Classification of past and present life on Earth

The study of present-day organisms increases our understanding of past organisms and environments

4.1 The need to classify organisms

- ***explain the need for scientists to classify organisms***

Biological classifications

The discovery of how different organisms are related is summarised in biological classifications. The classification of life is a hierarchy of names (taxonomic ranks) that includes all known organisms on Earth.

Scientific classification is an efficient, accurate way of communicating about organisms between scientists. When based on relationships, this kind of classification is predictive and useful for all areas of biology. Current knowledge of how organisms are related through evolutionary descent is summarised in biological classification.

The word 'taxonomy' is used to refer to the methods and principles of classification and rules that govern the naming of all organisms.

Scientists need to classify organisms to assist in the following:

- s*implification*—a classification system makes it easier to simplify the description of groups of organisms and bring a sense of order to the vast range of groups on Earth
- *communication*—by using a name for a group of organisms, such as *Eucalyptus*, scientists can communicate with one another about the group without having to list all the properties known to occur in every member species
- *predictions*—classification serves also to predict information that we do not yet have. For example, if a set of organisms share characteristics A, B, C and D that no other organisms have, and we find another organism of which all we know is it has characteristics A and B, we can predict that it will also have C and D. Predicting information is useful. For example, the Morton Bay chestnut (see Fig. 4.1) contains a chemical that controls cancer cells and inhibits the AIDS virus. In search for other sources of this medically important chemical, researchers turn to taxonomy to reveal related plants, finding the *Alexa* from South America.
- *relationships*—current knowledge of how organisms are related through evolutionary descent is summarised in biological classification. It assists in interpreting relationships between groups of organisms, which has become a rapidly changing and evolving area due to advances in biochemical technologies
- *conservation*—classification provides us with information about the relationship of groups of organisms with their environment. The classification of groups of organisms

(a)

provides valuable information about the functioning of the organism and their interactions with their environment, and those that are rare or endangered may be protected from further decline using this vital information.

(b)

Figure 4.1 Morton Bay chestnut (*Castanospermum australe*)—native to coastal rainforests and beaches in Australia from around Lismore, NSW to Cape York Peninsula, Queensland: (a) tree can reach heights of up to 30m; (b) seeds inside seed pod may contain valuable chemicals

Construction and use of dichotomous keys

- ***perform a first-hand investigation and gather information to construct and use simple dichotomous keys and show how they can be used to identify a range of plants and animals using live and preserved specimens, photographs or diagrams of plants and animals***

FIRST-HAND INVESTIGATION

BIOLOGY SKILLS

P13
P14
P15

Aim

1. To gather information.
2. To construct simple dichotomous keys.
3. To show how dichotomous keys can be used to identify a range of plants and animals.

Background information

A dichotomous key is used to make the identification of organisms simple, quick and easy. This type of key uses two alternatives at each level of a flowchart or diagram in order to classify organisms. Each key level requires the observation of structural or visual characteristics of the unknown organism and a decision of one description out of two alternatives as you move through the key. Dichotomous keys may be represented in two ways: one is represented as a basic flowchart; the other is represented by numbers and letters. They both work exactly the same; however, one is more simplified than the other (see Fig. 4.2).

TR

Extension activity

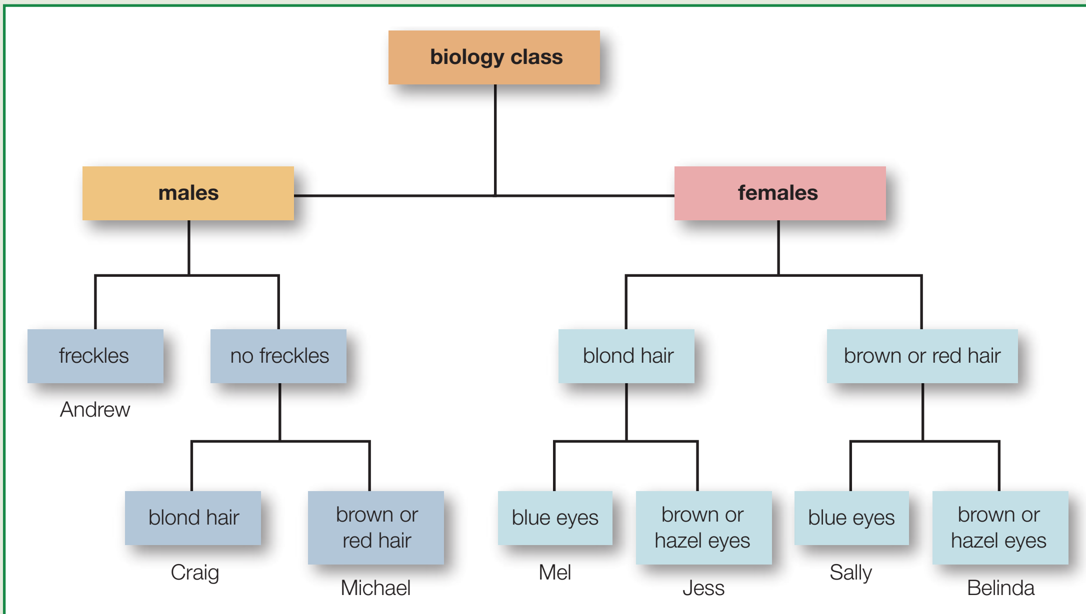


Figure 4.2 Flowchart design for easy construction of a dichotomous key

Figure 4.3 Key to plant groups

1a Possess roots and stems . . . . go to 2

b Do not possess roots and stems . . . . go to 3

2a Possess seeds . . . . go to 4

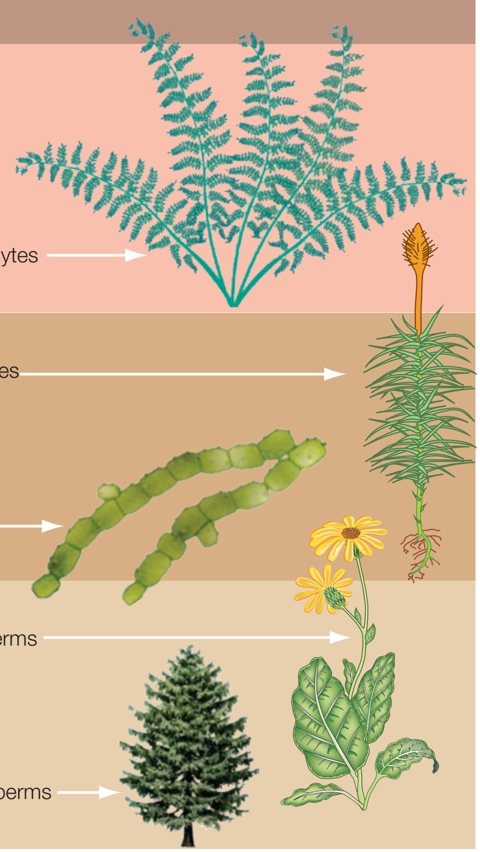
b Do not possess seeds. . . . . Pteridophytes

3a Possess leaves . . . . Bryophytes

b Do not possess leaves . . . . Algae

4a Possess or reproduce by flowers . . . . Angiosperms

b Do not possess or reproduce by flowers . . . . . . Gymnosperms



1a More than three pairs of legs . . . . **not an insect**

1b Three pair of legs only . . . . go to **2**

2a With wings . . . . go to **6**

2b Without wings . . . . go to **3**

3a Ant-like with a narrow waist; ranges in size from 1 to 25 mm (ants) . . . . **Hymenoptera**

3b Not as above . . . . go to **4**

4a Ant-like with a wide waist; ranges in size from 5 to 20 mm . . . . **Isoptera**

4b Not as above . . . . go to **5**

5a With two antennae-like appendages located at the end of the abdomen which is used as a spring; may be held under the abdomen; ranges in size from 3 to 6 mm (springtails) . . . . **Collembola**

5b Has three pairs of legs, but no wings, and does not fit any of the above descriptions . . . . **Immature insect**

6a With only a single pair of wings; the second pair of wings modified into a pair of knob-like gyroscopic organs (attached to the end of stalks) known as halteres; ranges in size from 6 to 65 mm (flies) **Diptera**

6b With two pairs of wings . . . . go to **7**

7a The wings are equal or nearly equal in size with a long slender abdomen; dragonflies range in size from 28 to 150 mm, damselflies range in size from 25 to 65 mm (dragonflies and damselflies) . . . . **Odonata**

7b Not as above . . . . go to **8**

Note: Key only includes selected insect orders and numbering from 1 to 7.

Figure 4.4 Key to selected insect orders (only includes a small portion of all insect orders using numbering from 1 to 7)

Method

Gathering information

Read the 'Background Information' provided and collect information on a variety of different plant and animal dichotomous keys. You may be provided with keys by your teacher or you may need to source the keys from secondary sources. Make sure that you use valid sources for your keys, such as universities or government environmental agencies.

Part 1 Constructing dichotomous keys

Use the students in your biology class today to construct a dichotomous key for identifying the names of each person in the class. You may start off which a large dichotomous division such as male or female, or freckles or no freckles. Depending on the visual characteristics of the class members, continue on from there dividing the group into two until each individual has been identified. Figure 4.2 illustrates an easy way of constructing a dichotomous key. Other more advanced versions may be set up similar to those in Figures 4.3 and 4.4.

Part 2 Using dichotomous keys to identify plants and animals

Select a number of live and preserved plant and insect specimens (at least four of each). Using the keys provided in Figures 4.3 and 4.4 (or those provided by your teacher), determine the scientific name used to classify each specimen into its correct group.

Results

List the pathway selected through your key in order to determine the name of each specimen. Write the name of the group you classified each organism into. For example, 1b, 2b, 3a, Hymenoptera (ant).

Discussion/conclusion

1. Describe what is meant by a dichotomous key and what it is used for.
2. List the groups of plants and animals that you identified using keys.
3. Discuss any possible disadvantages you found in using the keys for identifying specimens.

4.2 Classification systems

- ***describe the selection criteria used in different classification systems and discuss the advantages and disadvantages of each system***

Classification systems are based on the observations of differences between organisms. These differences may occur in an organism's anatomical structure, physiology (functioning), behaviour or biochemistry. Anatomical structure is most commonly used in classification systems; however, more recently biochemistry has been favoured by scientists. As a result, different systems of classification have been used over time; however, with advances in technology, systems have become more refined and use different selection criteria on which to base groups of organisms. There are advantages and disadvantages to all systems of classification. Examples of both modern and older classification systems are compared in Table 4.1. These examples are represented diagrammatically in Figure 4.5.

Table 4.1 Comparison of advantages and disadvantages in three selected classification systems

Classification system	Kingdom names	Selection criteria	Advantages	Disadvantages
6 kingdoms (most recent system: Woese 1990)	■ Bacteria ■ Archaea ■ Protista ■ Plantae ■ Fungi ■ Animalia	■ Molecular criteria ■ Order of bases in particular genes (e.g. ribosomal RNA genes and gene coding for specific proteins)	■ Provides genetic similarities between organisms ■ Biochemical information provides more information leading to possible evolutionary relationships between organisms ■ Can infer when past evolutionary diversion from a common ancestor occurred	■ Requires costly, time-consuming procedures ■ Requires the use of experts in molecular techniques ■ The use of both biochemical and anatomical information may lead to differing interpretations ■ Upsets the traditional method of classification

Classification system	Kingdom names	Selection criteria	Advantages	Disadvantages
5 kingdoms (Whittaker 1969)	■ Monera ■ Animalia ■ Plantae ■ Fungi ■ Protista	■ Structural features ■ Procaryotic or eucaryotic	■ Easily observed in an organism ■ More constant in an organism's lifetime (no seasonal change or change with maturity) ■ Can infer reproductive methods	■ Structures may vary between males and females of a species ■ Internal biochemistry (genetic similarities) is not available for inferring evolutionary links
3 kingdoms (Linnaeus 1735)	■ Mineral ■ Vegetable ■ Animal	■ Structural features ■ Organised body and life (to separate mineral from vegetables and animals) ■ Power of locomotion (to separate vegetables and animals)	■ Easily observed in an organism ■ More constant in an organism's lifetime (no seasonal change or change with maturity) ■ Can infer reproductive methods	■ Structures may vary between males and females of a species ■ Internal biochemistry (genetic similarities) is not available for inferring evolutionary links

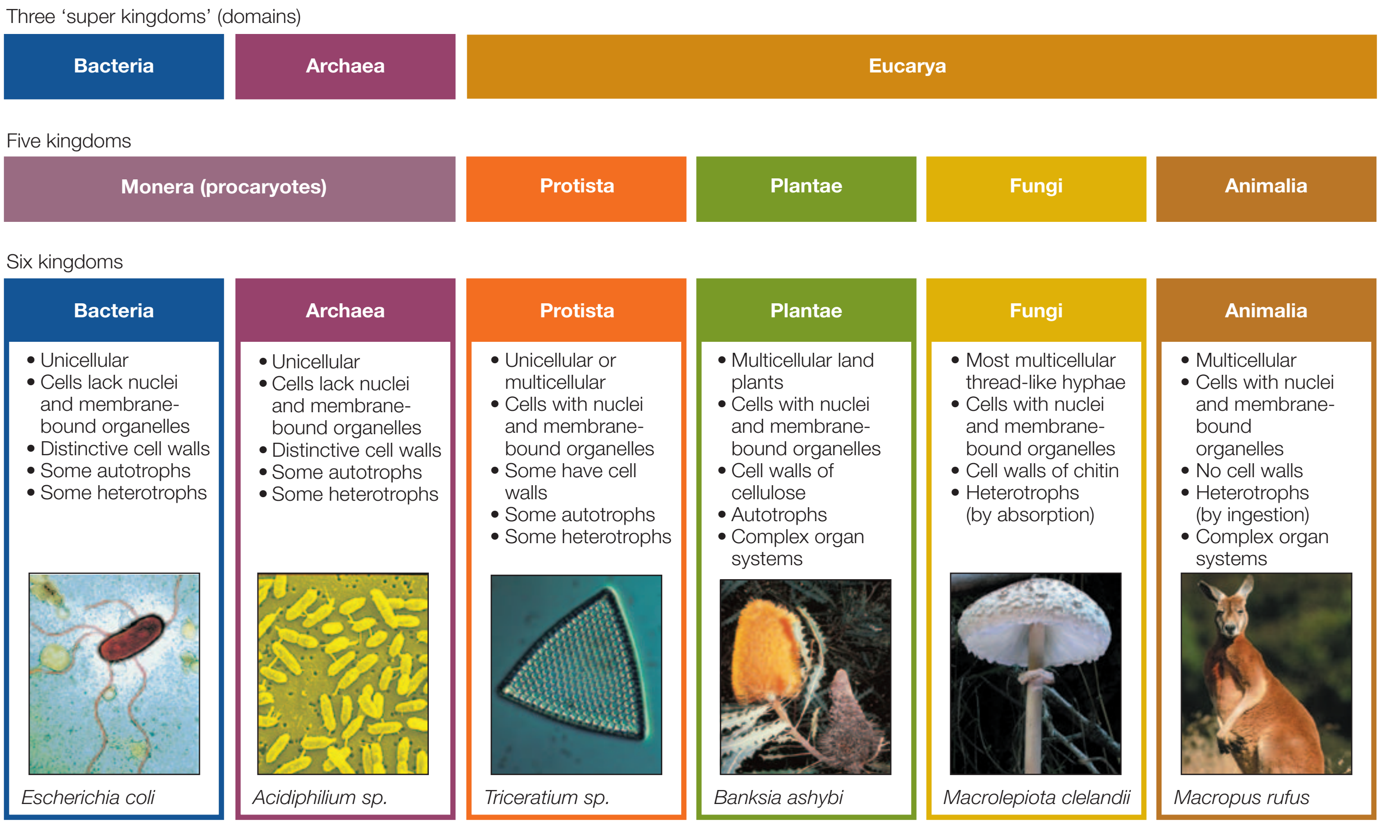


Figure 4.5 Three different schemes for the classification of the major groups of cellular life

4.3 Levels of organisation assist classification

■ ***explain how levels of organisation in a hierarchal system assist classification***

In the biological system of classification, a group is recognised and given a Latinised name: for example, Plantae (multicellular land plants) and Magnoliophyta (flowering plants). Since the time of Swedish naturalist Carolus Linnaeus (1707–1778) (see Fig. 4.6), the biological system has been conceived as a hierarchy with specific levels or ranks. Thus, the group Plantae has the rank of kingdom and Magnoliophyta is a phylum.

Figure 4.6
Carolus Linnaeus

A mnemonic you could use to help remember the correct order of these groups (kingdom, phylum, class, order, family, genus, species) is: **King Phi**l **class**es **ord**inary **families** as **gen**erous and **spec**ial. Of course, you may find it easier to remember one of your own.

Having simple levels of hierarchy for classification makes it an easy and systematic way to name organisms according to their characteristics. Examples of the use of this biological system of classification are shown in Table 4.2.

The rank order of groups commonly used today is:

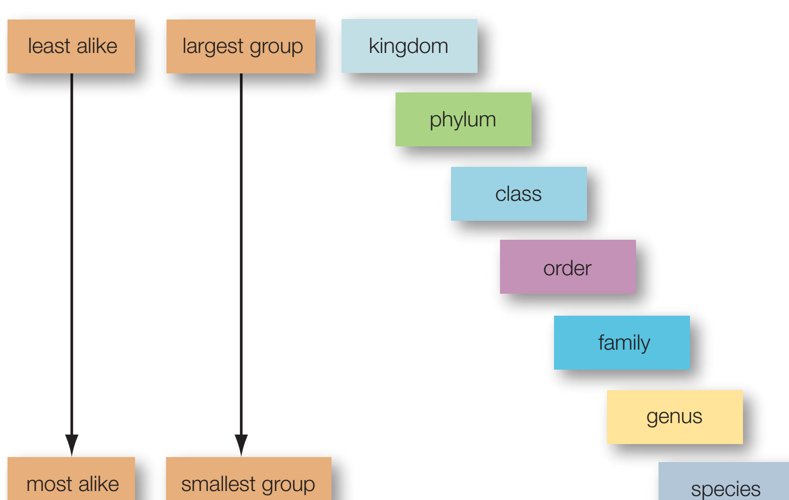


Table 4.2 Biological classifications of Australian organisms

Rank	Platypus	Koala	Dingo	Blue gum	Kangaroo Paw
Kingdom	Animalia	Mammalia	Mammalia	Plantae	Plantae
Phylum	Chordata	Chordata	Chordata	Magnoliophyta	Magnoliophyta
Class	Mammalia	Mammalia	Mammalia	Magnoliopsida (dicots)	Liliopsida (monocots)
Subclass	Prototheria	Theria	Theria	Rosidae	Liliidae
Order	Monotremata	Marsupialia	Carnivora	Myrtales	Liliales
Family	Ornithorhynchidae	Phascolarctidae	Canidae	Myrtaceae	Haemodoraceae
Genus	Ornithorhynchus	*Phascolarctos*	*Canis*	*Eucalyptus*	*Angiozanthos*
Species	*O. anatinus*	*P. cinereus*	*C. lupus* subsp. *dingo*	*E. globulus*	*A. manglesii*

Impact of changes in technology

4.4

- ***discuss, using examples, the impact of changes in technology on the development and revision of biological classification systems***

Examples of changes in microscope technology

As you have already discovered in Chapter 2, microscope technologies have changed a lot in the 19th and 20th centuries. The light microscope first revealed that living things were made up of cells. With improvements in light microscopes and the introduction of the electron microscope fine details of the internal structure of cells were seen. In the 1950s, the electron microscope revealed procaryotic cells, leading to a separate kingdom, Monera. In 1967, Fungi were identified as a separate, multicellular eucaryotic kingdom. It was at this time that our classification systems were revised from the two-kingdom system to the five-kingdom system.

Examples of changes in geological technology

Relative dating techniques

Relative dating techniques provide information about the sequence that fossils appear:

- *principle of superposition*—youngest rock layers are found at the top, oldest layers are found at the bottom
- *stratigraphic correlation*—same relative age when similar layers of rock contain similar fossils
  —index fossils (used to date other organisms found in the same rock layers)
  —fluoride-nitrogen relative dating (the older the fossil, the higher the amount of fluoride in comparison to nitrogen).

Absolute and radiometric dating techniques

Absolute and radiometric dating techniques provide information on the age of the fossil:

- *carbon-14 dating*—rate of decay of carbon is used to estimate the age of young fossils
- *potassium-argon dating*—rate of decay of potassium to argon is used to estimate the age of older fossils

- *electron-spin resonance (ESR)*—the amount of accumulation of higher-energy electrons over time is used to date fossils of varying age
- *thermoluminescence*—the amount of accumulated electrons over time, and hence luminescence when heated, is used to date clay products surrounding fossils.

Example of changes in biochemical technology

Changes in biochemical technology have been a more recent occurrence and include:

- *DNA sequencing*—compares variation in the order of bases in gene DNA
- *mitochondrial DNA as a molecular clock*—mutates at predictable rates so can be used to date evolutionary events
- *karyotype analysis*—comparison of chromosomes from photographs
- *DNA-DNA hybridisation*—determines the similarity of DNA from different species to indicate genetic relationship
- Comparison of haemoglobin
  - —amino acid sequencing (comparison of sequences reflects degree of difference)
  - —electrophoresis (compares electrical charges on protein molecules of closely related species)
  - —immune response testing (looks at the reaction between two species' proteins, if they react they are very similar)

Impact on the revision of classification systems

With the development in the last two centuries of microscopy and biochemistry, our knowledge of the kinds of organisms on Earth has increased remarkably. Cell biology has revealed fundamental differences between procaryotes and eucaryotes. Bacterial classification is changing with the discovery of differences in ribosomal DNA between major groups. Observations of ultrastructure, cell wall biochemistry and photosynthetic pigments of algae show them to be an assemblage of organisms with diverse relationships.

How the major groups are related to one another is still being discovered. This uncertainty of relationships is reflected in continuing changes to classification, including the recent recognition of super kingdoms and the expansion of the number of kingdoms.

Many biology books follow the traditional system that recognises five kingdoms: Monera, Protista, Fungi, Plantae and Animalia. The discovery in 1977 of the two major groups within Monera (Archaea and Eubacteria) by Woese was based largely on differences at a molecular level, not anatomical structure. Two major evolutionary lineages are now recognised among the procaryotes, and they are classified by many taxonomists as the super kingdoms Bacteria and Archaea (see Fig. 4.5).

An example of another recent change to a classification system occurred in 1998 by an international group of botanists. A new classification for the families of flowering plants occurred, now using both the traditional structural appearance of plants as well as the new technique of gene sequencing. Plants were grouped by similarities in their DNA structure. Not only have groups of flowering plants been renamed, but now new evolutionary relationships have been suggested. The Australian family Proteaceae (e.g. banksias) was shown to be related to the family Platanaceae (plane trees).

Binomial system

4.5

- ***describe the main features of the binomial system in naming organisms and relate these to the concepts of genus and species***

The ranks or categories of genus and species have a special significance because they form the basis of the binomial system, perfected by Linnaeus. In the binomial system, the nature of each kind of organism is described by two parts: *Homo sapiens* (humans), *Pan troglodytes* (chimpanzee) and *Gorilla gorilla* (gorilla). (It is interesting to note that in 1758, Linnaeus placed chimpanzees in the genus *Homo*.) In the binomial system the genus name is always written first (with a capital letter) and the species name is written second, as in *Eucalyptus viminalis* or *Banksia serrata*. Both the genus and species names are always written in italics.

The taxonomic category, species, is the lowest rank in the Linnaean hierarchy to which all organisms must be classified. Although structurally very similar within the one species, there are still variations between males and females and different ages or maturity levels.

Difficulties in classifying extinct organisms

4.6

- ***identify and discuss the difficulties experienced in classifying extinct organisms***

When trying to classify organisms scientists look for similar characteristics to ones already previously classified and dated, from fossil evidence, or with modern present-day living organisms. When trying to classify an extinct organism, there are no modern-day living organisms to compare it to and assist in identifying the characteristics for classifying the organism. Also, an extinct organism may only provide fossil evidence of its existence and the quality of this evidence may vary. Fossil evidence may be incomplete or poorly preserved. This creates problems in determining the organism's characteristics as a whole. The conditions of its past environment may be required to determine the characteristics it may have had to exist in such an environment. Scientists may need to analyse similarities with other organisms living in a similar environment of that time, or even organisms living in a similar environment in the present day.

However, with modern technologies assessing molecular and biochemical evidence now, rather than only the structural focus of classification in the past, we can determine much more information about the organism even when it is partially or poorly preserved. Once this information is collected using all the available scientific technologies, scientists must then put the whole story together around this organism and use and interpret the evidence and test results in order to categorise and classify the organism. Different scientists may make different interpretations from the same information or evidence. Subconscious bias and preconceptions influence scientific interpretation. Arguments still continue over the validity of some evidence.

All classification systems create controversy since they depend upon human decisions about the features that are important characteristics of a group or organism. Classification systems are constantly changing due to the discovery of new evidence and fresh interpretations of current evidence. In addition, significant changes have occurred recently because of the biochemical technologies now available. New genetic links are being found. The more recent systems have changed from the traditional 'premolecular' one due to the recent genetic technology indicating new genetic links.

4.7 Assistance to understanding present and past life

- ***explain how classification of organisms can assist in developing an understanding of present and past life on Earth***

There are many alternative views on the evolutionary relationships between different groups of organisms. Although often based on the same evidence, different interpretations have arisen and are constantly changing and conflicting. However, by attempting to arrange and order groups of organisms scientists are able to look at possible evolutionary pathways and relationships. Our present-day organisms are much easier to classify than those that only lived in the past. However, we can look at similarities between modern-day organisms and those from the past to develop an understanding of the differences between present and past life. Some organisms may now be living in similar environments to those in which they lived in the past; however, many organisms have had significant changes in the environments and demonstrated changes in response to this. It is with this in mind that we gain a better understanding of the evolution of organisms over time on Earth and the changes that occurred alongside the environmental changes on Earth.

SR TR

Answers to revision questions

REVISION QUESTIONS

1. Explain five reasons why scientists need to classify organisms.
2. Construct a dichotomous key (including numbers and letters) to identify the following five organisms (koala, kangaroo, crocodile, kookaburra and echidna).
3. Use Figure 4.4 on page 225, to key out the insect (see Fig. 4.7) below. Include all steps taken to reach your conclusion.
4. Describe two different systems of classification and discuss the advantages and disadvantages of each one.
5. List the seven levels (in rank order from least alike to most alike) used in the biological system of classification.
6. Discuss the impact of two examples of changes in technology on the development and revision of biological classification systems.
7. Describe the main features of the binomial system in naming organisms using a specific example.
8. Identify and discuss the difficulties experienced in classifying extinct organisms.
9. Explain how the classification of organisms can assist in developing an understanding of present and past life on Earth.

Figure 4.7
An insect example