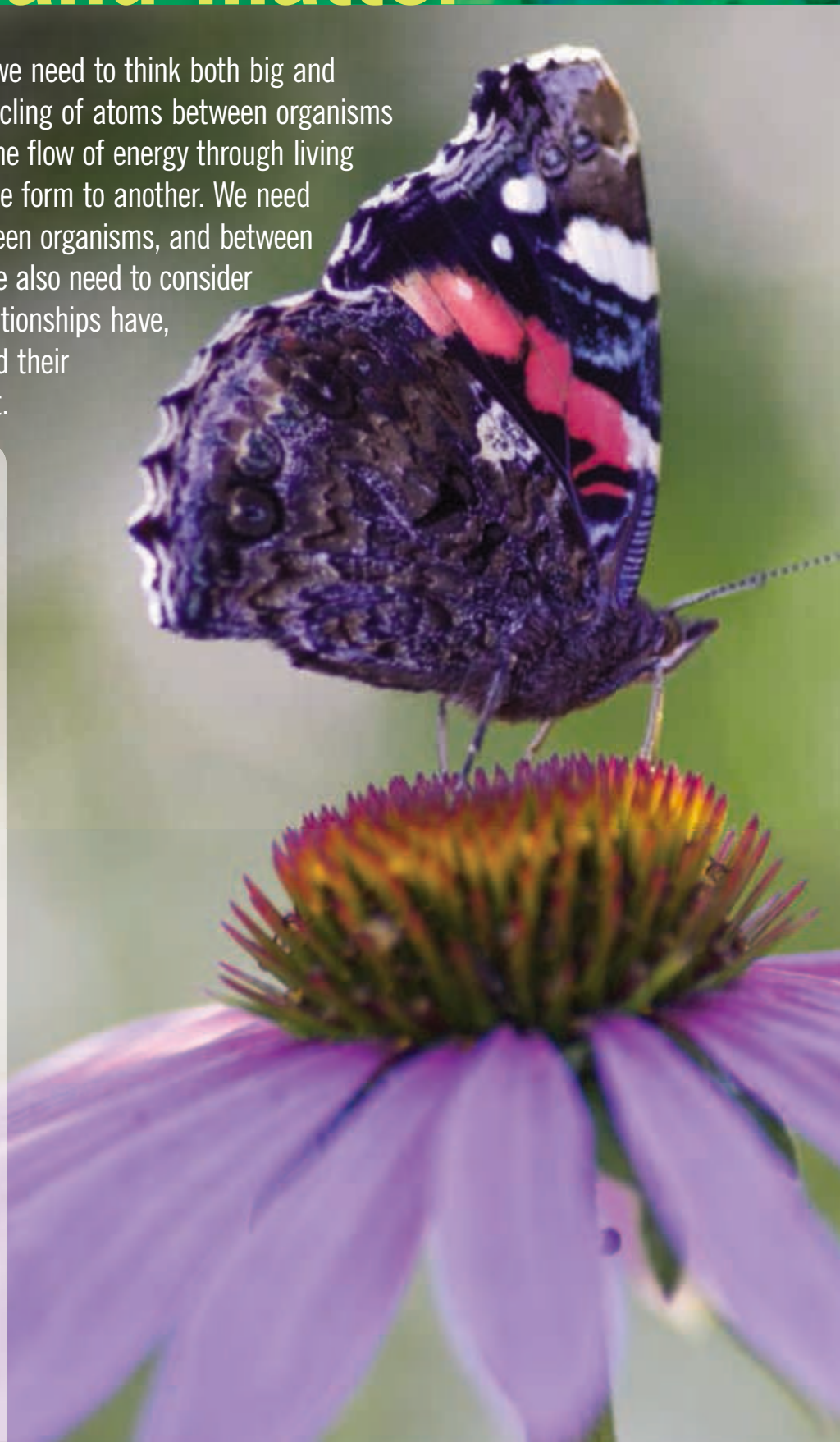
5 Ecosystems — flow of energy and matter

When we think about ecosystems, we need to think both big and small. We need to consider the recycling of atoms between organisms and within their environment and the flow of energy through living organisms and its changes from one form to another. We need to appreciate the relationships between organisms, and between organisms and their environment. We also need to consider the potential effects that these relationships have, not only on individual organisms and their environment, but also on our planet.



Think about ecosystems

- How can stomata help pull water up a plant?
- Is being green essential for photosynthesis?
- Why do some cells have more mitochondria than others?
- What's the difference between nitrifying and denitrifying bacteria?
- Why do energy pyramids always have the same basic shape?

In this chapter:

YOUR QUEST

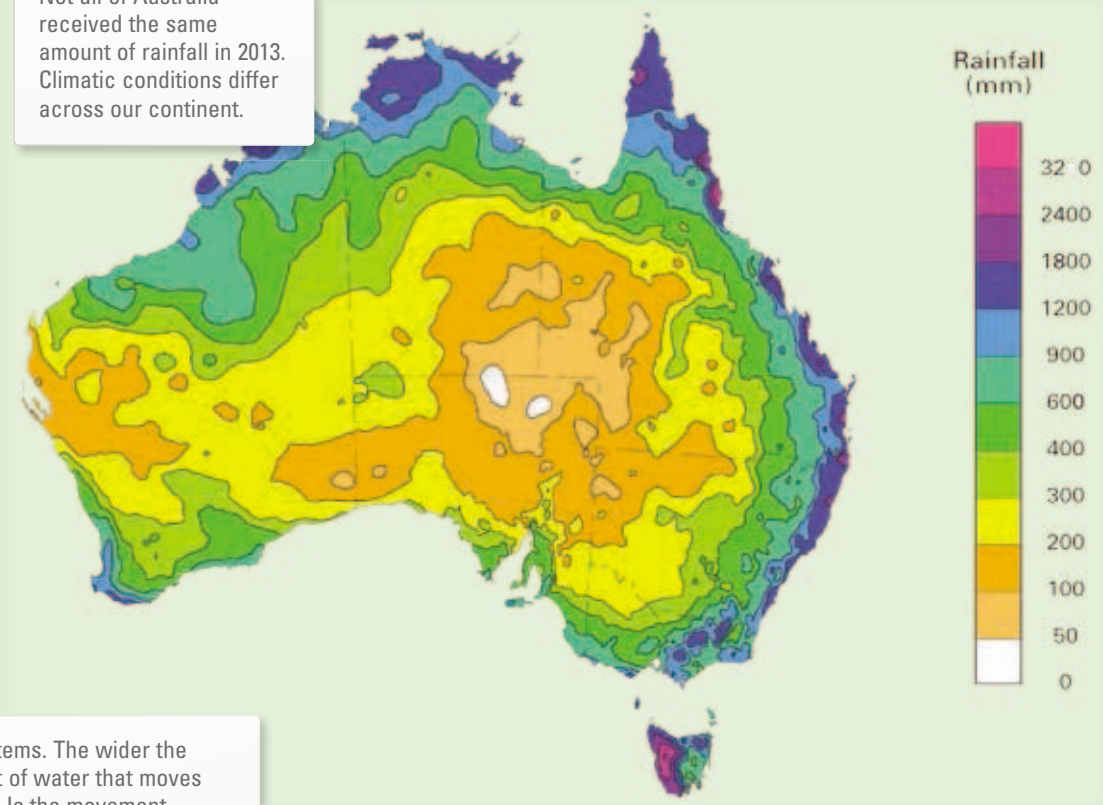
Water

Organisms need water to survive. The good news is that water cycles through ecosystems. The bad news is that, at times, the amount of water available can be too great (as in the case of floods) or too little (as in the case of drought).

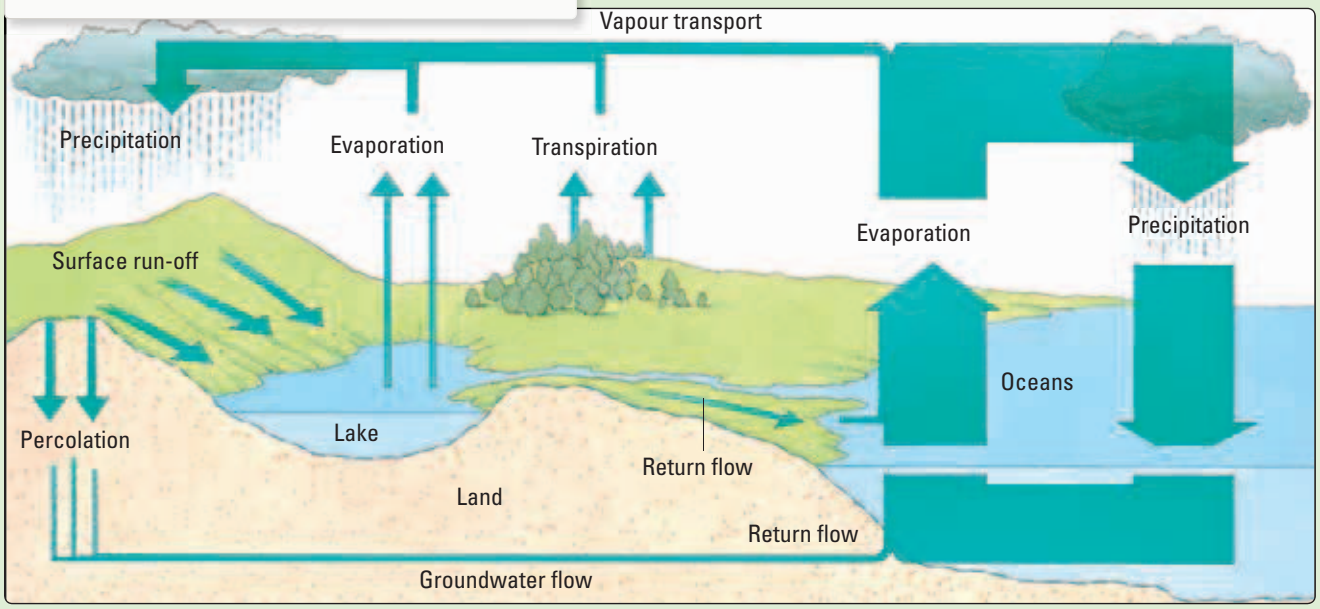
Some species have adapted to these conditions and possess adaptations that increase their chances of survival. Other organisms are not so fortunate and severe conditions of too much or too little water can result in their death. If too many of a particular type of organism die, then the decrease in their population size can have implications not only for other members of their food web, but also for other biotic and abiotic factors within their ecosystem.

THINK, INVESTIGATE AND CREATE

Carefully examine the water cycle and the 2013 Australian rainfall figures. Australia is considered to be one of the driest continents on Earth, yet there is a variety of ecosystems within it. Use a range of resources to answer the following essential question: How can *where* an organism lives affect *how* it lives? Present your findings as a set of models or in a creative multimedia format.



Not all of Australia received the same amount of rainfall in 2013. Climatic conditions differ across our continent.



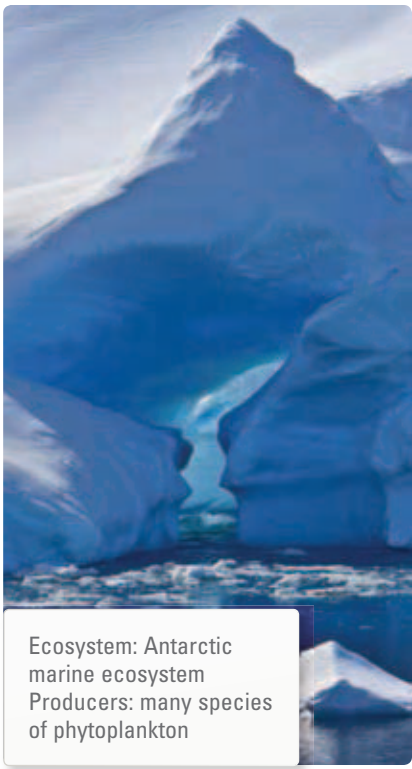
Water cycles through ecosystems. The wider the arrow, the greater the amount of water that moves through that part of the cycle. Is the movement of water by transpiration greater or less than the movement by evaporation from the ocean surface?

Systems: Ecosystems

Living together

You are a multicellular **organism** of the **species** *Homo sapiens*. When you are with others of your species in the same area at a particular time, you belong to a **population**. When the population you are part of is living with populations of other species, then collectively you could be described as a **community**. Communities of organisms living together interact with each other and their environment to make up an ecosystem.

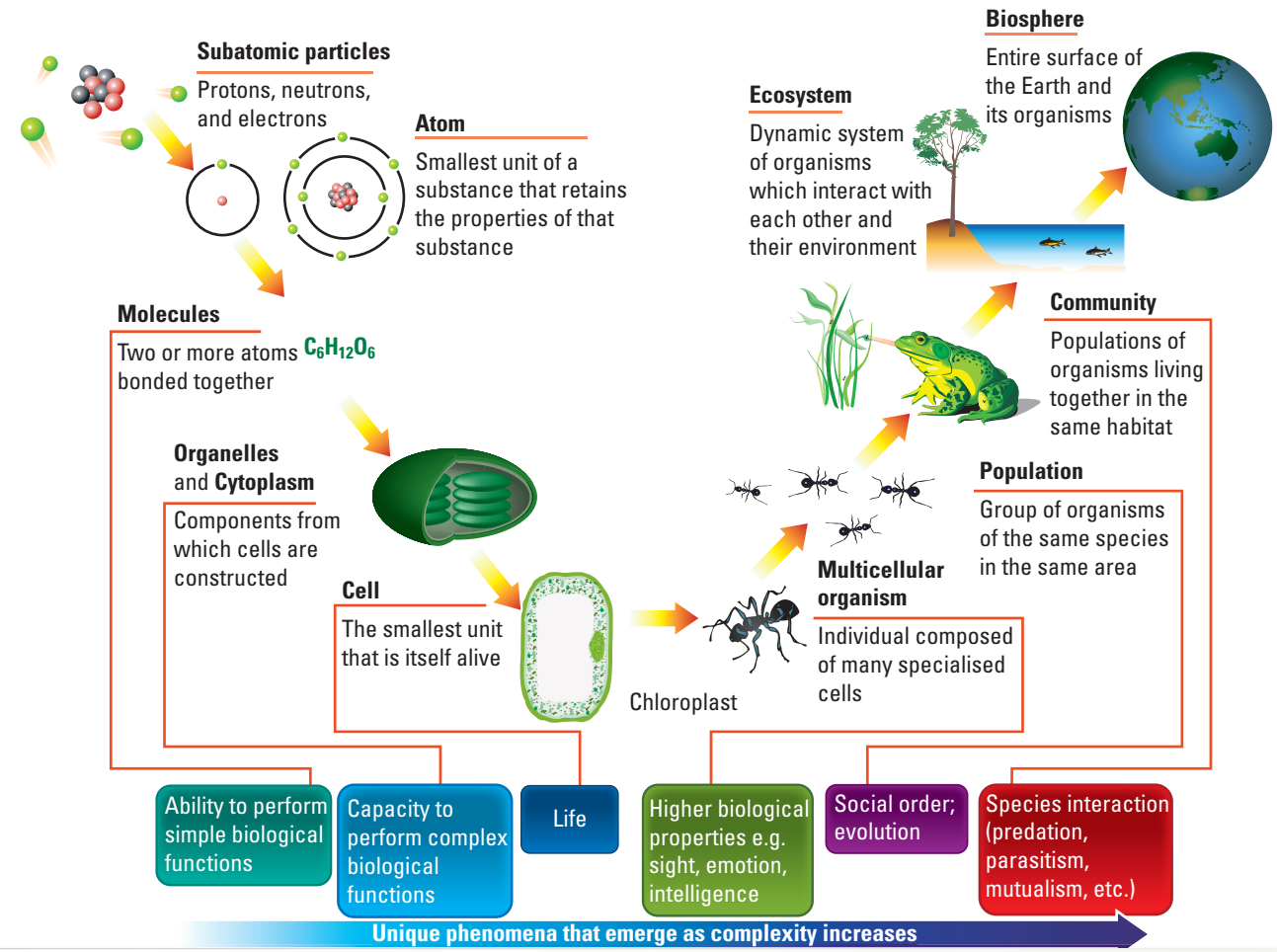
Ecosystem: temperate marine kelp forest
Producers: algae, including the string kelp, *Macrosystis angustifolia*



Ecosystem: Antarctic marine ecosystem
Producers: many species of phytoplankton

Ecology

An **ecosystem** is a complex level of organisation made up of living (biotic) parts, such as communities of organisms, and non-living (abiotic) parts, such as the physical surroundings. The study of ecosystems is known as **ecology**.



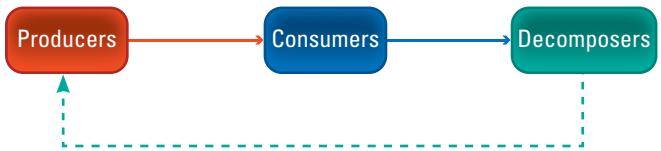
Levels of biological organisation. As each level increases, structural complexity increases and unique phenomena may emerge.

Ecosystem: temperate closed forest
Producers: various woody flowering plants, ferns and mosses

How do you get your food?

The members of every community within an ecosystem can be identified as being either a producer (autotroph), consumer (heterotroph) or decomposer. The feeding relationships between these groups can be shown in food chains or food webs (see section 5.7).

While **producers** are responsible for capturing light energy and using this energy to convert inorganic materials into organic matter, **decomposers** break down organic matter into inorganic materials (such as mineral ions) that can be recycled within ecosystems by plants.



Producers

Producers within ecosystems are essential as they are at the base of the food chain. Plants are examples of producers. They use the process of **photosynthesis** to capture light energy and use it to convert simple inorganic substances (carbon dioxide and water) into organic substances (glucose). Since plants are able to convert glucose into other essential organic substances and do not need to feed on other organisms, they are often referred to as **autotrophs** ('self-feeders').

Plants also release oxygen gas as a waste product of photosynthesis. This molecule is essential for a type of cellular respiration called aerobic respiration — a process essential to the survival of the majority of organisms on our planet.

Consumers

As animals are unable to make their own food, they are called **heterotrophs** ('other-feeders'), and because they obtain their nutrition from consuming or eating other organisms, they are called **consumers**. Consumers are divided into different types on the basis of their food source and how they obtain it.

The koala is a herbivore.

The dung beetle is a detritivore.

The Tasmanian devil is a carnivore.

Herbivores eat plants and are often described as being **primary consumers** because they are the first consumers in a food chain. **Carnivores** eat other animals and are described as secondary or tertiary consumers in food chains or webs. Humans are examples of **omnivores**, which means we eat both plants and animals.

Another group of consumers releases enzymes to break down the organic matter in rotting leaves, dung and decaying animal remains, and then absorbs the products that have been externally digested. This group of consumers is known as **detritivores**, and they include earthworms, dung beetles and crabs.

Decomposers

While producers convert inorganic materials into organic matter, decomposers convert organic matter into inorganic materials. This is an example of how matter can be recycled within ecosystems so that they remain sustainable.

Fungi and bacteria are common examples of decomposers within ecosystems. These heterotrophs obtain their energy and nutrients from dead organic matter. As they feed, they chemically break down the organic matter into simple inorganic forms or mineral nutrients. Their wastes are then returned to the environment to be recycled by producer organisms.

Interactions between species

Species exist in an ecosystem within a specific **ecological niche**. The niche of a species includes its habitat (where it lives within the ecosystem), its nutrition (how it obtains its food) and its relationships (interactions with other species within the ecosystem).

Interactions within an ecosystem may be between members of the same species or between members of different species. Examples of types of interactions include **competition**, predator–prey relationships and symbiotic relationships such as **parasitism**, **mutualism** and **commensalism**.

Competition

Organisms with a similar niche within an ecosystem will compete where their needs overlap. Competition between members of different species for the same resource (e.g. food or shelter) is referred to as **interspecific competition**. Competition for resources between members of the same species (e.g. mates) is referred to as **intraspecific competition**.

WHAT DOES IT MEAN?

The word *ecology* comes from the Greek terms *oikos*, meaning 'home', and *logos*, meaning 'study'.

Predator–prey relationship

In a **predator–prey relationship**, one species kills and eats another species. The predator does the killing and eating and the prey is the food source. Examples of predator–prey relationships include those between eagles and rabbits, fish and coral polyps, spiders and flies, and snakes and mice. How many others can you think of?

Herbivore–plant relationship

Plants cannot run away from herbivores! How then can they protect themselves against being eaten? Some plants protect themselves by using physical structures such as thorns, spines and stinging hairs; others use chemicals that are distasteful, dangerous or poisonous.

Symbiotic relationships

Symbiotic relationships are those in which the organisms living together depend on each other. Examples of symbiotic relationships include parasitism, mutualism and commensalism.

Interaction	Species 1	Species 2
Parasitism	✓ (Parasite)	× (Host)
Mutualism	✓	✓
Commensalism	✓	**0**

✓ = benefits by the association; × = harmed by the association; **0** = no harm or benefit

Type of symbiotic relationship	Description	Example
Parasite–host	Parasites are organisms that live in or on a host, from which they obtain food, shelter and other requirements. Although the host may be harmed in this interaction, it is not usually killed. Some parasites are considered to be pathogens, as they can cause disease. This means that the functioning of their host is in some way impaired or damaged.	
	Parasites living *on* the host are called ectoparasites (e.g. fungi, fleas, ticks, leeches and some species of lamprey [see photo at right]). An example of an ectoparasite is the fungus that causes tinea or athlete's foot. The fungus secretes enzymes that externally digest the skin that it is attached to. It then absorbs the broken-down nutrients. This causes your skin to break and become red and itchy.	
	Parasites living *inside* their host are called endoparasites (e.g. flatworms such as *Echinococcus granulosus* or roundworms such as *Ascaris lumbricoides).* Tapeworms (see photo at right) are an example of an endoparasite. Their heads have suckers (and sometimes hooks) to firmly attach themselves to the walls of their host's intestine. They do not need a digestive system themselves as they live off the digested food within the intestine. Tapeworms vary in length from 1 cm to 10 cm. As each tapeworm contains both male and female sex organs, they don't need a mate to reproduce.	
Parasitoids	A new group of consumers has been suggested, called parasitoids ('-oid' means '-like'). These organisms are halfway between predators and parasites. While they act like parasites, they kill their hosts within a very short period. Examples of organisms that may be classified as parasitoids are mainly wasps (see photo at right) and flies. The female parasitoid lays her egg(s) in the body of the host; when the eggs hatch, they eat the host from the inside. The host is killed when vital organs have been eaten. This relationship has applications in horticulture as a potential biological control method for pests feeding on crops.	
Mutualism	An interaction between organisms of two different species in which they both benefit is called mutualism. In many cases, neither species can survive under natural conditions without the other. Tiny protozoans found in the intestines of termites help them to digest wood. These organisms are dependent on each other for their survival. Another example is that of lichen (see photo at right), which is often found growing on rocks or tree trunks. Lichen is made up of a fungus and an alga living together. The alga uses light from the sun to make glucose and the fungus uses this as food. The fungus shelters the alga so that it does not get too hot or dry out.	
Commensalism	An example of commensalism is found between remora fish and sharks. Remora fish are often found swimming beneath sharks and benefit by being able to feed on leftover scraps; the sharks are not harmed but receive no benefit. The organism that benefits is referred to as the commensal and the other is sometimes referred to as the host. Clownfish and sea anemones are another example (see photo at right). While the clownfish (*Amphiprion melanopus)* lives among the tentacles of the sea anemone, it is unaffected by their stinging cells and benefits from shelter and any available food scraps.	

UNDERSTANDING AND INQUIRING

REMEMBER

1 Use Venn diagrams to compare the following relationships.
   (a) Commensalism and mutualism
   (b) Parasitism and commensalism
   (c) Predator–prey and parasite–host
2 State the name of the species to which you belong.
3 Outline the relationship between species, organisms, populations, communities and an ecosystem.
4 Define the term *ecology*.
5 Construct a flowchart that shows the relationship between producers, consumers and decomposers.
6 Construct a continuum to arrange the following in terms of increasing complexity: biosphere, cell, population, molecules, organisms.
7 Explain why producers are essential to ecosystems.
8 Construct a Venn diagram to compare autotrophs and heterotrophs.
9 Distinguish between herbivores, carnivores, omnivores and detritivores.
10 Identify a type of organism that you may find in
   (a) a temperate marine kelp forest ecosystem
   (b) a temperate closed forest ecosystem
   (c) an Antarctic marine ecosystem.
11 Distinguish between producers and decomposers.
12 Identify two common examples of decomposers.
13 Define the term *ecological niche*.
14 Distinguish between *interspecific competition* and *intraspecific competition*.
15 Construct a table to summarise the similarities and differences between parasitism, mutualism and commensalism.

INVESTIGATE, THINK AND DISCUSS

16 (a) List three examples of predators and then match them to their prey.
   (b) Suggest structural, physiological and behavioural features that may assist:
      (i) predators in obtaining food (e.g. webs, teeth, senses, behaviour)
      (ii) prey in avoiding being eaten (e.g. camouflage, mimicry, behaviour, chemicals).
17 In the interaction between a clownfish and a sea anemone, which is benefited?
18 Use a flowchart to describe how a parasite obtains its food.
19 Suggest why a parasite does not normally kill its host.
20 Use a visual thinking tool to show the difference between a commensal and a parasite.
21 Is a mammalian embryo a parasite? Explain your answer.
22 Parasite–host relationships also exist within the plant kingdom. The two main types of these relationships are holo-parasitism (in which the parasite is totally dependent on the host for food) and hemi-parasitism (in which the parasite obtains some of its nutrients from the host but can make some itself). Some plant species belonging to the genus *Rafflesia* are examples of holo-parasites, and many Australian species of mistletoe are hemi-parasites. Research and report on:
   (a) *Rafflesia* parasites and their host *Tetrastigma*
   (b) pollinators for *Rafflesia* flowers
   (c) one of the following hemi-parasites:
      (i) sheoak mistletoe (*Amyema cambagei*) and its host *Casuarina cunninghamiana*
      (ii) paperbark mistletoe (*Amyema gaudichaudii*) and host *Melaleuca decora*.
23 Decide whether the following relationships are examples of parasitism, commensalism or mutualism.
   (a) A dog with a tapeworm in its intestine, absorbing the digested food
   (b) Egrets staying near cows and feeding on the insects they stir up
   (c) Harmless bacteria *Escherichia coli* living in human intestines
   (d) Root nodules of clover contain bacteria — the clover benefits, but can survive without the bacteria; the bacteria don't live anywhere else
   (e) A fungal disease on human skin, such as ringworm
24 The koala and the bacteria that live in its gut have a symbiotic relationship. Find out how each of the organisms benefits from this relationship.
25 Choose one of the following parasites: malaria parasites, tapeworms, ticks, insects that make galls in trees, blight-causing bacteria. Explain how it infests its host and how it affects its host.
26 Click on the **Parasites** weblink in your eBookPLUS to find out about the symptoms and treatment of some common parasites in humans.

27 Some clovers (Trifolium) produce cyanide. Find out how this may protect them against being eaten.
28 Find examples of ways that Australian plants try and protect themselves from being eaten by herbivores.
29 Use internet research to identify three problems that can be investigated about interactions between organisms.
30 Construct a model that simulates interactions between at least four different types of organisms.

5.1 Food webs

Mapping ecosystems

Are you at home? What does that mean to your survival? A habitat is the name given to the place where an organism lives.

It needs to be convenient and provide conditions that are comfortable to the functioning of cells and life processes of its inhabitants. The match between the environmental conditions and the needs of organisms is responsible for the **distribution** and **density** of species within it.

An **ecosystem** may contain many habitats. It is made up of living or **biotic factors** (such as other organisms) and non-living or **abiotic factors** (such as water, temperature, light and pH) that interact with each other.

Tolerance — the key to survival

Each species has a **tolerance range** for each abiotic factor. The **optimum range** within the tolerance range is the one in which a species functions best. Measuring the abiotic factors in a habitat can provide information on the abiotic requirements for a particular organism in that habitat. Can you think of features that organisms possess to increase their chances of survival in some habitats more than in others?

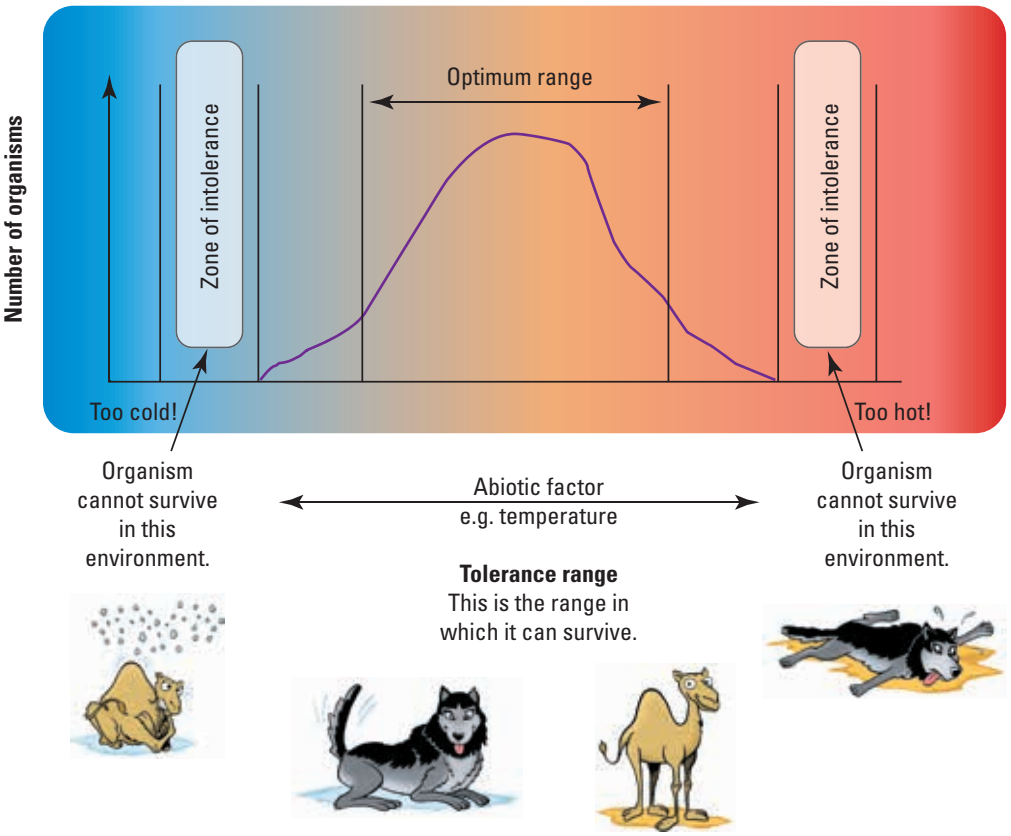
How many and where?

Investigation of an ecosystem involves studying how different species in it interact. To do this, you need to:

1. identify the organisms living in the ecosystem by using keys and field guides
2. determine the number or density of different species in the particular area. This indicates the biological diversity (**biodiversity**) within the ecosystem.
3. determine the distribution of the different species or where they are located.

Sampling an ecosystem

Sampling methods are used to determine the density and distribution of various populations and communities within the ecosystem. **Transects** are very useful when the environmental conditions vary along the sample under investigation. **Quadrats** can be used to estimate the distribution and abundance of organisms that are stationary or do not move very much. The **mark, release and recapture** sampling method is used to determine the abundance of mobile species.



Life in a square

A quadrat is just a sampling area (often 1 square metre) in which the number of organisms is counted and recorded. When organisms are counted in a number of quadrats, this is usually considered to be representative of the total area under investigation. The average density of the total area can be estimated using the equation shown on the next page.