

Characteristics and classification of living organisms

Where did life come from?

No-one knows how or even exactly when living things first appeared on Earth. Each religion and culture has its own viewpoint about the origin of life. Most scientists think that this probably happened between 3.8 billion and 4 billion years ago. The most generally believed scientific theory is that, in the strange conditions that were then present on Earth, molecules gradually associated with each other to form the very first simple cells. Once that had happened, evolution took place which led, over the unimaginable length of time between then and now, to all the different kinds of living organisms that exist today.

But this is not the only theory. Some scientists think that perhaps simple life forms arrived on this planet from outer space, carried on a meteor. This is not a crazy idea, because we know that molecules that are typical of living organisms can be found in space. But this still does not explain how life arose in the very first place.

Is Earth the only planet to support life? We do not know. So far, we have no evidence of there being any other living things out there in the universe. A project known as SETI, (Search for Extra-Terrestrial Intelligence) uses telescopes to constantly search space for radio waves that could have been sent to us from intelligent life forms on other planets (Figure 1.1). Many astronomers think that it is very unlikely that Earth is the only planet on which living things can be found – but we simply do not know. And, even if there is alien life out there somewhere, would it be anything like us?



▲ Figure 1.1

These radio telescopes in California are part of the SETI project.

1.1 Characteristics of living organisms

If you look around you, you can probably see a number of living and non-living things. It is usually easy to tell which are alive and which are not. People, for example, are obviously alive because they move around. Plants are obviously alive because they grow (Figure 1.2).

► **Figure 1.2**

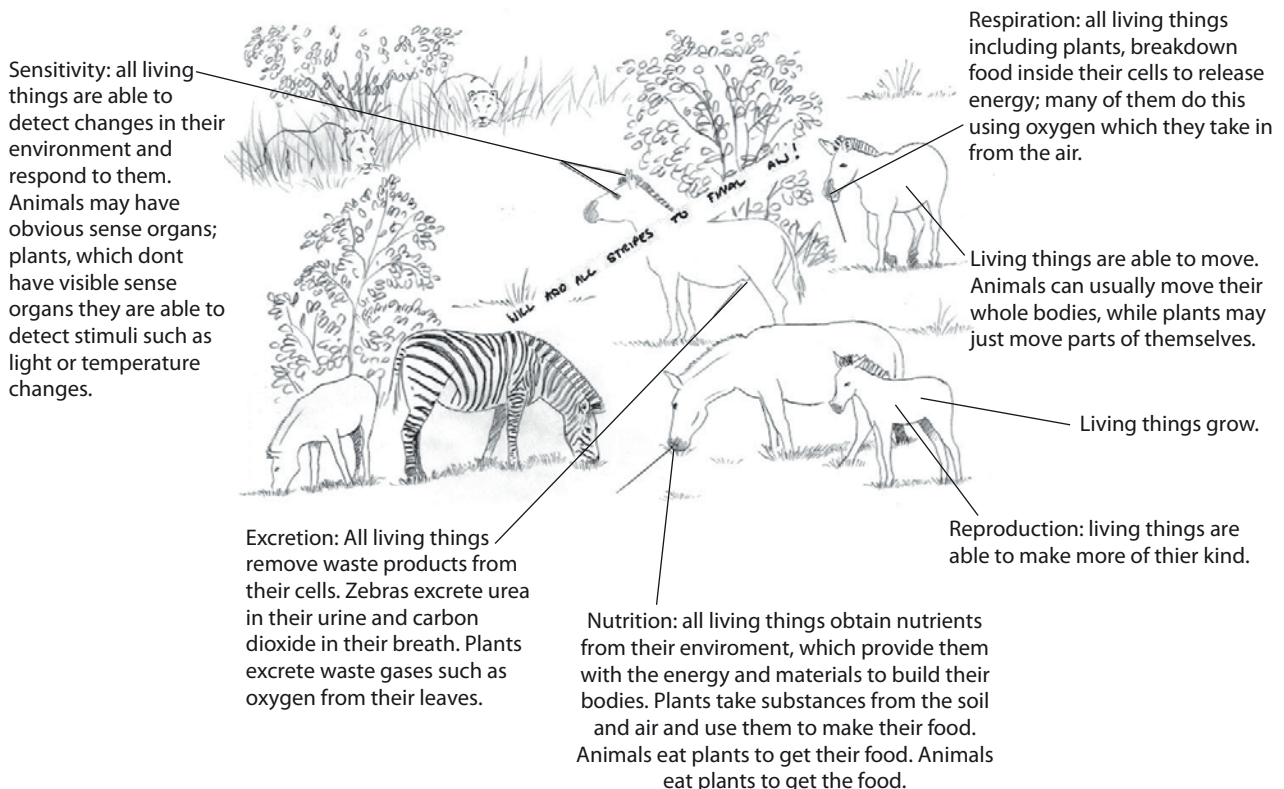
What can you see here that is alive?
What is not alive? How can you tell?



Living things are called **organisms**. Living organisms have seven characteristics that make them different from non-living things (Figure 1.3).

▼ **Figure 1.3**

The characteristics of living things.



- 1 **Nutrition** All organisms need to take in substances from their surroundings. We, like all animals, eat food. Plants have to take in carbon dioxide and water to make their food. We can define nutrition as:

the taking in of nutrients (e.g. organic substances and mineral ions) containing the raw materials for growth and tissue repair, absorbing and assimilating them.

- 2 **Excretion** Chemical reactions, often called **metabolic reactions**, take place inside the cells of every living organism. Some of the substances made by these reactions are toxic (poisonous) and must be got rid of. Others, even though they may not be harmful, are in excess of what the organism needs. Getting rid of these substances is called excretion. We can define excretion as:

the removal from organisms of toxic materials, the waste products of metabolism (chemical reactions in cells) and substances in excess of requirements.

- 3 **Respiration** All living organisms need energy. They get this by breaking down nutrients, such as glucose, inside their cells. This releases the energy from the nutrients. We can define respiration as:

the chemical reactions that break down nutrient molecules in living cells to release energy.

- 4 **Sensitivity** Living organisms are sensitive to things around them. They can sense changes in their surroundings, and respond to these changes. These changes are of many types, such as changes in temperature, light intensity, sound, day length and the presence of chemicals. We call all of these things **stimuli** (singular: stimulus). We can define sensitivity as:

the ability to detect or sense changes in the environment (stimuli) and to make responses.

- 5 **Reproduction** Every kind of living thing (but not necessarily every individual) is able to make new organisms like itself. We can define reproduction as:

the processes that make more of the same kind of organism.

- 6 **Growth** Some of the nutrients that living organisms take in are used to help cells to grow, and to help to make more cells. We can define growth as:

a permanent increase in size and dry mass by an increase in cell number or cell size or both.

(You can find out what is meant by 'dry mass' on page 000.)

- 7 **Movement** All organisms are able to move. Some, including most animals, are able to move their whole body from place to place, and this is called locomotion. But even seemingly non-moving organisms, such as plants, are able to move *parts* of themselves. If you look at some living plant cells under a microscope, you may be able to see the tiny structures within each cell moving around. We can define movement as:

an action by an organism or part of an organism causing a change in position or place.



QUESTION

- 1.1 The engine of a car uses petrol (gasoline). Oxygen from the air combines with the petrol, releasing energy which is used to turn the wheels of the car. Waste gases from the burned petrol are given off in the exhaust fumes of the car.
- Which characteristics of a car are similar to which characteristics of a living organism?
 - Explain why a car is not classified as a living organism.

1.2 Classifying living organisms

Nobody knows how many different kinds, or **species**, of living organisms there are on Earth. About 1.4 million species have been described and named. But many biologists think this may be only about one-tenth of all the species on Earth. We have almost certainly discovered most of the large land animals, but there are probably many animals living in the deep oceans which have never been seen by humans. And biologists estimate that there are millions of insects and smaller animals and plants that have not yet been discovered.

To make it easier to study these organisms, biologists have sorted them into groups. This sorting is called **classification**.

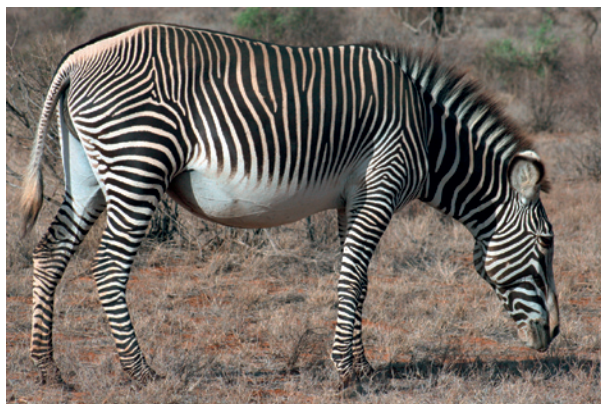
Living organisms have evolved over hundreds of millions of years. (You can read about evolution in Chapter 15.) Living organisms are all related to one another. Biologists classify them by putting closely related organisms into the same group.

Naming living organisms

The living organisms that people are familiar with all have common names. People who speak English call a zebra 'a zebra'. However, there are different kinds of zebras. For example, Grevy's zebra and the plains zebra have different stripe patterns (Figure 1.4). In Swahili, the language of the people who share their home country with zebras, Grevy's zebra is 'kanjanga' and the plains zebra is 'punda mila'. Each language has its own name for a zebra, or for different kinds of zebras.

▼ **Figure 1.4**

Grevy's zebra (left), A plains zebra (right).



To avoid confusion, biologists have given each kind of organism its own unique, two-word name. This is called a **binomial** (meaning ‘two name’). This idea was first thought of in 1735 by Linnaeus, a Swedish scientist. Linnaeus wanted to make sure that scientists all over the world could communicate about living organisms, even though they spoke different languages and so had different names for the same kind of organism. In those days, most educated people could read and write Latin, so this was the language he chose. We still use Linnaeus’s naming system today.

Each kind of organism has a Latin name made up of two words. For example, the binomial of Grevy’s zebra is *Equus grevyi*. The binomial of the plains zebra is *Equus burchelli*.

The first part of the name is the **genus** that the organism belongs to. The second part of the name is the **species**. All the different kinds of zebras, and other horse-like animals, belong to the same genus, *Equus*. But Grevy’s zebra and the plains zebra belong to different species, so the second parts of their binomials are different.

Notice that the name of the genus is given a capital letter, and the name of the species has a small letter. The name is written in italics. If you are writing by hand, you obviously cannot write in italics, so instead you can underline the name.



QUESTIONS

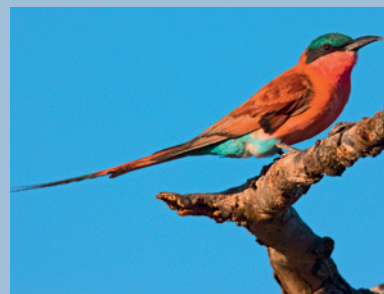
- 1.2 Humans belong to the genus *Homo* and the species *sapiens*. What is the binomial of a human?
- 1.3 Figure 1.5 tells you the names and binomials of three birds that live in southern Africa.



a) Redfronted tinker barbet,
Pogoniulus pusillus.



b) Little bee-eater,
Merops pusillus.



c) Carmine bee-eater,
Merops nubicoides.

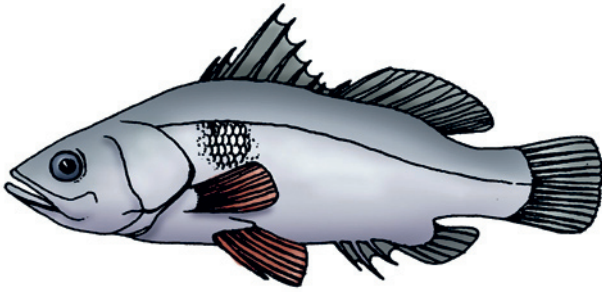
▲ **Figure 1.5** These three birds all live in southern Africa.

Which two of these birds do biologists think are most closely related? How did you work this out?

The vertebrates

Perhaps the most familiar group of organisms is the vertebrates. For many people, vertebrates are what they mean when they use the word ‘animal’. However, to a biologist, animals include all the invertebrates as well – organisms like insects and worms.

Vertebrates are classified into groups called **classes**. Figures 1.6 to 1.10 show a vertebrate from each class.



▲ **Figure 1.6**
A Nile perch, *Lates niloticus*.



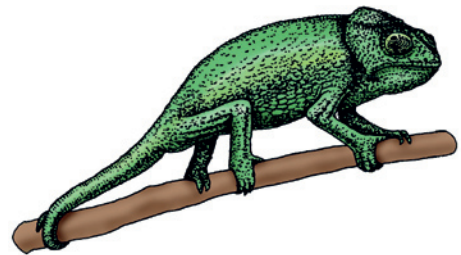
▲ **Figure 1.7**
A fire salamander, *Salamandra salamandra*.

Amphibians

These are vertebrates with a smooth, moist skin (Figure 1.7). The adults of some amphibians, such as salamanders, live on land. Others, such as newts, spend a lot of time in the water. But almost all amphibians have to go back to the water to lay their soft, jelly-like eggs. These eggs hatch into tadpoles, which gradually change into adults. Like fish, tadpoles exchange gases through gills, but adult amphibians exchange gases through their skin and through lungs. Unlike fish, amphibians have ears, and you can sometimes see their eardrums. Amphibians have four legs, or limbs.

Reptiles

These are vertebrates with a scaly skin (Figure 1.8). Some of them, such as crocodiles, spend a lot of time in water. Others, such as lizards, live on land. All reptiles lay their eggs on land. These eggs have waterproof shells. Like frogs, reptiles have ears, but their eardrums are deep inside their heads, so that you see a hole rather than the eardrum on the surface of the head. Most reptiles have four legs, although snakes have lost theirs.



▲ **Figure 1.8**
A chameleon, *Chamaeleo chamaeleon*.

Birds

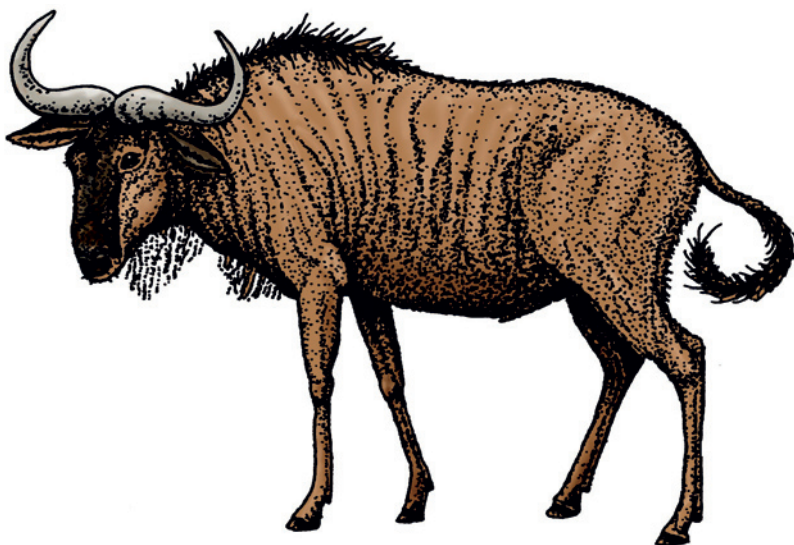
These vertebrates are very easy to recognise, because they have feathers and a beak (Figure 1.9). Birds are very closely related to reptiles, and, like reptiles, have scaly legs and holes leading to their eardrums. The front limbs of birds have become wings, and most birds can use these to fly. All birds lay their eggs on land. These eggs have harder shells than most reptile eggs.

Mammals

These vertebrates have hair (Figure 1.10). The eardrum of a mammal, like those of reptiles and birds, is deep inside the head, but all mammals have a pinna (flap) on the outside of the ear. Female mammals have mammary glands, which make milk to feed their young. Mammals do not lay eggs. Mammals have teeth of different types – incisors, canines, premolars and molars. Other vertebrates have only one type of tooth, if they have them at all.



▲ **Figure 1.9**
A sacred ibis, *Threskiornis aethiopicus*.



◀ **Figure 1.10**
A gnu or wildebeest, *Connochaetes taurinus*.

 **QUESTION**

1.4 Copy Table 1.1, then fill in the spaces. The first row has been done for you. You can find the information you need on pages 00–00.

▼ **Table 1.1**
Characteristics of some vertebrates.

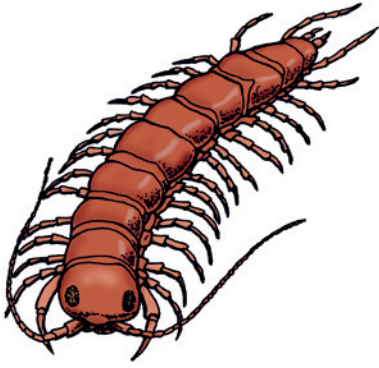
Class	Body covering	Limbs	Ears	Eggs	Any other points
Fish	Scales	No proper limbs; they have fins to help with swimming and balance.	No ears; they have a lateral line instead.	Surrounded by soft jelly and laid in water.	Almost all fish live in water.
Amphibians					
Reptiles					
Birds					
Mammals					

 **Activity 1.1**
Classifying vertebrates

Arthropods

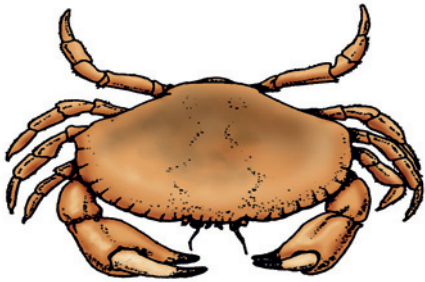
There are more different species of arthropods on Earth than all other animals put together. Arthropods are invertebrates, which means that they do not have a backbone. Arthropods have the following characteristics.

- They have jointed legs.
- They have a hard, outer covering over their bodies, called an **exoskeleton**. This protects them, supports them and has muscles attached to it to allow them to move. In terrestrial (land-living) arthropods it also stops their bodies from losing water and drying out.
- The body of an arthropod is always divided into many segments.



▲ **Figure 1.11**
A myriapod, the centipede *Lithobius*.

▶ **Figure 1.12**
An insect, the desert locust *Schistocerca gregaria*.



▲ **Figure 1.13**
A crustacean, the edible crab *Cancer pagurus*.

▶ **Figure 1.14**
An arachnid, the North African scorpion *Androctonus australis*.

There are several different groups of arthropods, including **myriapods**, **insects**, **crustaceans** and **arachnids**.

Myriapods

Myriapods (Figure 1.11) include the centipedes and millipedes. They are arthropods with long, thin bodies made up many similar segments. They have many pairs of legs. ('Myriapod' means 'thousand legs'.) Myriapods have a single pair of antennae. Centipedes are usually fast-moving predators. Millipedes generally move more slowly, and are herbivores.

Insects

Insects (Figure 1.12) are probably what most people first think of when arthropods are mentioned. Insects have a body that is clearly divided into a head, a thorax and an abdomen. You can usually see that the thorax is made up of three segments, and the abdomen of around 10 or 11 segments. Insects have three pairs of jointed legs, one pair attached to each of the three segments of the thorax. Most insects have two pairs of wings, also attached to the thorax. Insects have a single pair of antennae. Most adult insects have compound eyes.

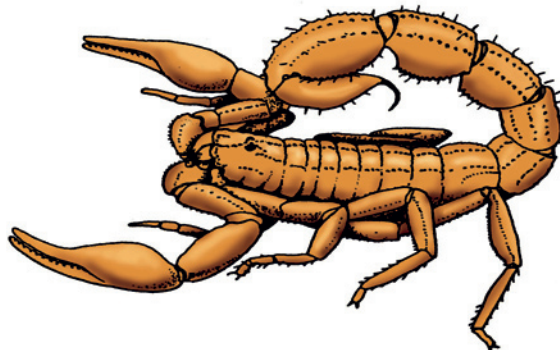


Crustaceans

Crustaceans (Figure 1.13) include crabs, shrimps and woodlice. Their exoskeleton is usually especially strong, because it contains calcium salts that make it very hard. Crustaceans have many pairs of legs (but not as many as myriapods). Crabs have five pairs. Crustaceans have two pairs of antennae. Their body is made up of a combined head-and-thorax called the cephalothorax, and an abdomen. Each of these parts is made up of many segments.

Arachnids

Arachnids (Figure 1.14) are the spiders and scorpions. Like crustaceans, their body is divided into a cephalothorax and abdomen. They have four pairs of legs and no antennae.





QUESTION

1.5 Draw a table (similar to the one in Question 1.3) with five columns and five rows. In the first column, list the four groups of arthropods we have just discussed. The remaining four columns should be headed:

- Number of legs
- How the body is divided up
- Number of antennae
- Other special features.

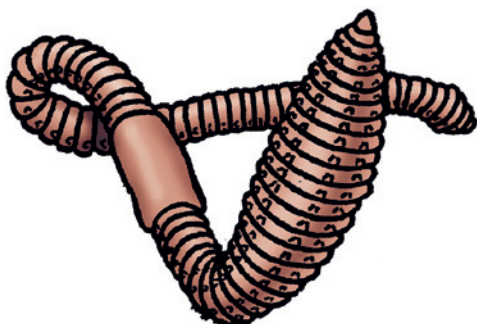
Now fill in all the spaces in your table, to summarise the ways in which the four groups of arthropods can be identified.



Activity 1.2
Classifying arthropods

Annelids

Annelids are worms with bodies made up of many segments (rings). Earthworms are annelids, and so are the tube worms that you may see in rock pools on a beach. Leeches are also annelids. Figure 1.15 shows an annelid.



◀ **Figure 1.15**

An annelid, the earthworm *Lumbricus terrestris*.

Some annelids have an obvious head, which may have antennae. For other annelids, though, it can be difficult to tell which end is which. Annelids never have legs, but some of them do have tiny, stiff hairs called chaetae which help them to grip the surface they are travelling over.



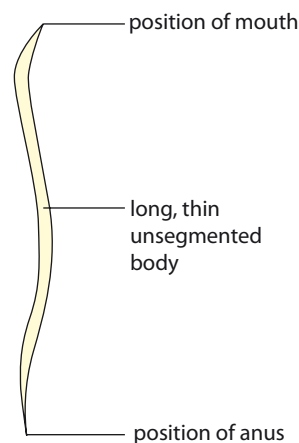
QUESTION

1.6 Describe **one** similarity and **one** difference between arthropods and annelids.

Nematodes

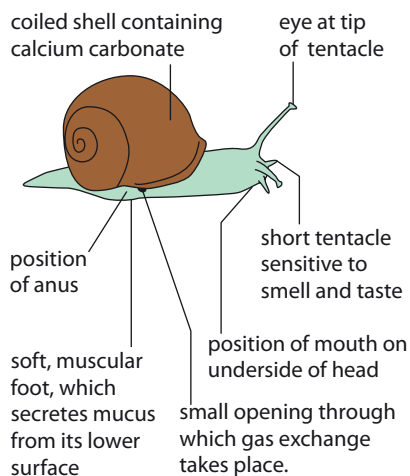
Nematodes, like annelids, are worms. However, their bodies are not divided into segments. Nematodes usually just look like long, thin, white animals with no obvious head and no legs (Figure 1.16). They do not have chaetae.

Many nematodes are parasites, some of which live in the digestive systems of other animals. Other kinds of nematodes live in the soil.



▲ **Figure 1.16**

A nematode, *Ascaris*.



▲ **Figure 1.17**

A mollusc, the garden snail *Helix aspersa*.

Molluscs

Molluscs include slugs, snails, mussels, oysters, limpets, octopuses and squids (Figure 1.17). All molluscs have soft bodies that are not divided into segments. Sometimes the body is enclosed in a hard shell made of calcium carbonate. Sometimes, as in slugs, there is no shell. Sometimes, as in octopuses and squids, there is a shell *inside* the soft body.

Most molluscs can move around on a soft foot that secretes slimy mucus to help them slide along. Many of them, such as slugs and snails, have a rough tongue that they use to scrape away at leaves or other plant material that they eat. Some, such as mussels, are filter feeders. They draw water through their gills and trap any tiny bits of food that are floating in it. Octopuses and squids are much more mobile than most molluscs and they can swim actively and use their long tentacles to catch other animals to eat.

Plants

So far in this chapter, all the living organisms we have looked at have been animals. Animals belong to the animal kingdom, one of five **kingdoms** into which all living organisms are grouped. If you look at Figure 1.18, you can pick out the other four kingdoms. One of these is the **plant kingdom**. Within each kingdom, organisms are divided into groups called phyla (singular: phylum).

The fundamental difference between plants and animals is the way that they feed. Plants **photosynthesise**. This means that they use energy from sunlight to make sugars out of carbon dioxide and water. They use a green pigment called **chlorophyll** to capture the energy from sunlight. This is why plants are green.

All living organisms are made up of **cells**. We will look at these in detail in Chapter 2. Plant cells are different from animal cells because they are always surrounded by a **cell wall** made out of a substance called **cellulose**. Animal cells do not have cell walls.

There are several different phyla of plants, but you only need to know about one of them – the **flowering plants**. It is not difficult to remember that these are the kinds of plants that have flowers. Non-flowering plants include mosses, ferns and liverworts.

Flowers are the parts of a plant responsible for sexual reproduction. Inside the flower, fertilisation takes place and **seeds** are produced. Each seed contains a tiny embryo plant, which can grow into an adult plant after the seed germinates. The rest of the plant is made up of **roots**, **stems** and **leaves**.

Monocots and dicots

The flowering plants are divided into two groups. These are the **monocotyledonous plants** and the **dicotyledonous plants** (Figure 1.19 and Figure 1.20). They are often called monocots and dicots for short. These names refer to the number of cotyledons in their seeds. Cotyledons are structures that, in some plants, grow into the first leaves when the seed germinates (page 000). Seeds of monocots have just a single cotyledon, while seeds of dicots have two.

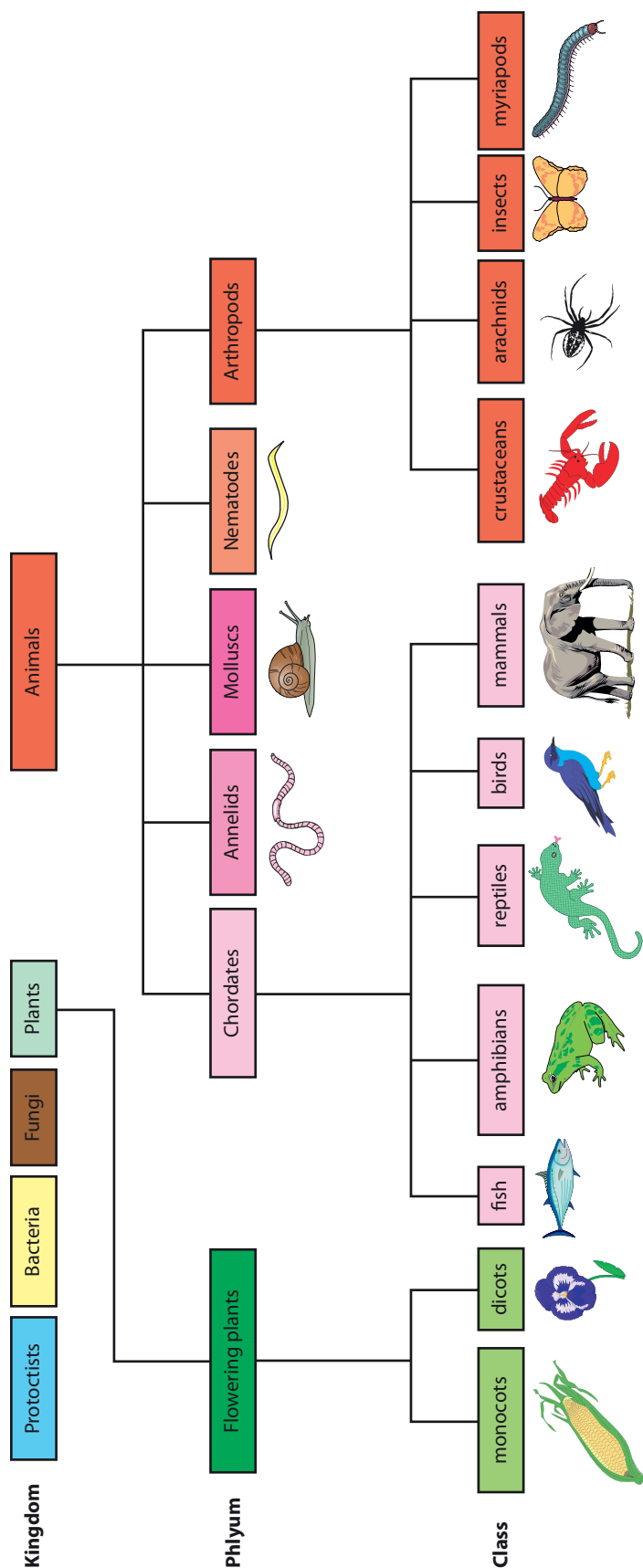
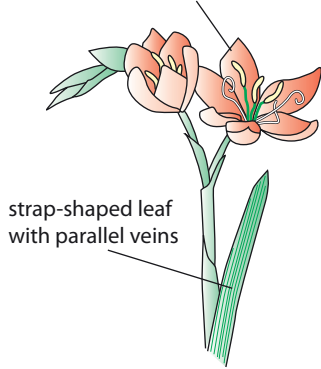


Figure 1.18
 A summary of the classification of some important groups of living organisms. Vertebrates are part of phylum Chordata in the animal kingdom.

flower with three petals, three sepals,
three stamens and three carpels

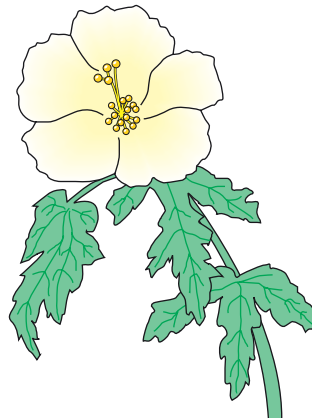


▲ **Figure 1.19**

A monocot, the kaffir lily *Schizostylis*.

▶ **Figure 1.20**

A dicot, the hibiscus *Hibiscus trionum*.



Even if you don't have any seeds to look at, you can still often tell monocots and dicots apart. Many monocots have long, strap-shaped leaves with parallel veins. Most dicots have leaves with a branching pattern of veins.

If you can see the flowers, this can give you another clue. Monocots usually have flowers with numbers of parts divisible by three. For example, they tend to have flowers with three or six petals. Dicots generally have flowers with numbers of parts divisible by four or five. For example, they may have flowers with four, five or ten petals.

▶ **Figure 1.21**

Maize leaves.



QUESTION

1.7 Fig 1.21 shows some leaves of a maize plant.



- Is maize a monocot or a dicot? How can you tell?
- What would you expect to find if you could look closely at (i) a maize seed and (ii) a maize flower?



Activity 2.3

Drawing biological specimens

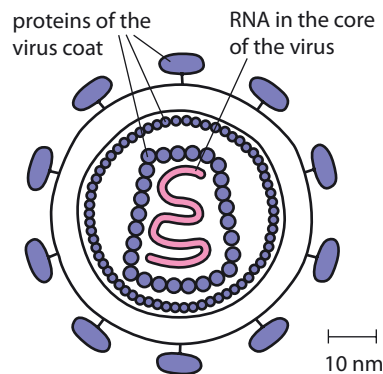
Viruses

Viruses are very, very small. A virus is only about 100 nm across. (nm stands for nanometre. One nanometre is 1×10^{-9} m.)

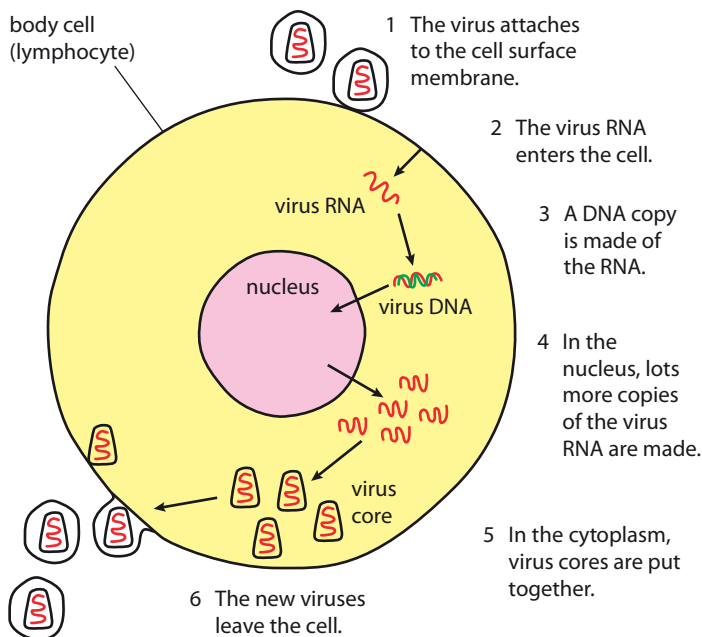
Most scientists would say that viruses are not actually living things. This is because they are not made of cells, and they do not have any of the characteristics of living things, unless they hijack a living cell. Only then can they reproduce.

Figure 1.22 shows a virus. Viruses have an outer coat made of protein and an inner core made of nucleic acid. Nucleic acids are the hereditary material of all living things. DNA and RNA are nucleic acids. Some viruses contain RNA, and some contain DNA. The virus in Figure 1.22 is the human immunodeficiency virus, HIV, which contains RNA.

Figure 1.23 shows how HIV reproduces. It gets inside a white blood cell in a person's body, and forces the cell to make multiple copies of the virus. The new viruses burst out (Figure 1.24) and are ready to infect more white blood cells. Not surprisingly, this kills the cells.



▲ Figure 1.22
The human immunodeficiency virus, HIV. It is drawn as though part of its outer protein coat has been removed, so that you can see inside.



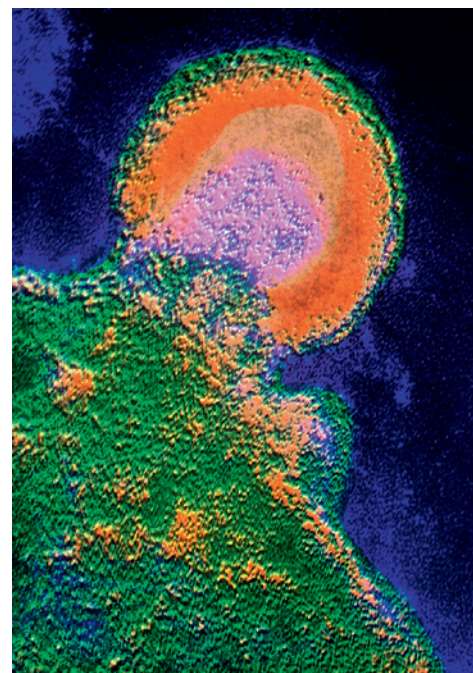
◀ Figure 1.23
How HIV reproduces. Viruses cannot reproduce on their own, but only inside a living cell. The RNA inside this virus carries instructions for making more viruses just like itself.

There are many different viruses that can infect human cells, including the cold virus and the polio virus. Some viruses infect other kinds of organisms, such as plants or bacteria.

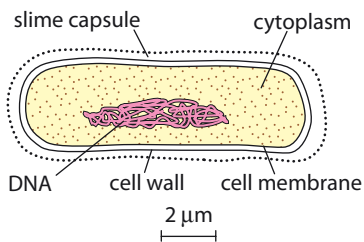
Bacteria

Bacteria are everywhere. They live in water, in soil, in food, in you and almost everywhere else you can think of. Someone has worked out that the total mass of all the bacteria in a human body is around 2 kg. Many of these live in the digestive system, and they do no harm to us at all.

Bacteria are single-celled organisms. Their cells are much smaller than the cells of plants and animals. A bacterial cell is about one thousandth the size of one of the cells of which you are constructed.



▲ Figure 1.24
A human immunodeficiency virus, HIV, bursting out of a white blood cell (shown in green) ($\times 000$).



▲ **Figure 1.25**

A bacterium. Rod-shaped bacteria like this are called bacilli.

Bacterial cells, like plant cells, have cell walls (Figure 1.25). However, these walls are not made of cellulose. They contain substances called peptidoglycans.

The most important difference between the cells of bacteria and all other organisms is that bacterial cells never have a nucleus. As you will see in Chapter 2, animal and plant cells do have a nucleus, in which they keep their DNA. In bacteria, the DNA is just kept as a long strand in the cytoplasm.

Fungi

Long ago, fungi were classified as plants. Like plants, they grow anchored in one spot, and they do not appear to feed in the same way that animals do.

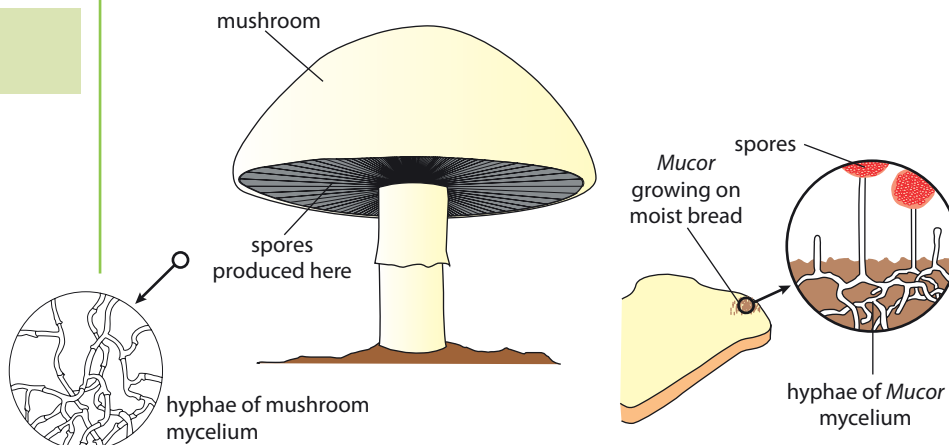
But a closer look shows that they are really not very like plants at all. Most importantly, fungi do not photosynthesise and never contain chlorophyll. Instead, they feed by secreting enzymes onto their food, digesting it and then absorbing it into their cells. Fungi can feed on almost any organic material (that is, substances made by living things) such as our own food, animal droppings or even old leather shoes. This is called **saprotrophic** nutrition. Many fungi live in the soil, and digest whatever animal and plant waste products are to be found amongst the soil particles. Many fungi live in close association with the roots of plants, an arrangement from which both the fungus and the plant appear to benefit.

Figure 1.26 shows some different kinds of fungi. The main body of a fungus is called a **mycelium**. The mycelium is made up of many threads called **hyphae**. The hyphae grow through whatever the fungus is feeding on. Each hypha is surrounded by a cell wall, but this is not made of cellulose like plant cells. Different fungi have different substances in their cell walls, such as chitin.

At certain times of year, some fungi produce mushrooms or toadstools above the ground. These are their reproductive structures, producing thousands of tiny spores which can be dispersed to other areas where they grow into a new mycelium.

▶ **Figure 1.26a**

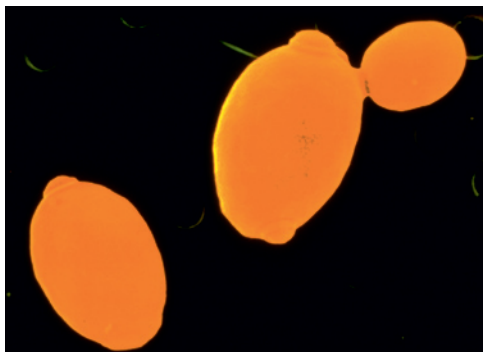
A mushroom, *Agaricus*.



▲ **Figure 1.26b**

A bread mould, *Mucor*.

Yeast is a rather strange fungus, because it is made up of a single cell. Yeast has no hyphae and no mycelium.



◀ **Figure 1.26c**
Yeast cells, *Saccharomyces*, as seen with a microscope ($\times 0000$).

Adaptations to the environment

All living things have features that help them to survive in their environment. These features are called **adaptations**.

Most fungi, for example, have :

- bodies made of long thin threads that can grow through the soil or through whatever they are feeding on (such as a piece of bread)
- hyphae which can secrete enzymes to digest the material they are growing on
- the ability to grow tall mushrooms or toadstools in which spores are produced, which can be carried away on the wind or on the feet of an insect.

1.3 Using keys

If you want to find out the name of a living organism you have found, you may be able to look it up in a book and find a picture of it. This is often a good way of identifying organisms. But it does not always work. Perhaps your organism is a different colour from the picture, or perhaps there is no picture of it, or the picture is not good enough for you to be sure that it really shows the organism you have found.

Biologists often use a **dichotomous key** to help them to identify an organism. This is a list of descriptions, arranged in pairs. You look at the first pair of descriptions and decide which one of them fits your organism. In a good key, the descriptions are written so that only one of the pair can fit. So, for example, the first pair of characters might be:

- has legs
- does not have legs.

Even if you have never seen your organism or anything remotely like it before, you should be able to tell if it has legs or not. It is really important that these pairs of descriptions are clearly different. For example, you would not find it easy to decide between this pair:

- has long legs
- has short legs.

You would have no idea whether your organism's legs were long or short. They might look quite long to you, but perhaps the person who wrote the key thought they were short. Good keys always give you a perfectly clear choice to make, which doesn't depend on needing to compare the organism with anything else.

▲ **Figure 1.27**
Five kinds of insects.

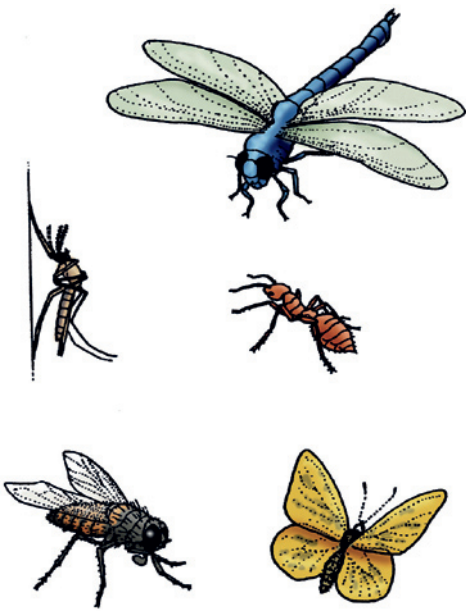


Figure 1.27 shows five kinds of insects. We can use the key below the figure to identify them. Take one organism at a time. Each time you have decided which of the pair of descriptions fits this organism, move on to the number that follows that description.

- | | | |
|---|---------------------------------------------|-----------|
| 1 | wings present | go to 2 |
| | wings absent | ant |
| 2 | has one pair of wings | go to 3 |
| | has two pairs of wings | go to 4 |
| 3 | legs not as long as body | house fly |
| | legs longer than body | mosquito |
| 4 | wings covered with brightly coloured scales | butterfly |
| | wings transparent | dragonfly |

For example, we can identify **A** like this. Look at the choices in **1**. **A** has wings, so we go on to **2**. It has two pairs of wings, so we move to **4**. It has transparent wings, so it is a dragonfly.

Try working through the other four organisms in the same way.

▲ Figure 1.27
Five kinds of insects.



QUESTION

- 1.8 Write a dichotomous key to help a stranger to identify five people in your class. You should be able to do it in no more than three or four pairs of descriptions.

Summary

Now that you have completed this chapter, you should be able to:

- list and describe the characteristics of living organisms
- define the terms *nutrition*, *excretion*, *respiration*, *sensitivity*, *reproduction*, *growth* and *movement*
- define and describe the binomial system of naming species
- classify the five classes of vertebrates – fish, amphibians, reptiles, birds and mammals – using their visible external features
- list the main visible, external features used in the classification of flowering plants, and the features of monocotyledonous and dicotyledonous flowering plants
- list the main visible, external features used in the classification of arthropods, and of insects, crustaceans, arachnids, nematodes and molluscs
- list the main features used in the classification of viruses, bacteria and fungi, and their adaptation to their environment
- use a dichotomous key to identify an unknown organism