1.1 Biology is the study of life and living organisms

OBJECTIVES

- To understand that living things differ from non-living things
- To be able to list the characteristics of living things
- To understand that energy must be expended to maintain life

The dawn of life

Scientists believe that the Earth was formed from an enormous cloud of gases about 5 billion years ago. Atmospheric conditions were harsh (there was no molecular oxygen, for example), the environment was very unstable and conditions were unsuitable for life as we know it.

Many scientists believe that the first and simplest living organisms appeared on Earth about 2.8 billion years ago. These organisms probably fed on molecules in a sort of 'soup' (called the **primordial soup**) which made up some of the shallow seas on the Earth at that time. A question that has always intrigued scientists, philosophers and religious leaders is:

> What distinguishes these first living organisms from the molecules in the primordial soup?

In other words, what is life?

Characteristics of living organisms

You know that a horse is alive, but a steel girder is not. However, it is not always so obvious whether something is alive or not – is a dried-out seed or a virus particle living or non-living? To try to answer questions like this, biologists use a list of characteristics that living organisms show.

Living organisms:

- **Respire**
- Show **irritability** (sensitivity to their environment) and **movement**
- **Nourish** themselves
- **Grow** and **develop**
- **Excrete**
- **Reproduce**

The opposite page gives more details of the characteristics of life.

You may see other similar lists of these characteristics using slightly different words. You can remember this particular list using the word RINGER. It gives **Ringer's solution** its name. This is a solution of ions and molecules that physiologists use to keep living tissues in – it keeps the cells alive.

As well as the characteristics in the 'ringer' list, living things have a **complex organisation** that is not found in the non-living world. A snowflake or a crystal of quartz is an organised collection of identical molecules, but even the simplest living cell contains many different complex substances arranged in very specific structures.

Living things also show **variation** – the offspring are often different from one another and from their parents. This is important in adaptation to the environment and in the process of evolution.

How the characteristics of life depend on each other

Each of the characteristics of life is linked to the others – for example, organisms can only grow if they are nourished. As they take nourishment from their environment, they may also produce waste materials which they must then excrete. To respond to the environment, they must organise their cells and tissues to carry out actions. Because of the random nature of reproduction, they are likely to show variation from generation to generation.

Depending on energy

The organisation in living things and their ability to carry out their life processes depends on a supply of **energy**. Many biologists today define life as a set of processes that result from the organisation of matter and which depend on the expenditure of energy.

In this book we shall see:

- how energy is released from food molecules and trapped in a usable form
- how molecules are organised into the structures of living organisms
- how living organisms use energy to drive their life processes.

1. Nutrition: the taking in of materials for energy, growth and development. Plants require light, carbon dioxide, water and ions and make their foods using the process of photosynthesis. Animals require organic compounds and ions (and usually water) and obtain their foods 'ready made' by eating them.

2. Growth and development: the processes by which an organism changes in size and in form. For example, as a young animal increases in size (as it grows), the relative sizes of its body parts change (it develops). Growth is a **permanent** increase in size and dry mass, and results from an increase in cell number or cell size or both.

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

4. Reproduction: the processes that make more of the same kind of organism – new individuals. An organism may simply split into two, or reproduction may be a more complex process involving fertilisation. Reproduction makes new organisms of the same species as the parents. This depends on a set of chemical plans (the genetic information) contained within each living organism.

5. Respiration: the chemical reactions that break down nutrient molecules in living cells to release energy for metabolism. The form of respiration that releases the most energy uses oxygen. Many organisms have **gaseous exchange** systems that supply their cells with oxygen from their environment.

6. Irritability (or sensitivity): the ability to detect or sense changes in the internal or external environment and to make appropriate responses. The changes are called stimuli and the responses often involve **movement** (an action by an organism or part of an organism causing a change of position or place).

Q

1. Approximately how many years passed between the formation of the Earth and the appearance of the first living organisms?
2. What sort of molecules do you think might have been present in the primordial soup?
3. **RINGER** is a word that helps people remember the characteristics of living organisms. Think of your own word to help you remember these characteristics.
4. Suggest **two** ways in which reproduction is essential to living organisms.

1.2 The variety of life

OBJECTIVES

- To know that organisms can be classified into groups by the features that they share
- To appreciate why classification is necessary
- To understand the use of a key
- To be able to name the five kingdoms, and describe their distinguishing characteristics
- To understand the hierarchy of classification
- To know why a binomial system of nomenclature is valuable

The need to classify living things

Variation and natural selection lead to evolution. Evolution, and the isolation of populations, leads to the development of new species (see page 238). Each species has different characteristics, and some of these characteristics can be inherited by successive generations of this species. Observing these inherited characteristics allows scientists to put all living organisms into categories. The science of placing organisms into categories on the basis of their observable characteristics is called **classification**. There are so many different types of living organism (i.e. an enormous variety of life) that the study of these organisms would be impossible without an ordered way of classifying them.

E For example, classification is important in

- **Conservation**: scientists need to be able to identify different organisms in habitats which are being managed, and they need to control which organisms are used in breeding programmes
- **understanding evolutionary relationships**: organisms which have many of the same features are normally descended from common ancestors. The more features shared by different organisms, the more recently they separated from one another during evolution.

Classification keys

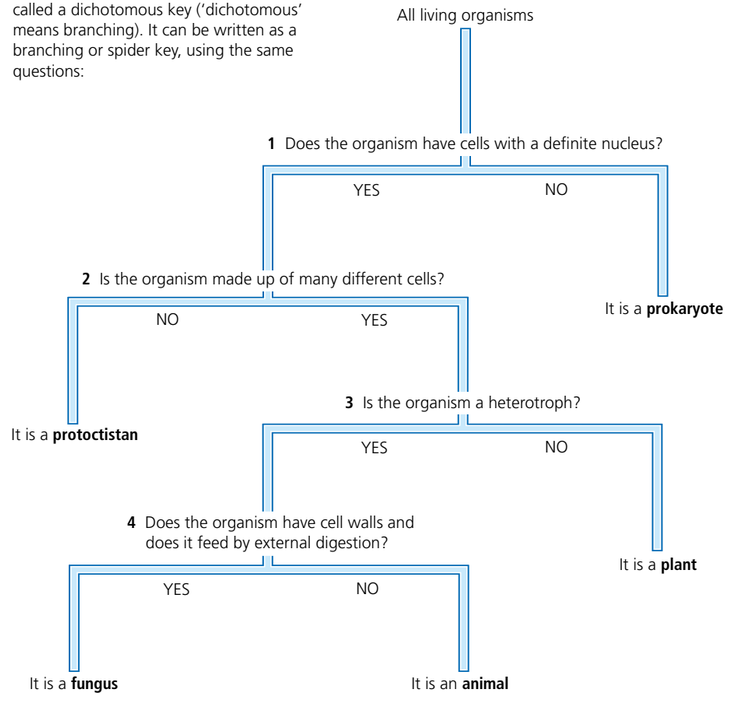
Taxonomists (people who study classification) place organisms into groups by asking questions about their characteristics, such as 'Does the organism photosynthesise?' or 'Does the organism contain many cells?'. A series of questions like this is called a **classification key**. Examples of such keys are shown below and on the opposite page.

E The characteristics of living organisms used to make classification keys have traditionally been based on **morphology** and **anatomy** (the shape and structure of organisms) because this was what the scientists could easily observe and measure.

1 Does the organism have cells with a definite nucleus?	YES NO	Go to question 2 It is a prokaryote
2 Is the organism made up of many different cells?	YES NO	Go to question 3 It is a protoctistan
3 Is the organism a heterotroph?	YES NO	Go to question 4 It is a plant
4 Does the organism have cell walls and does it feed by external digestion?	YES NO	It is a fungus It is an animal

▲ A key may be used to place an organism in one of the five kingdoms

▶ This kind of key, with only two answers to each question (in this case, YES or NO), is called a dichotomous key ('dichotomous' means branching). It can be written as a branching or spider key, using the same questions:



The five kingdoms
Prokaryote
Protoctistans
Plants
Fungi
Animals

Branching keys are easy to use, but take up a lot of space when fully drawn out. For this reason the listed form of a dichotomous key like the one shown opposite is usually used for identification of organisms outside the laboratory.

Five kingdoms

Using the key above, it is possible to place any living organism into one of five very large groups. These groups, distinguished from one another by obvious characteristics of morphology and anatomy, are called the **five kingdoms**. Each of these kingdoms contains an enormous number of different species, and keys can be used within a kingdom to place any individual species into further groups. The diagram on the next page shows the names of these groups, and how the lion is classified within the Animal Kingdom.

Hierarchy of classification*

The sequence of kingdom, **phylum, class, order, family, genus** and **species** is called a **hierarchy of classification**.

Notice that each classification group is given a name. Lions belong to the class Mammalia and the order Carnivora, for example. The final two group names are written in *italics* – this is a worldwide convention amongst scientists. The lion is called simba in Swahili,

león in Spanish and leu in Romanian but is known as *Panthera leo* to scientists in each of these countries. This convention of giving organisms a two-part name made up of their genus and species was introduced by the Swedish biologist Carolus Linnaeus. He gave every organism known to science a two-part name based entirely on the body structure of the organism. This binomial system of nomenclature is still in use today (binomial = 'two name').

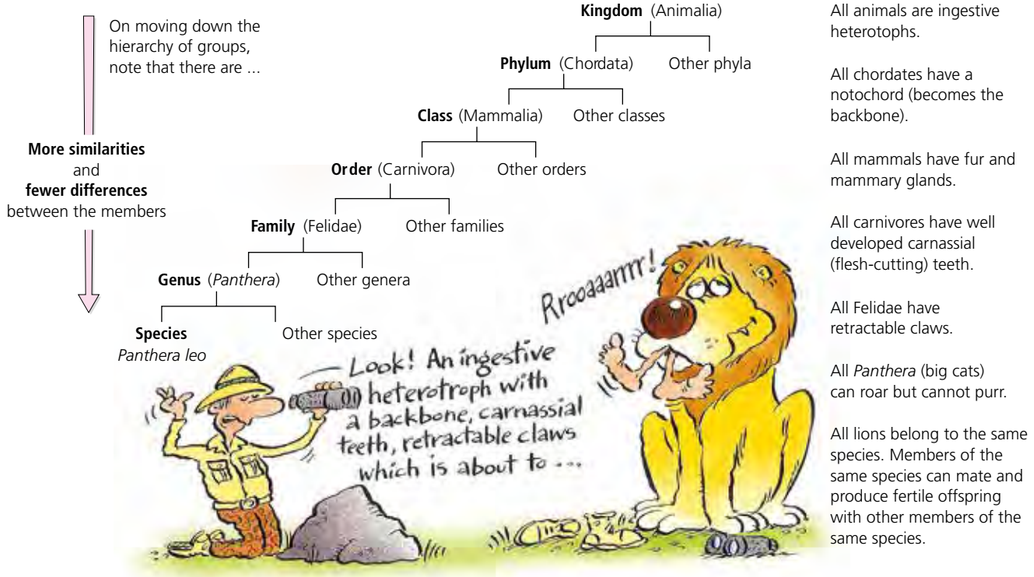
E New species today may be classified based on characteristics such as protein structure, chromosome number or gene (DNA or RNA) sequence, which Linnaeus knew nothing about. Each organism, even each individual, has its own DNA profile. Scientists can compare the DNA profiles of different species.

E How this helps in classification

- **Protein structure:** organisms which are closely related (share a more recent ancestor) have very similar amino acid sequences in proteins such as haemoglobin.

Organisms that are closely related have very similar DNA profiles – humans and chimpanzees, for example, share 98.6% of their genes!

- **DNA structure:** closely related organisms have very similar base sequences in DNA (see page 214) because there has been less 'evolutionary time' for mutation to change these base sequences.



▲ The hierarchical classification of the lion

Q

1 State which of the following is the best definition of classification.
   - **a** Giving every organism a name
   - **b** Arranging organisms into groups
   - **c** Describing the external features of organisms
   - **d** Identifying all living organisms

2 State which of the following is the correct binomial name for the English oak (a species of oak tree).
   - **a** *Quercus robur*
   - **b** *Quercus Robur*
   - **c** *quercus robur*
   - **d** *QUERCUS ROBUR*

3 Arrange these classification groups in order of size (from the largest to the smallest):
class, family, genus, kingdom, order, phylum, species.

4 The scientific names for the weasel and mink are *Mustela nivalis* and *Mustela vison*, respectively. Both of these animals belong to the order Carnivora, as do the fox (*Vulpes vulpes*) and otter (*Lutra lutra*). The otter, mink and weasel all belong to the family Mustelidae.
   - **a** Which feature must they have in common to belong to the order Carnivora?
   - **b** Which two animals are most closely related?
   - **c** Which animal is the most different from the other three?
   - **d** Suggest one feature that places all of these organisms in the Animal Kingdom.

5 The scientific name for the human is *Homo sapiens*. State the meaning of this name.

6 The table below lists some of the characteristics of living organisms.
   - **a** Match each characteristic with its definition. Write the letter and number to show your answer, for example, **a–4**.

Characteristic	Definition
a excretion	**1** the ability to detect changes in the environment
b nutrition	**2** processes that make more of the same organism
c sensitivity	**3** removal of the waste products of metabolism
d reproduction	**4** taking into the body of materials for energy, growth and development

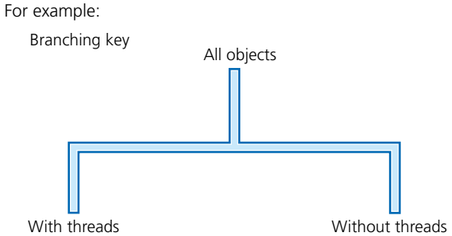
   - **b** Suggest why many biologists believe that respiration is the most significant characteristic of a living organism.

MAKING A KEY – INVESTIGATION

Examine the collection of objects.

- Choose a feature that allows you to divide the group into two approximately equal-sized subgroups.
- Draw a 'branch/fork' and use the feature that you have chosen to place each object into one of the two groups.

For example:



- Repeat this branching process until you have separated all the objects on the basis of some observable external characteristic.
- Remove all the objects and ask one of your classmates to use the key to identify one of the objects (you choose which one they should try to identify).

1.3 Fungi

OBJECTIVES

- To know the structure of a fungus
- To understand the methods of nutrition used by fungi
- To understand the use of spores in fungal reproduction
- To appreciate the impact of fungi on the lives of humans

Fungal cells have a common structure

The fungi are a very large group of organisms. They range in size from single-celled yeasts to enormous fungi whose underground parts may occupy an area greater than a football or hockey field.

Fungal cells have a cell wall made of a mixture of substances including **chitin**. The cytoplasm contains many organelles including nuclei, ribosomes and mitochondria (see page 24), because the fungus manufactures digestive enzymes. It feeds by **saprotrophic** ('dead-feeding') **nutrition**, as illustrated below.

Reproduction in fungi

Single-celled yeasts reproduce asexually by binary fission, but all other fungi reproduce by the production of **spores**.

Requirements of fungi

Fungi have very similar requirements to those of bacteria, that is:

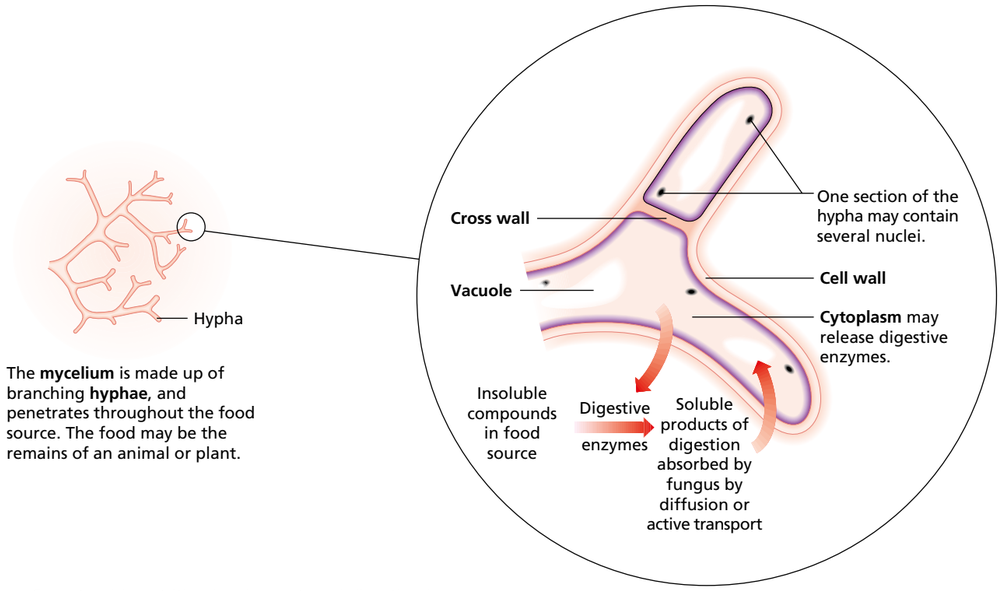
- a moist environment, so that they can absorb the soluble products of digestion of their food source in solution
- a warm environment, so that enzymes can work at their optimum temperature
- a nutrient source to provide the raw materials and energy required for growth.

Fungi do not require light because they do not rely on photosynthesis for the production of food compounds. This means that fungi are rarely found in light environments, because such environments are usually too warm and dry for fungal growth.

The importance of fungi

Fungi have a number of effects on the lives of humans. For example:

- they are **decomposers**, and play a vital role in **nutrient cycles** (see page 254)
- mould fungi consume food which might otherwise be eaten by humans (see page 254)
- fungi may be agents of disease, as in athlete's foot, for example (see page 112)
- they may themselves be a source of food, for example, mushrooms
- fungi are used in biotechnology – the brewing and baking industries (see page 276) are entirely dependent on the activities of yeast, for example.



▲ Saprotrophic nutrition involves external digestion by enzymes