the end of this section you should be able to:

- Explain the importance of planting and growing trees.
- Know how to plant and grow trees in your community.

As you have seen in this unit, Ethiopia is a country with many different ecosystems. However, our country has been changing dramatically. Once, much of the land was covered with forests. Only 100 years ago 40% of Ethiopia was covered with forests – now that is only 3%. This deforestation is causing many problems. Trees produce oxygen and remove carbon dioxide from the air. They help to reduce the effects of air pollution and also reduce global warming. Trees hold the soil in place and without them our soil is becoming unstable and blowing away. Trees also help absorb water – they prevent soil erosion and help to prevent the formation of great areas of deserts.

Figure 6.25 *Tree planting in Ethiopia – a success story!*

In 2007 the Ethiopian Government decided to take action to begin to replace some of the trees and forests we have lost. In 2008 alone 687 million trees were planted as part of the nationwide tree-planting campaign. In fact Ethiopia tops the roll of honour for the most trees planted in a worldwide effort to rebuild some of our lost forests. So far we have planted more than 1.4 billion!

This is where you can help. The idea is to plant two-year-old saplings from five of our indigenous trees, and we need young people to do this. To plant a tree successfully, the soil must be prepared, a big hole must be dug and water must be put into the hole before the tree is planted.

Once the sapling is in place, the soil must be pressed very firmly around it and often a stake is used to support the young tree as it starts to grow and get established. The young trees need to be cared for once they have been planted. For at least the first year they will need extra water if the season is very dry. They may need to be protected from animals that might eat them. But if we can restore some of our lost trees, everyone will benefit, not only in Ethiopia, but across the world.

Activity 6.3: Planning a tree-planting programme

You are going to plan a tree-planting programme for your local area. You may also have the opportunity to go out and plant some young trees and take care of them. Do this activity in groups.

Method

1. Decide where it would be most useful to plant some trees.
2. Decide which type of trees it would be best to grow in your area.
3. Decide how many trees you would like to be able to plant.
4. Investigate how to plant the trees to give them the best chance of surviving and doing well.
5. Make posters to explain your plans to local people and get their support.
6. Make a report for the local media explaining your tree-planting programme and the benefits it will bring to people in the area.

Summary

In this section you have learnt:

- That it is very important to plant and grow trees in Ethiopia to replace the many forests that have been lost.
- That trees are important for many reasons including taking carbon dioxide out of the atmosphere, holding the soil together and providing us with food and many other products.
- How to plant and grow trees in your community, including how to plan the best place to plant the trees.

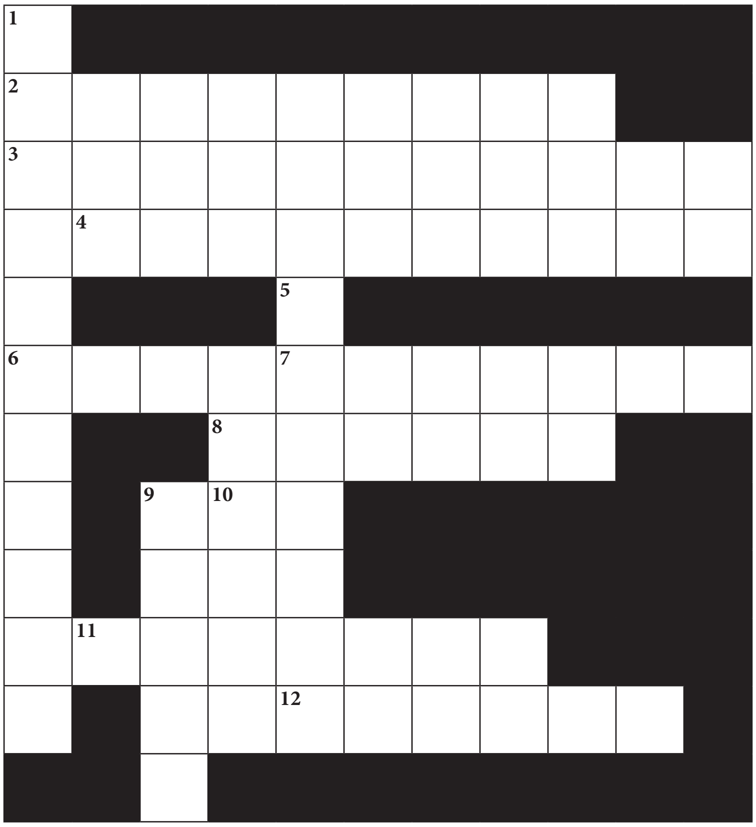
End of unit questions

1. a) List the main problems that face animals living in cold conditions like the Arctic.

   b) List the main problems that face animals living in the desert.
2. Give three ways in which animals staying in the Arctic throughout the winter keep warm and explain how the adaptations work.
3. Give three ways in which animals living in a desert manage to keep cool without sweating so they don't lose water.

4. Give three adaptations that help plants living in dry conditions to reduce water loss from their leaves.
5. Give one example of an animal adaptation and one example of a plant adaptation that makes the organism more likely to reproduce successfully.
6. Explain why it is important to plant more trees in Ethiopia.
7. Describe carefully the best way to plant a young tree to make sure that it will survive and grow well.

Copy the crossword puzzle below into your exercise book (or your teacher may give you a photocopy) and solve the numbered clues to complete it.



Across

2 A life-supporting environment (9)

3 The struggle between organisms for resources (11)

4 The special features which allow organisms to survive in difficult conditions (10)

6 Animals which are eaten by predators (4)

7 The biological material made by living organisms (7)

8 The living components of an ecosystem (6)

11 The home of a living organism (7)

12 The greenhouse effect is due to gases such as ****** dioxide in the atmosphere (6)

Down

1 Organisms which break down droppings and dead organisms at the end of a food chain (11)

5 Non-living components of an ecosystem (7)

9 Simple links between organisms which feed off each other are known as a food ***** (5)

10 Complex feeding relationships between organisms are known as food **** (4)

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