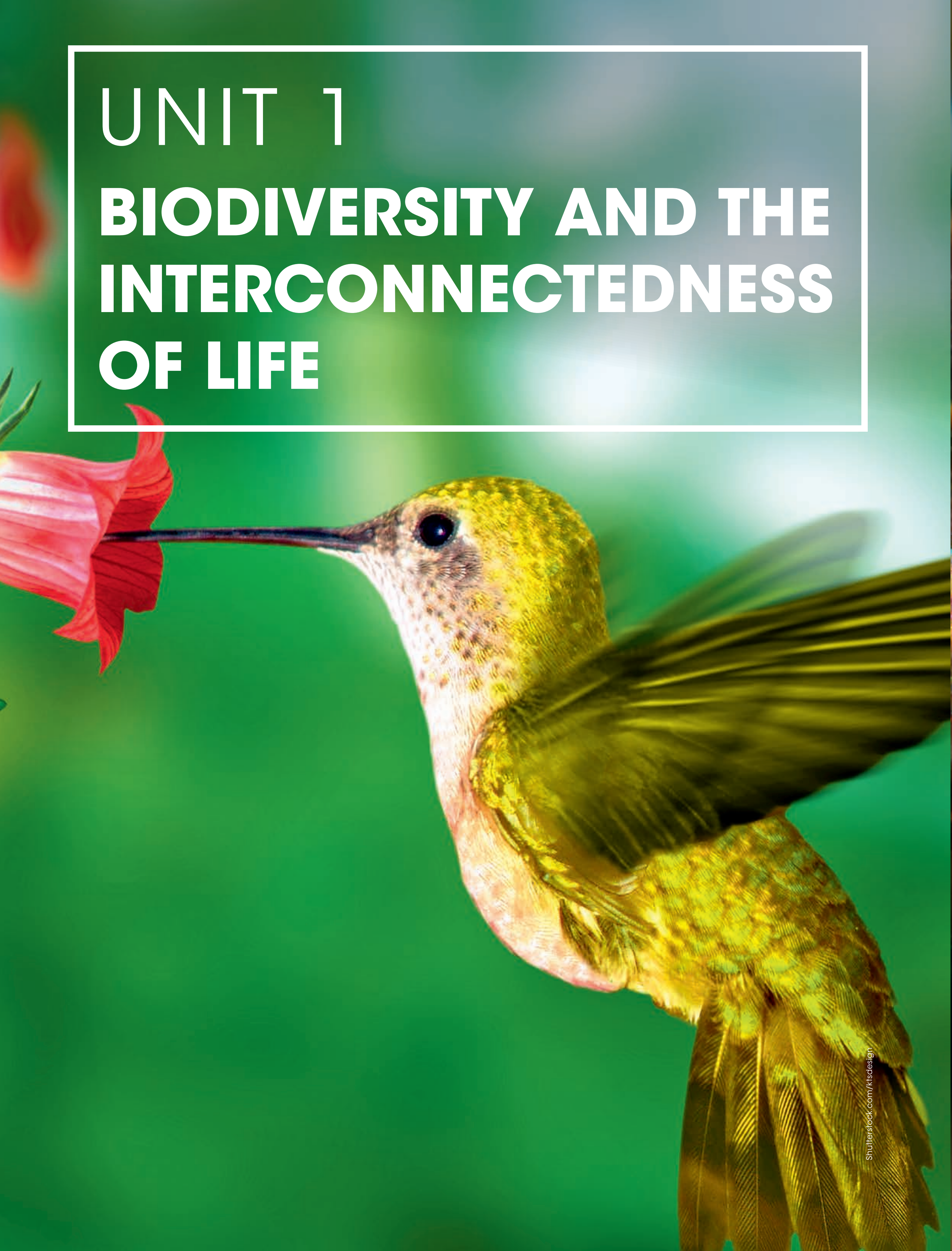
UNIT 1

BIODIVERSITY AND THE INTERCONNECTEDNESS OF LIFE



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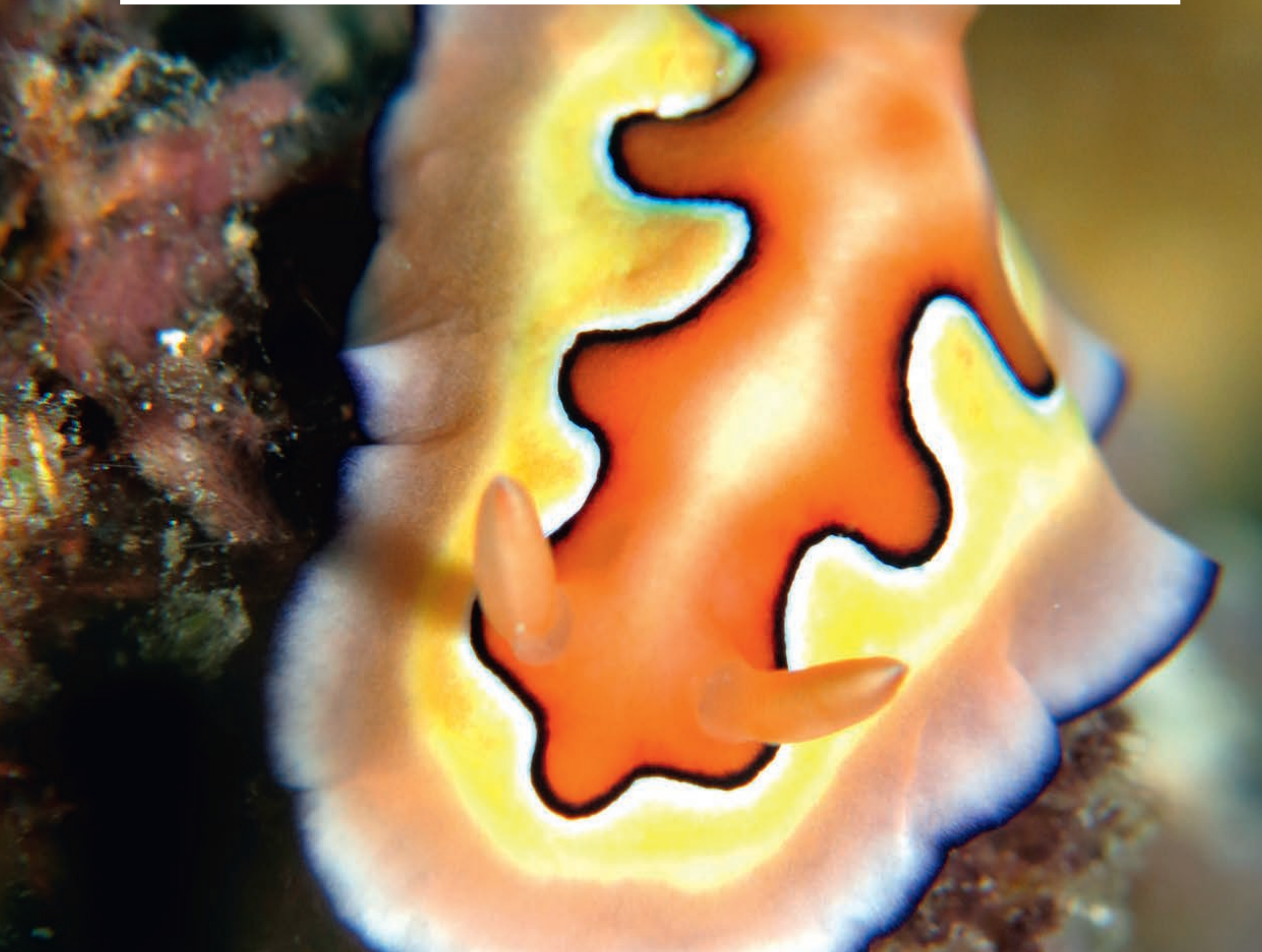
CHAPTER 1
BIODIVERSITY



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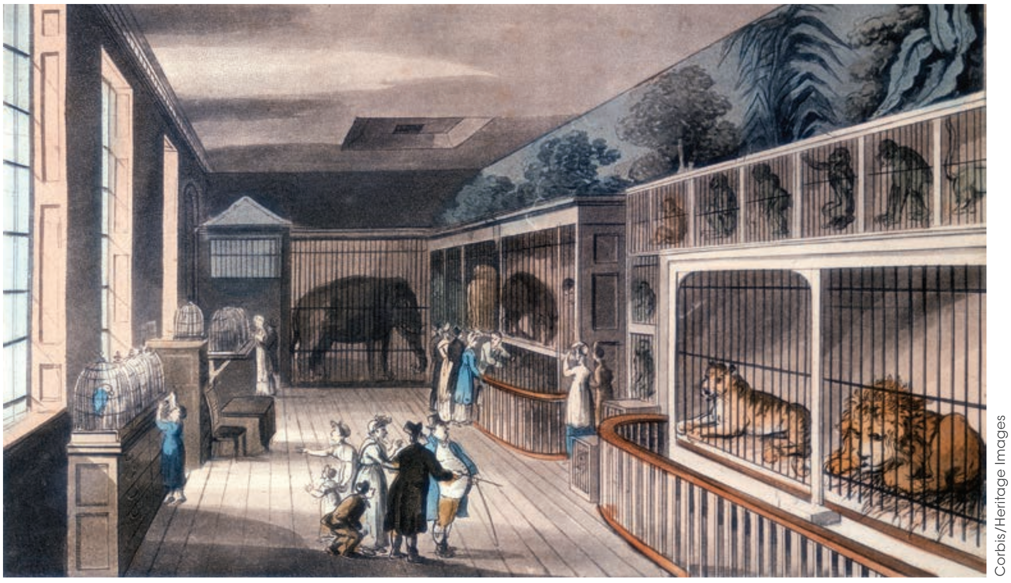
By the end of this chapter you will have covered the following material.

Science Understanding

- Biodiversity includes the diversity of species and ecosystems; measures of biodiversity rely on classification and are used to make comparisons across spatial and temporal scales (ACSBL015)
- Most common definitions of species rely on morphological or genetic similarity or the ability to interbreed to produce fertile offspring in natural conditions – but, in all cases, exceptions are found (ACSBL018)

Figure 1.1 ▶
The Royal Menagerie (an early form of the zoo), Tower of London, 1816



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Theories of evolution are covered in more detail in Unit 3 Biology.

ALFRED RUSSEL WALLACE ONLINE

An overview of the writings of Alfred Russel Wallace

We live in a world with amazing forms of life. In many places, there are still more unknown **species** to be uncovered. Back in the 18th and 19th centuries, explorers sailed the world on voyages of discovery. Naturalists and collectors took advantage of these voyages and they wrote detailed accounts of what they observed. These accounts were widely read back home in Europe by a public fascinated by exotic places and things. The general public in Europe was sceptical of the far-off lands and they marvelled at the specimens brought back from expeditions. Wealthy patrons sponsored collectors to bring back live exotic animals and plants, and private menageries and public zoos were created. At the same time, naturalists began to question age-old beliefs about the physical and living world around them. They noticed how unseen lands brought unknown species and they began to wonder why this was so. It was in part due to his own voyage of discovery that Charles Darwin developed his theory of evolution by natural selection.

The diversity of life: endless forms most beautiful

Life on Earth is extremely diverse. **Biodiversity** describes the great variety of life that is full of wondrous creatures. This diversity is now recognised for its importance, not just from a scientific perspective, but also as a vital factor in the long-term survival of all life on Earth including the societies in which we live. The study of biology is about understanding diverse living systems in all their detail, from entire continents to minute cellular processes.

Figure 1.2 ▼
One of the new species discovered by Wallace in Sarawak: the flying frog, *Rhacophorus nigropalmatus*

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Voyages of discovery

Alfred Russel Wallace was perhaps one of the greatest collectors of biodiversity of all time. He travelled and collected for 4 years in the Amazon and almost 8 years in the Malay Archipelago (now Indonesia/Malaysia). During that time, Wallace discovered 5000 new species and collected more than 125 660 specimens, as well as live individuals. He collected almost 110 000 insects, 7500 shells, 8050 bird skins and more than 400 mammal and reptile specimens.

Sadly, on his boat voyage back from collecting specimens in the Amazon, his ship caught fire and he lost almost all of his specimens and notebooks. His surviving notes and drawings from his lifetime span thousands of pages and can now be accessed via the Wallace Online website.

▲ Figure 1.3
Semioptera wallacii, Wallace's standardwing, the new bird of paradise that Wallace discovered on the island of Batchian (now the Bacan Islands in Indonesia).

▲ Figure 1.4
A specimen and watercolour of *Banksia serrata*, discovered by Sir Joseph Banks (after whom it is named) during his voyage on the *Endeavour.*

Biodiversity is the full range of different living things in a particular area. Mainly, we speak of genetic diversity, ecosystem diversity and species diversity.

HMS *Endeavour*

On 28 April 1770, HMS *Endeavour*, under the command of Lieutenant James Cook, entered Botany Bay. Over several months the captain and his crew gradually made their way up the east coast of Australia. This expedition had the responsibility of carrying out scientific studies as well as being the usual political and strategic mission. The naturalist on board the *Endeavour* was Joseph Banks. Banks was an independently wealthy gentleman who paid his own way, and contributed £10 000 to the expedition. The plant material he collected from eastern Australia was extensive and accounted for approximately 110 new **genera** and 1300 new species. In his own account, written just after leaving the Australian coast, Banks noted the barrenness and 'sameness' of the arid landscape. He also noted 'in general the countrey (sic) afforded a far larger variety than its barren appearance seemd to promise'. He did not observe many insects overall, but did note the abundance of ants; a diverse group well-known to all Australians.

THE ENDEAVOUR JOURNAL OF SIR JOSEPH BANKS

Read Sir Joseph Banks' own account of his visit to the east coast of Australia. In the diary this section begins in April, 1770.

HMS *Beagle*

'Endless forms most beautiful' is how Charles Darwin described the extraordinary variety of living things he experienced on his journey around the world. In January 1836 he set foot on Australian soil. He did not travel far from Sydney but noted the strangeness of Australia's animals. He observed several animals that were clearly similar in form and behaviour to animals in England. These included crows and magpies, as well as the ant lion, a small insect that digs pits in sandy soil into which unsuspecting prey can fall. These species were named after familiar species in Europe, but they actually belong to completely different species. Darwin speculated in his diary about why and how such different animals could arise to fill such similar roles in the living world.

QUESTION SET 1.1

Remembering

1 Recall the names of three naturalists or collectors.

2 Recall the number of new plant species Banks collected when he visited Australia on board HMS *Endeavour*.

3 Outline some reasons why Europeans were puzzled by different-looking animals and plants collected overseas.

4 Describe the observations Banks and Darwin made about Australia's ecology.

Biodiversity of Australia

Australian flora and fauna stands apart from that of the rest of the world for several reasons. Firstly, it is quite different to that found anywhere else on Earth. The vast forests of eucalypts that characterise the Australian landscape are not found outside Australia and South-East Asia. Eucalypts have recently been introduced to a number of other regions of the world. Climates such as those of California and the Mediterranean allow them to grow extremely well. Perhaps more widely recognised outside Australia are our unique fauna characterised by many different types of marsupials, which for many people around the world typify Australia more than anything else.

The second important characteristic is diversity. It has been estimated that Australia has approximately 1 million species of plants, animals and micro-organisms, representing approximately 7% of the world's total. Australia is one of only two developed nations, along with the US, to be recognised as a 'megadiverse' country; a country possessing particularly diverse **ecosystems**. Australia is one of the most sparsely populated megadiverse countries in the world. A report prepared for the Australian Biological Resources Study in 2009 estimated that 566 398 species exist in Australia.

We have more species of higher plants than 94% of countries on Earth. We have more reptile species than any other continent. Most importantly, we have many **endemic** species that occur nowhere else on Earth. This means that Australia's biodiversity is both large and unique making it of significant importance on a global scale.

Figure 1.5 ▶ The Northern hairy-nosed wombat, said to be Australia's most endangered marsupial

AUSCAPE/Dave Watts

Scientific literacy: The Great Barrier Reef

The World Heritage Committee meets once a year and consists of 21 representatives elected from 190 member countries. One of the committee's tasks is to recommend inscriptions (inclusions) on the World Heritage List. The List aims to recognise and protect sites of cultural and natural significance.

The Great Barrier Reef is a site of remarkable variety and beauty on the north-east coast of Australia. It contains the world's largest collection of coral reefs. It also holds great scientific interest as it is the habitat of species such as the dugong and the large green turtle, both of which are threatened with extinction.

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▲ **Figure 1.6**
The Great Barrier Reef from the air

As the world's most extensive coral reef ecosystem, the Great Barrier Reef is a globally outstanding and significant entity. Practically the entire ecosystem was inscribed on the World Heritage List in 1981, covering an area of 348 000 km^2. The Great Barrier Reef includes extensive cross-shelf diversity, stretching from the low water mark along the mainland coast up to 250 km offshore. This wide depth range includes vast shallow inshore areas, mid-shelf and outer reefs, and beyond the continental shelf to oceanic waters more than 2000 m deep.

Within the Great Barrier Reef there are some 2500 individual reefs of varying sizes and shapes, and more than 900 islands, ranging from small sandy cays (small island) and larger vegetated cays, to large rugged continental islands rising, in one instance, to more than 1100 m above sea level. Collectively these landscapes and seascapes provide some of the most spectacular maritime scenery in the world.

On many of the cays there are spectacular and globally important breeding colonies of seabirds and marine turtles; Raine Island is the world's largest green turtle breeding area. On some continental islands, large aggregations of over-wintering butterflies periodically occur.

The latitudinal and cross-shelf diversity, combined with diversity through the depths of the water column, encompasses a globally unique array of ecological communities, habitats and species. This diversity of species and habitats, and their interconnectivity, make the Great Barrier Reef one of the richest and most complex natural ecosystems on earth. There are more than 1500 species of fish, approximately 400 species of coral, 4000 species of mollusk, some 240 species of birds, plus a great diversity of sponges, anemones, marine worms, crustaceans and other species. No other World Heritage site contains such biodiversity. This diversity, especially the endemic species, means the Great Barrier Reef is of enormous scientific and intrinsic importance, and it also contains a significant number of threatened species.

Source: UNESCO/CLT/WHC, from http://whc.unesco.org/en/list/154, Great Barrier Reef article

Questions

1 Define biodiversity in the context of the Great Barrier Reef.

2 When listed, the *International Union for the Conservation of Nature* evaluation stated '… if only one coral reef site in the world were to be chosen for the World Heritage List, the Great Barrier Reef is the site to be chosen'. Give three reasons why the Great Barrier Reef is an exemplary coral reef.

3 One of the selection criteria for inclusion on the World Heritage List is 'to contain the most important and significant natural habitats for *in situ* conservation of biological diversity, including those containing threatened species of outstanding universal value from the point of view of science or conservation.' How does the Great Barrier Reef meet this criterion?

4 Evaluate the goals and efficacy of declaring natural areas as World Heritage sites.

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Figure 1.7 ▲
An Australian rainforest is a very complex and diverse ecosystem.

Describing biodiversity

What is biodiversity? This is understood to mean that there are many different types of organisms living on Earth. Scientists have come to recognise biodiversity at a number of different levels. The first to be recognised, and still one of the most obvious to us today, is at the level of species. A species is most often defined as a group of morphologically similar organisms that is capable of interbreeding to produce fertile offspring.

The second to be recognised is at the level of ecosystems. Organisms live in quite complex communities and a range of different physical environments. Consider the difference between the sorts of communities and physical conditions present in the alpine regions of Australia to those found in the tropics.

An ecosystem is an interacting community of populations of organisms and the physical environment in which they live.

The third, and most recent, level at which biodiversity is considered is the level of genetics. Genetic diversity is now widely recognised for its biological importance. Every individual carries a large number of genes that code for all of their inherited traits, and different individuals carry many different genes. For example, the whole human **population** carries many different eye or hair colour genes. A whole population will carry many different genes. In general terms, it seems that populations with higher genetic diversity (i.e. the greatest mix of different genes) are more resilient. This makes them more likely to survive sudden changes in the environment than populations with low genetic diversity.

Diversity of species

If you look around your classroom you will notice diversity. Clearly each person is a different individual – we take pride in our individuality. However, we also have an instinctive understanding that we all belong to the same 'kind'. We are all human and belong to the human species, *Homo sapiens*. In the 18th century, at the time of the great voyages of discovery mentioned earlier, Europeans erroneously identified the various indigenous groups they came across as quite different 'kinds', and occasionally even as different sub-species to European 'Man'. While this may have been consistent with social understandings of the time, we now know that there is no scientific basis for this. The entire human population is more closely related and less genetically diverse than other populations of mammals. So we are, indeed, all one 'kind'.

Biodiversity represents many different species, rather than referring to many different individuals within populations. The written record of biodiversity is the number of different species recorded and compared. It does not make sense to refer to the total human population of 5–6 billion different individuals as an example of biodiversity. But referring to Sydney Harbour as supporting 570 different species of fish and 3600 species of invertebrates is just as clearly a good example of biodiversity. So our concept of a species is central to our understanding of biodiversity and how complex ecosystems evolved and function.

DIVERSITY IN YOUR LOCAL REGION

How many different species have been identified in your local area? The *Atlas of Living Australia* could answer this for you.

What is a species?

In general terms, a species is an interbreeding 'kind'. Most cultures, modern and ancient, developed sophisticated, accurate and scientifically supportable knowledge about their local environment. Their classification systems would generally include an accurate identification of different species, how they related to other organisms and to the physical environment, and how their distribution varied with the seasons. One of the most studied regions in this regard is the Amazon in South America. This is not only one of the most biodiverse regions on Earth, but it also has the greatest diversity of indigenous societies who have had little contact with western civilisation. These cultures often have an encyclopaedic knowledge of their local environment, combining extensive systems of classifying the organisms of importance to their lives combined with detailed stories describing how these organisms relate to each other and to their physical environment.

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▲ **Figure 1.8**
The Toco Toucan is native to the Amazon rainforest in South America.

The biological species concept

In biological terms, a species is a group of organisms whose members have the potential to interbreed in nature and produce viable, fertile offspring. This is essentially the **biological species concept**. It was proposed by Ernst Mayr around 1942. Most importantly, individuals within a species are reproductively isolated from individuals not belonging to that species. This definition has one very important link to the processes of evolution. Current models suggest that when populations of individuals become unable to interbreed, the evolution of new species can occur.

Unit 3 Biology covers the topic of evolution.

Limitations of the biological species model

While the biological species model has relevance to the processes whereby new forms of life evolve, particularly at the genetic level, there are a number of problems in using this definition. For example, it is not possible to apply it to fossils of extinct organisms, because it is impossible to really know which individuals could interbreed with another. Of personal relevance is our understanding of how our own species evolved. Archaeologists have found many pre-human fossils but cannot use the biological species model to classify them. Some fossils clearly represent species that are different to modern humans, but some other fossils are more difficult to classify.

Often, where two identified species have populations that overlap to some extent, there are zones where **hybrid** organisms exist. Hybrids are difficult to classify because they are the result of individuals from two different species interbreeding. They generally do not survive well outside restricted hybrid zones and generally do not displace either of the parent species, but they do play an important role within the ecosystem. Hybrids present a problem from a conservation perspective because most legislation is designed to identify a particular species for protection, and therefore does not protect the hybrid organisms, despite their role in the overall ecological system.

For example, following the loss of ice sheets in Arctic regions, polar bears have been driven into the more forested regions where grizzly bears live. Occasionally they interbreed to produce a polar-grizzly bear hybrid. These have been called grolar bears (and some are half grizzly, half grolar; or half grolar, half polar), and seem to survive quite well in the wild in some situations. But they do not displace either of the polar bear and grizzly bear parental populations.

Other species concepts

When examining fossils, the **morphological species concept** is most commonly applied. This concept characterises a species by its form, or morphology. In the case of the human family tree, it is most often the skull that is best preserved and identified morphologically. However, there can be many disagreements between scientists about which morphological features should be used, and when the features are sufficiently different to justify the creation of a new group.

The **phylogenetic species concept** identifies a species as being the smallest group of organisms who can all trace their origins to a single common ancestor. This is an important feature of all classification systems used today. They are all based on common ancestry. Any identified group has a common ancestor. For example, all primates share a common ancestor that existed around 60 million years ago, while all mammals share a common ancestor that existed around 120 million years ago. Application of the phylogenetic species concept to **extant** (living) organisms increasingly utilises genetic techniques, and most **phylogenetic trees** produced today are based almost solely on these. A phylogenetic tree is a family tree of species that is based on their ancestry. The branching points on the tree show the common ancestor of all species above that point.

For more information on phylogenetic trees see Chapter 2.

While there are many different models used for identifying species, there is still an important underlying idea. That is, a species shares a gene pool to which all organisms outside that species do not have access. Another important feature is that genes can flow relatively easily between all individuals within a particular species. If different populations within a species become isolated for extended periods of time, the evolution of new species is likely to occur.

A species is most often defined as an interbreeding group of organisms that is capable of producing fertile offspring.

A diversity of ecosystems

An ecosystem is composed of all living organisms, together with the physical environment (**abiotic factors**), in one particular area. Within an ecosystem, the communities of organisms and the physical conditions tend to be fairly uniform. All the components of an ecosystem are tightly linked by the cycling of nutrients and raw materials within it. These include CO_2, O_2, water, nitrogen, phosphorus and many other minerals. The living components are also linked by the transfer of energy through the system. In most systems the energy is initially transformed from light to chemical energy in food molecules, usually sugars, through **photosynthesis**, and then transferred between organisms via tightly linked **food webs**. The final transformation of energy is generally to heat.

Chapter 4 discusses the transformation of energy in ecosystems and the mechanics of food webs.

Development of the ecosystem concept

The German explorer Alexander von Humboldt is often regarded as the father of ecology. During his voyages during the early 1800s he took on the task of studying the relationships between organisms and their environment. He collected massive amounts of data, which were drawn on by scientists long after his death. He was a strong contender of the 'unity of nature', believing that the interrelationship of many sciences, including biology, meteorology and geology, was key to understanding why different organisms were found in particular regions. This was originally referred to as biogeography. The term ecosystem was not coined until 1935 by Arthur Tansley, a British ecologist.

The concept of ecosystems provides a powerful tool for understanding how the complexity of life works, but it is also a concept that is under current improvement and development. Our understanding of how ecosystems function is ongoing and the concept of ecosystems is not without its problems. It can be difficult to determine where the dividing line is between one ecosystem and another, because all life on Earth is connected through the cycling of nutrients and the transformation of energy through food webs. It tends to be assumed that an ecosystem has some level of isolation from other ecosystems, meaning that more materials are cycled and transferred within an ecosystem than between one ecosystem and another. In reality, materials *do* cross the boundaries separating one ecosystem from another. For example, a predator may have a range that crosses a number of different, identified ecosystems.

Ecosystems are generally regarded as being fairly homogeneous, but there may be regions within an ecosystem that vary significantly. It can be difficult for biologists to agree whether an ecosystem should be split into more than one ecosystem. Australian dingoes have ranges that extend many kilometres and they can survive in a variety of environments, including both arid and **temperate** habitats. Wherever two different ecosystems exist side by side, such as a forest and open grassland, dingoes are capable of ranging across both. This is an example of where a predator can affect more than one ecosystem.

QUESTION SET 1.2

Remembering

1 Describe the three levels at which diversity can be considered.

2 Contrast the following three species concepts.

  a Biological species concept

  b Morphological species concept

  c Phylogenetic species concept

3 Describe in your own words what an 'ecosystem' is.

Understanding

4 Outline some of the limitations of the biological species concept.

5 Define 'biodiversity' and provide an example that illustrates its meaning.

6 Dogs come in all sizes and colours, yet they are all members of the one species. Explain why this is so.

7 Outline the relationship between species diversity and ecosystems.

CHAPTER SUMMARY

- Life on Earth is characterised by its great diversity, at levels ranging from individual organisms to ecosystems.
- Biodiversity can be considered at a range of different levels: genetic, species and whole ecosystems.
- The concept of a species is fundamental to how we classify organisms and understand the evolutionary process. It represents the basic 'kind' of organism. There are a number of ways of defining a species but its essential characteristic is that it shares a gene pool.
- Definitions of what constitutes a species include the biological species concept, the morphological species concept and the phylogenetic species concept.
- Organisms are not uniformly distributed across the globe, but occur as collections of interacting populations within specific physical environments, which vary considerably in different locations.
- Voyages of discovery during the 18th and 19th centuries provided a wealth of information about the biodiversity of Earth's plants and animals, and also lead to the development of the concept of ecosystems.
- An ecosystem is an interacting community of populations of organisms and the physical environment in which they live.
- Ecosystems vary widely in response to different physical conditions and have also varied greatly over time.
- Australian ecosystems vary widely and exhibit great diversity.

CHAPTER GLOSSARY

abiotic factor a non-living factor within an ecosystem, including the physical landscape and weather

biodiversity the full range of different living things in a particular area or region; it can be described at various levels, including the range of different species, genetic diversity, or the diversity of ecosystems present in a larger area

biological species concept the definition of a species based on the capacity of individuals to interbreed

ecosystem a self-sustaining unit consisting of the interactions between the community and the environment

endemic a species that is native to a particular geographic region, and not introduced

extant a living species; as opposed to an extinct species

food web a diagram that shows how different organisms feed on each other, thereby transferring energy through an ecosystem; interconnecting food chains in an ecosystem

genus the classification level immediately above species; the genus name is included in the binomial naming system introduced by Carl Linnaeus in the 18th century (e.g. modern humans have the scientific name *Homo sapiens, Homo* is the genus)

hybrid an organism resulting from two different species interbreeding

morphological species concept the definition of a species based on physical characteristics

photosynthesis a chemical reaction using energy from the Sun to convert carbon dioxide and water into glucose and oxygen

phylogenetic species concept the definition of a species based on the smallest group of individuals sharing a common ancestor, often determined through genetic analysis

phylogenetic tree a system of classification based on common ancestry, often determined through genetic analysis; a diagram that shows the evolutionary relationship between organisms

population a group of individuals belonging to the same species living in a particular area at the same time

species a group of organisms that share a gene pool; all members of the same species have the capacity to interbreed to produce fertile offspring as long as they are not prevented by any physical barrier

temperate generally refers to regions that do not experience extremes of hot and cold; the temperate areas of the world are broadly those regions between the polar and equatorial regions

CHAPTER REVIEW QUESTIONS

Remembering

1 Species can be defined according to three different concepts. Explain the similarities and differences between these three concepts.

2 Explain what a hybrid is.

Understanding

3 Describe how you would explain 'biodiversity' to one of your friends studying Year 11 science, but not biology. How would you explain why biodiversity is important to species survival?

4 The term 'ecosystem' is quite a recent biological concept. Explain why it is a useful idea and identify some of its limitations.

5 State whether hybrids contribute to biodiversity. Explain your reasoning.

Evaluating

6 Discuss the ways in which Australia's flora and fauna are special in terms of global biodiversity.

7 The development of scientific ideas can be affected by the society in which it operates. To what extent did societal effects influence the development of our understanding of the biological world during the 19th century?