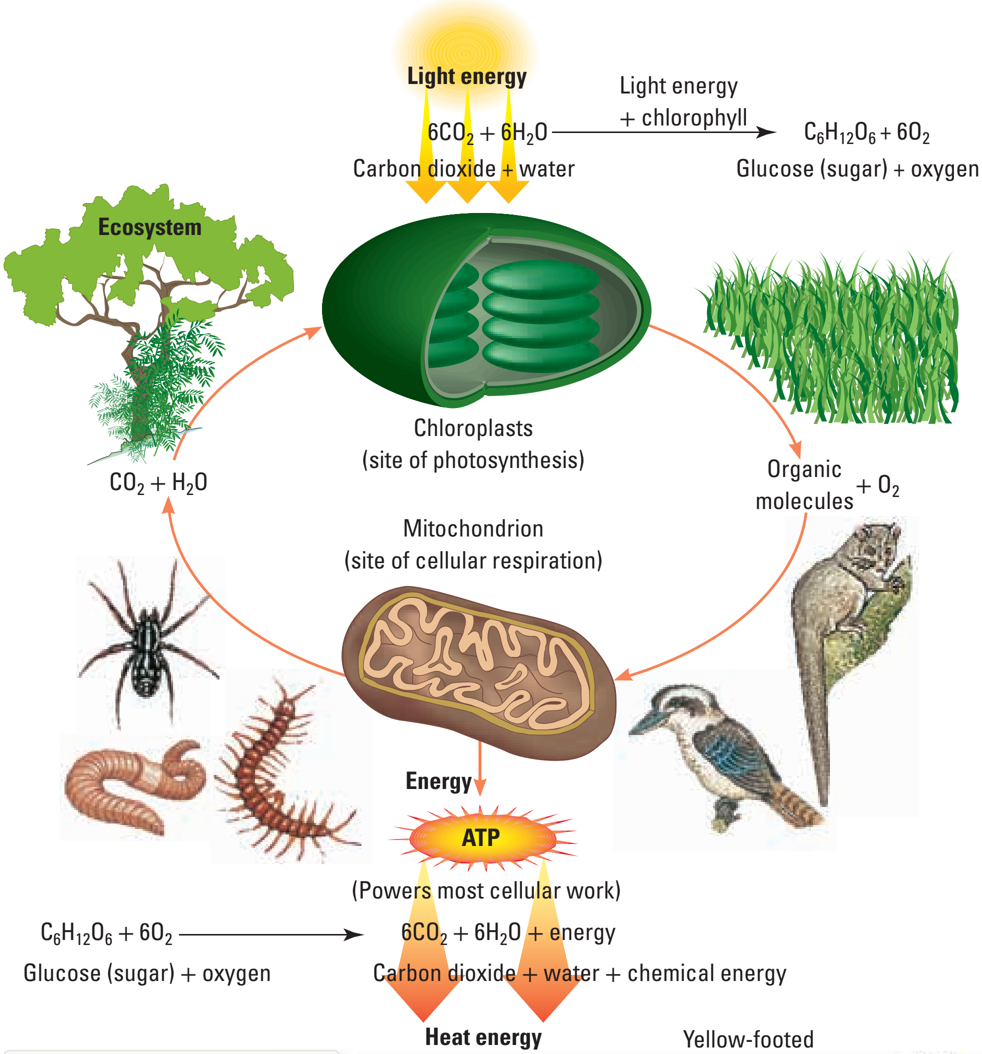
Sustainable ecosystems

Communities within ecosystems are made up of populations. Interactions between these populations and their environment enable matter to be recycled and energy to flow through the ecosystem.

Energy flows through ecosystems

Light energy is captured by producers and converted into chemical energy using the process of photosynthesis. Some of this energy is used by the producers themselves, some is released into the atmosphere and some is passed on through food chains to consumers. Energy flows through ecosystems.

Cellular respiration is a process that all living organisms use to convert energy into a form that their cells can use. Glucose and oxygen (the products of photosynthesis) are used in cellular respiration.



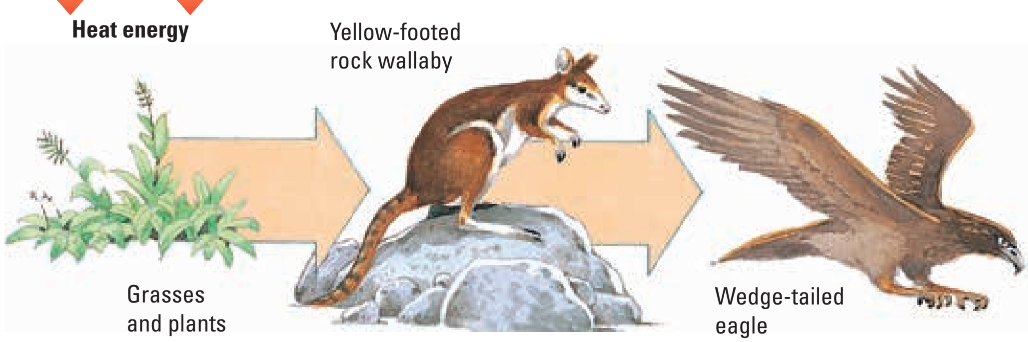
Photosynthesis is the process involved in capturing light energy and converting it into chemical energy. Respiration is the process that uses chemical energy produced from photosynthesis for energy to live.

Living in the dark

How can ecosystems exist on the ocean floor, where there is no light for photosynthesis? Rather than being photosynthetic, some organisms are **chemosynthetic**. They use energy released from chemical reactions (rather than light) to produce organic molecules. Examples of these non-photosynthetic producers are autotrophic bacteria such as *Thiobacillus* spp.

Food chains and food webs

Feeding relationships in ecosystems can be described as **food chains** and **food webs**. Food chains show the direction of the flow of energy. Interconnecting or linked food chains make up a food web.

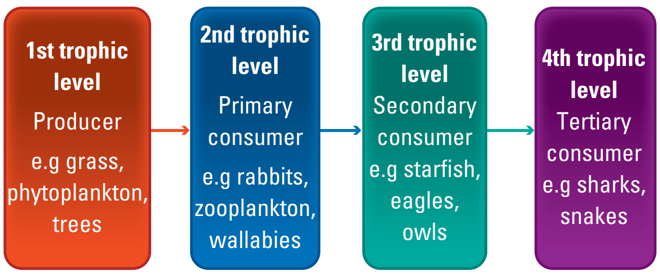


Trophic levels and orders

Within a food chain, each feeding level is called a **trophic level**.

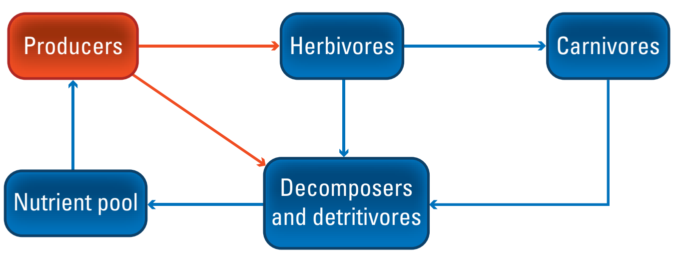
Producers make up the first trophic level and herbivores the next. As herbivores are the first consumers in the food chain, they are at the second trophic level and are referred to as **first-order** or **primary consumers**. Consumers that eat the herbivores are at the third trophic level and are called **second-order** or **secondary consumers**. As only about 10 per cent of the chemical energy is passed from one trophic level to the next, most food chains do not usually contain more than four trophic levels.

Some examples of organisms that could be present at each level are shown below. Organisms can appear within more than one trophic level.



Matter cycles through ecosystems

Food chains and food webs also describe how matter can be recycled through an ecosystem.Carefully observe each of the following figures to see how these relationships assist in maintaining a sustainable ecosystem.



A simplified view of how matter is cycled within an ecosystem

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Reducing your carbon footprint

Find out ten easy and practical things you can do to help stop global warming.

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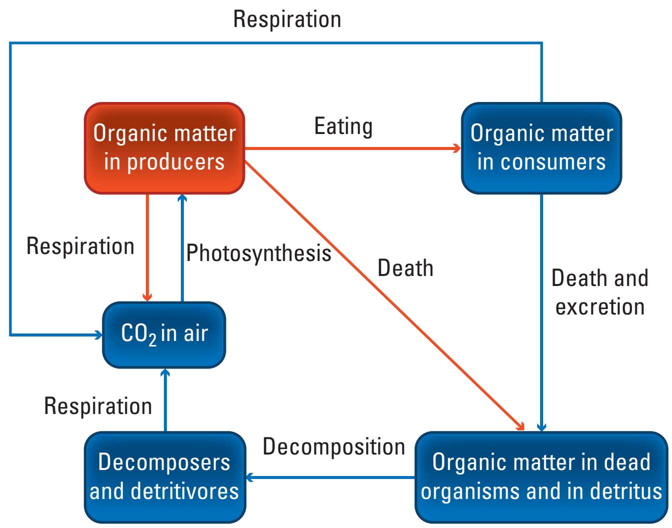
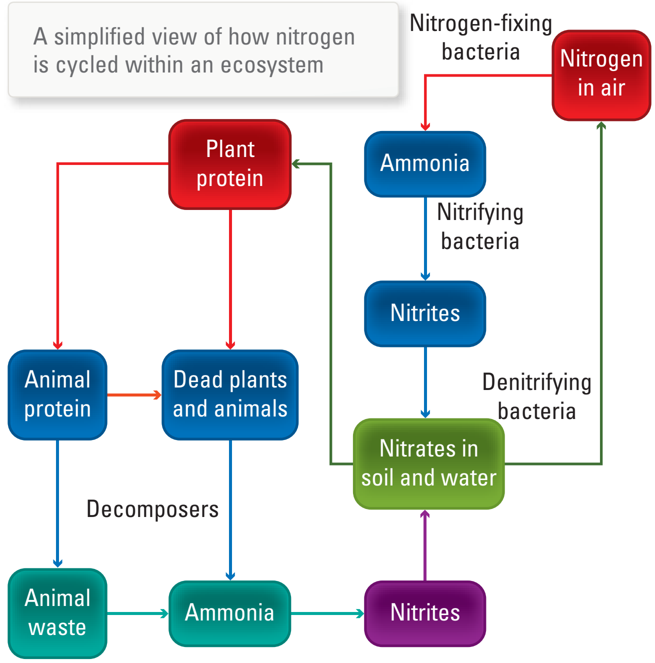
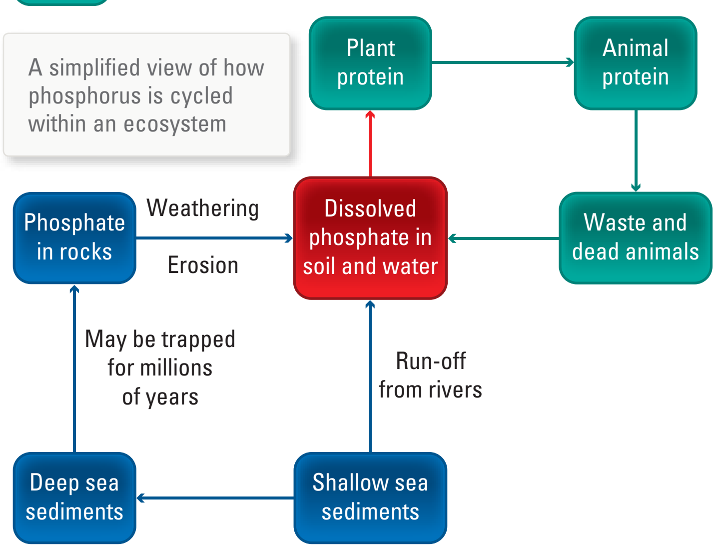


A simplified view of how carbon is cycled within an ecosystem

A simplified view of how nitrogen is cycled within an ecosystem



A simplified view of how phosphorus is cycled within an ecosystem



Ecological pyramids

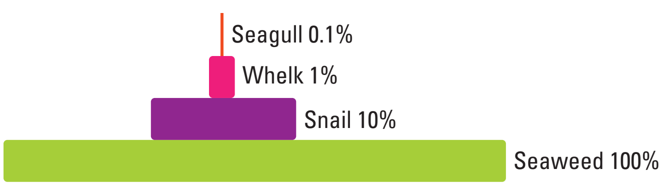
Ecological pyramids can provide a model that can be used to describe various aspects of an ecosystem. They can show the flow of energy, the recycling of matter through an ecosystem or the numbers of organisms and the relationships between them.

These pyramids are constructed by stacking boxes that represent feeding (or trophic) levels within a particular ecosystem. The size of the box indicates the number or amount of the feature being considered.

Energy pyramids

An **energy pyramid** for a food chain as described above would show a larger box at the bottom and smaller boxes as you move up the food chain. Energy pyramids always have this basic shape, because only some of the energy captured by producers is converted into chemical energy. Of the energy captured, only about 10 per cent is passed on through each feeding level, with about 90 per cent of the energy being transferred to the environment as heat or waste.

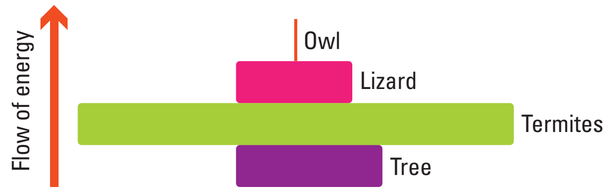
This decrease in energy along the food chain is one reason that the numbers of levels in food chains are limited. There is also a limit to the number of organisms that can exist at each level of the food chain. Energy pyramids show that, as you move up the food chain or web, there is less food energy to go around and therefore fewer of each type of organism.



An energy pyramid — only about 10 per cent of the food energy received at each level is passed through to the next; the other 90 per cent is transferred to the environment.

Pyramids of numbers and biomass

A **pyramid of numbers**, as the name suggests, indicates the population or numbers of organisms at each trophic level in the food chain. A **pyramid of biomass** shows the dry mass of the organisms at each trophic level. These pyramids can appear as different shapes due to reproduction rates or mass differences between the organisms.



A pyramid of biomass shows the dry mass of the organisms at each trophic level.

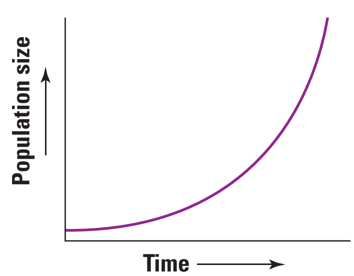
Population growth

The rate at which a population can grow is determined by its **birth rate** minus its **death rate**. The size of the population is also influenced by **immigration** (the number of individuals moving into an area) and **emigration** (the number of individuals leaving an area). It is also influenced by available resources, predators and disease. The overall growth rate can be calculated by the formula:

population growth = (births + immigration) − (deaths + emigration)

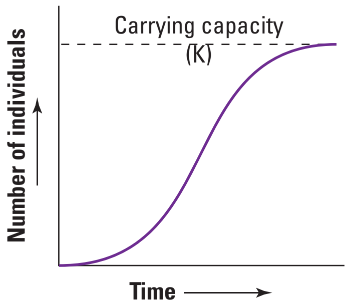
Growth without limits

If you were to provide a population with plenty of food, lack of predators and disease, it would grow rapidly. A bacterium, for example, divides every 20 minutes. Under favourable conditions, that single bacterium would produce a population of 1 048 578 individuals within 7 hours! Graphing this population growth would result in a J-shaped growth pattern known as **exponential growth**.



Carrying capacity

Populations, however, have only a limited amount of resources and if you were to graph their growth it would look more like an S-shaped, or **sigmoid**, graph. Eventually the population growth would be zero (overall). When this occurs the population is described as having reached a **steady state**, **plateau phase** or **equilibrium**. When the birth and death rates balance each other out, a point of **zero population growth** is reached. A population in its plateau phase contains the maximum number of individuals that its particular environment can carry — it has reached its **carrying capacity**.



Organisms need particular resources in order to survive. Some of these resources will be in limited supply, and organisms will need to compete with other organisms to get what they need. An ecosystem has limited resources and can carry only a particular number of organisms. This is called its carrying capacity, and is what causes a population to plateau when it reaches a particular size.

UNDERSTANDING AND INQUIRING

REMEMBER

1 Rank these terms in order of complexity:
- ecosystem
- population
- community.

2 Name the process that plants use to convert light energy into chemical energy.

3 Identify the products of photosynthesis that are used as inputs for cellular respiration.

4 Construct a Venn diagram to compare photosynthesis and chemosynthesis.

5 Construct a food chain that contains four organisms.

6 Identify an organism that you may find at each of the following trophic levels:
(a) 1st trophic level
(b) 2nd trophic level
(c) 3rd trophic level
(d) 4th trophic level.

7 Suggest why food chains rarely contain more than four trophic levels.

8 Construct linked flowcharts to show a simplified view of how:
(a) matter is cycled within an ecosystem
(b) carbon is cycled within an ecosystem
(c) nitrogen is cycled within an ecosystem
(d) phosphorus is cycled within an ecosystem.

9 Describe how ecological pyramids are used to describe various aspects of an ecosystem.

10 State a formula that could be used to calculate an increase in a population.

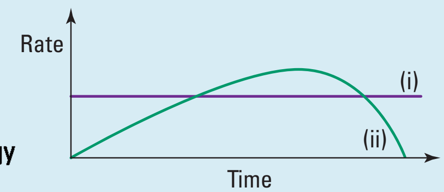
11 List three factors that may result in:
(a) an increased population size
(b) a decreased population size.

12 Describe the difference between sigmoid and exponential growth patterns.

13 Outline the relevance of carrying capacity to population growth.

THINK, DISCUSS AND INVESTIGATE

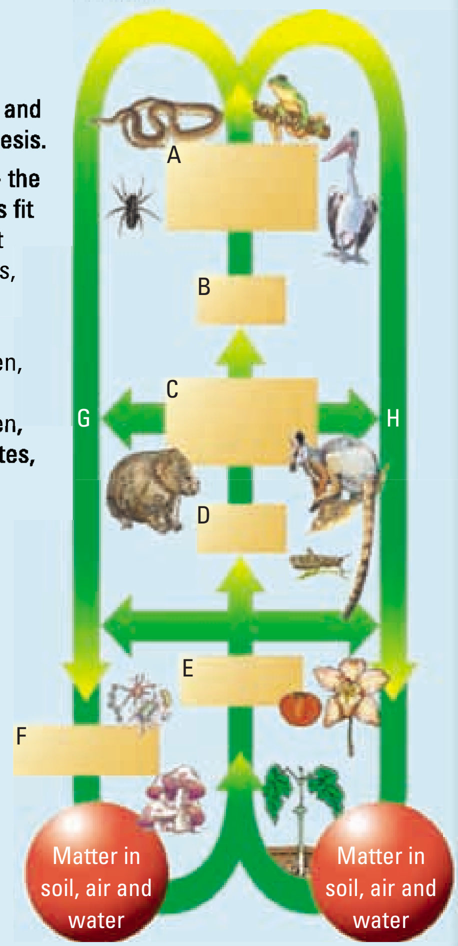
14 Look at the graph below showing the relationship between photosynthesis and respiration.



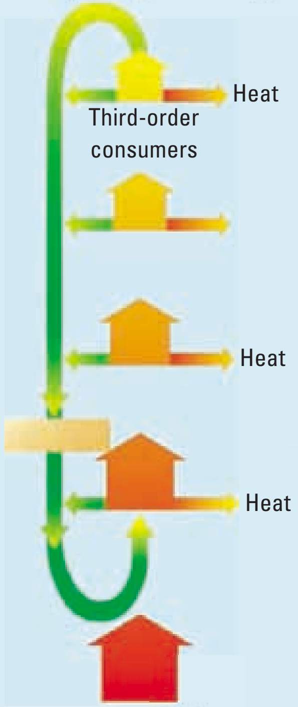
This graph shows the rates of photosynthesis and respiration for a plant over a 24-hour period.

(a) Which line of the graph represents the rate of photosynthesis?
(b) When would the rate of respiration be greater than the rate of photosynthesis?
(c) State three similarities between respiration and photosynthesis.

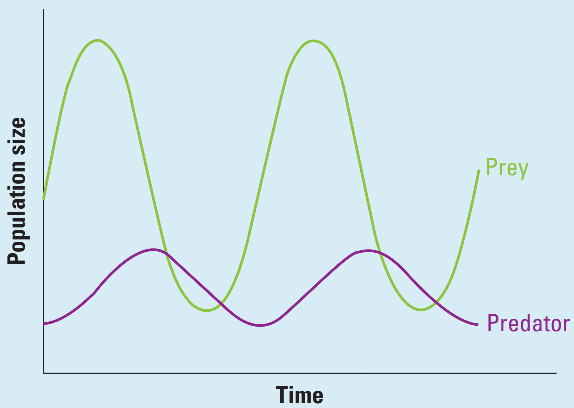
15 Suggest where the following labels fit on the figure at right: producers, decomposers, second-order consumer, eaten, first-order consumer, eaten, death and wastes, respiration.

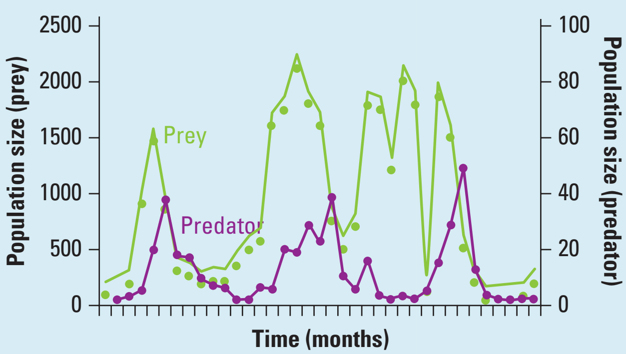


16 Suggest where the following labels fit on the figure below: producers, decomposers, second-order consumer, heat, first-order consumer, death and wastes, nutrients in soil, energy from sunlight.



17 Carefully observe the predator–prey graphs below.
(a) Comment on any patterns observed.
(b) Suggest reasons for the observed pattern.





18 Complete the following table.

Trophic level	Organism	Food source
First	Producer	Convert inorganic substances into organic matter using sunlight energy and the process of photosynthesis
	Primary consumer (herbivore)	Plants or other producers
Third		
	Tertiary consumer (carnivore)	

19 Investigate how scientists use models to predict changes in populations.

20 Select an organism and investigate the effect of seasonal changes on its population size.

21 Suggest why it is (a) necessary for energy to flow through ecosystems and (b) essential for matter to cycle through ecosystems.

22 Introduced species can have an effect on the feeding relationships within food webs.
(a) Find examples of three introduced species that have had such an effect in Australia.
(b) Find out when, why and how the species were introduced.
(c) Investigate the effect of the introduced species on Australian ecosystems.
(d) Research methods that have been used to reduce the effect of an introduced species or control its population size, and comment on the effectiveness of the methods.
(e) Construct a PMI chart on introduced species in Australia and discuss your comments with other students in your class.

23 Find out more about how autotrophic bacteria (such as *Thiobacillus* spp.) use chemosynthesis and where they may be found.

24 Some factors that have an impact on populations are related to the population size and are referred to as being density dependent. Other factors are density independent. Find out more about these two types of factors and share your findings with other students in your class.

25 Click on the **Food web** weblink in your eBookPLUS to build a food web.

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work sheet 5.4 Cycling of materials

Changes in populations

The effect of a change in size of a particular population on an ecosystem can be predicted by observing feeding relationships in food webs. If, for example, the number of the producers is reduced, it will not just be herbivores that are affected, but also the animals that eat them, which in turn affects the organisms that either eat them or are eaten by them.

If a new species is introduced it may compete for the resources of another species, leading to a reduction in that population. This may have implications for organisms that either eat or are eaten by the affected population.

Artificial ecosystems

Humans have created artificial ecosystems to maximise the production of their own food supplies and resources. The purpose of agriculture is to turn as much of the sun's light energy as possible into chemical energy in particular crops or pasture plants for animals. In order to achieve this, humans have attempted to control populations of other organisms. This has led to interference in food webs and hence the ecosystems that contain them.

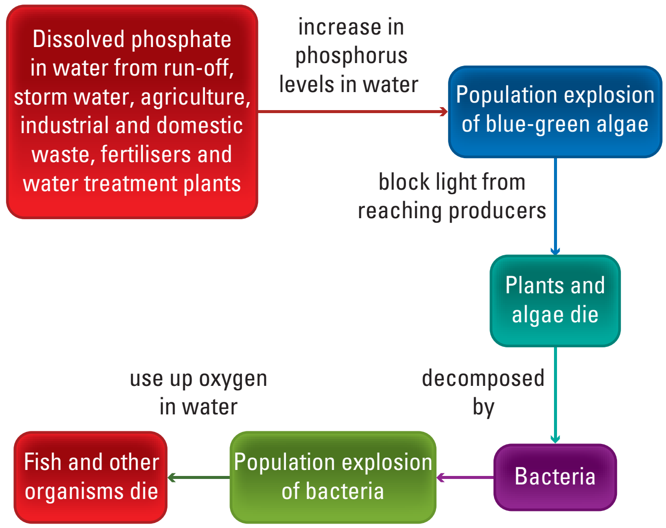
Taking away

To make room for crop plants, land has often been cleared of forests. The local habitats of many organisms have been destroyed. Organisms that may compete for resources or in some way potentially lower crop yields are considered to be pests and are also removed, or their populations killed or controlled.

Crops are often monocultures, consisting of only one species of plant. At the end of each growing season the crops are harvested, processed and removed from the ecosystem. There is little natural decomposition of dead material and exposed soil may be blown away by the wind. Valuable nutrients are lost. Such activities have led to the destruction of many natural ecosystems.

Giving back

Fertilisers are added in an attempt to replace some of the lost nutrients. Some of these may end up in waterways, adding large quantities of nitrogen and phosphorus to the water. This can lead to algal blooms or **eutrophication**, which may result in the death of organisms within the ecosystem.



Eutrophication is like suffocation of a waterway and can result in the death of organisms within the ecosystem.

Controlling pests

Organisms that compete for resources or potentially lower the yield of the plant crop being grown are considered to be pests that need to be controlled. Pest control may be carried out using chemical or biological control.

Biological control

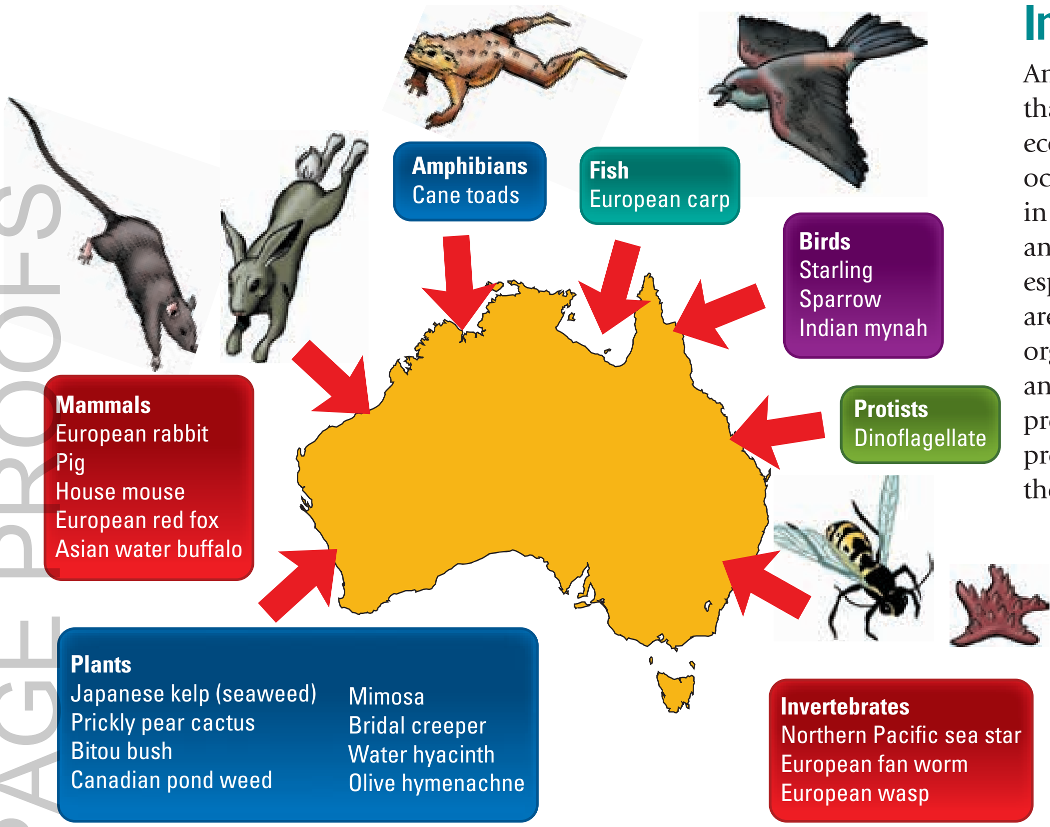
Biological control of unwanted organisms can exploit naturally existing ecological relationships. Predators or competitors may be used to kill or reduce numbers of the pests or somehow disrupt the pests' reproductive cycle. A disease, for example, might be used to kill the unwanted organism without harming other species. While some cases of biological control have proven to be successful, others (such as the introduction of cane toads and prickly pear plants) have caused a variety of new problems.

Chemical control

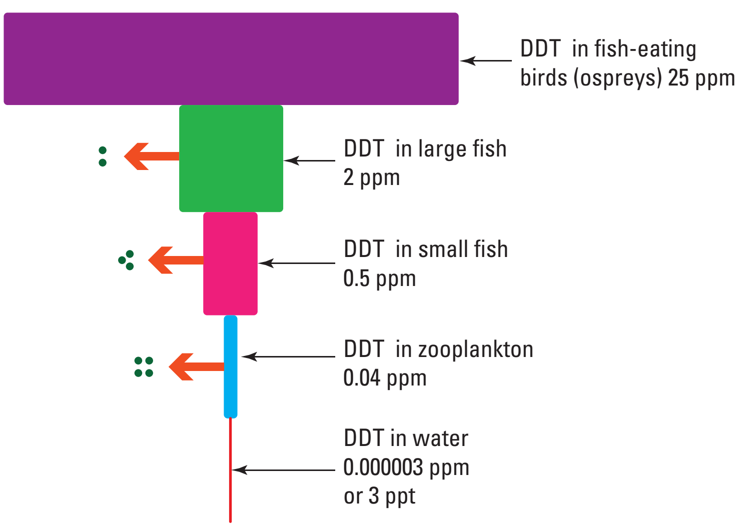
Chemical methods of control include the use of pesticides such as **insecticides**, **fungicides**, **herbicides** or **fumigants**. Herbicides kill plants other than the planted crop so that they do not compete for nutrients and water in the soil, and light from the sun. Insecticides are used to kill organisms that compete with humans for the food crops.

Introduced species

An **introduced species** is one that has been released into an ecosystem in which it does not occur naturally. The food webs in ecosystems are very delicate and can easily be unbalanced, especially when new organisms are introduced. These introduced organisms compete with other animals for food, provide predators with a new source of prey, or may act as predators themselves.



Although pesticides are still used in agriculture, their effectiveness on target pest species often decreases. Other species may also be affected within the ecosystem and the food webs in which the target species belongs. In some cases, concentrations of non-biodegradable pesticides (such as DDT) can be magnified along the food chain by a process described as **bioaccumulation** or **biological magnification**.



CANE TOADS

Ecological impact:

- Occupying water habitats so that native tadpoles cannot live there
- Killing fish that eat the tadpoles and other animals that eat the adult toads
- Eating our natural wildlife including frogs, small lizards, birds, fish and insects.
- Poisonous; fatal to animals that eat them

NORTHERN PACIFIC SEA STAR

Ecological impact:

- Potential great harm to our marine ecosystem and to marine industries
- Threatening biodiversity and shellfish aquaculture in south-eastern Tasmania and Port Phillip Bay
- It is a voracious predator. Some of our native marine species, such as scallops and abalone, don't recognise it as a predator, so do not try to escape it.
- No natural predators or competitors to keep the population under control

RABBITS

Ecological impact:

- Competing for food with the native animals such as kangaroos, wallabies, wombats and bandicoots
- Disrupting food webs and unbalancing ecosystems
- Building extensive underground warrens
- Stripping most of the vegetation in their area, causing another problem — erosion. Without plant roots to hold the soil, wind and rain carry the soil into creeks, rivers and lakes, causing further problems for the organisms that lived there.

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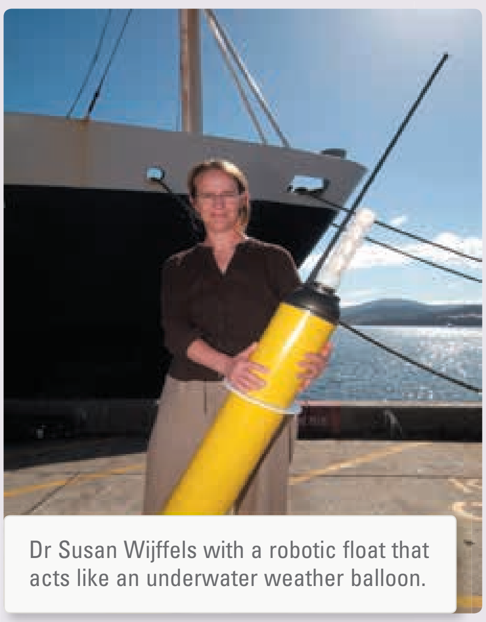
Native rats fighting for their habitat

Watch a video about rats that have been bred to be introduced into their native environment; how will the resident black rats react?

eles-1083

HOW ABOUT THAT!

Dr Susan Wijffels, CSIRO oceanographer and leader of the IMOS bluewater and climate node, is involved in research that investigates the impact of ocean ecosystems and the oceans' role in the carbon cycle. She is currently investigating the use of floating sensors, underwater gliders and satellite tags on marine animals. The tagging of these marine animals will provide information about when and where they feed and the types of salinity, pressure and temperatures that they feed in.



Dr Susan Wijffels with a robotic float that acts like an underwater weather balloon.

Cameras mounted on seals provide information from the depths of the sea.

HOW ABOUT THAT!

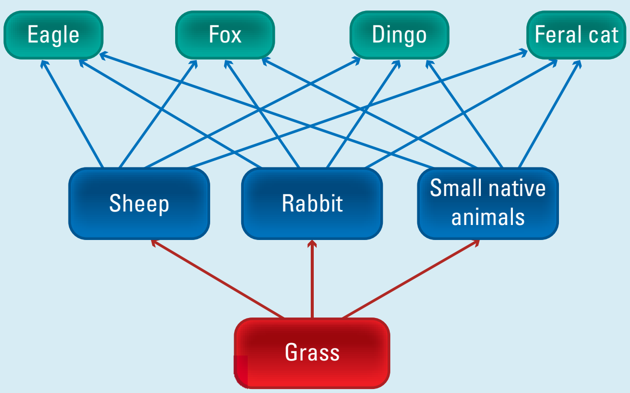
Researchers are working on an immunocontraception method that aims to block conception in rabbits to control their numbers. This method will use a virus that has been modified to contain genetic material that codes for the production of a protein essential for reproduction. When infected with this modified virus, (it is hoped that) the female rabbit produces the protein and her immune system responds by producing antibodies against it. These antibodies should then attack her eggs, blocking conception.

UNDERSTANDING AND INQUIRING

ANALYSE, THINK AND INVESTIGATE

1 Carefully examine the eutrophication flowchart at the beginning of this section.
   (a) Suggest how dissolved phosphate in waterways can be linked to algal blooms.
   (b) Do you think that suffocation is an appropriate description of the effect of eutrophication?
   (c) Find examples of algal blooms in Australia. Investigate:
      (i) the cause of the algal bloom
      (ii) consequences or effects of the algal bloom on the local ecosystem
      (iii) how algal blooms can be treated or prevented.

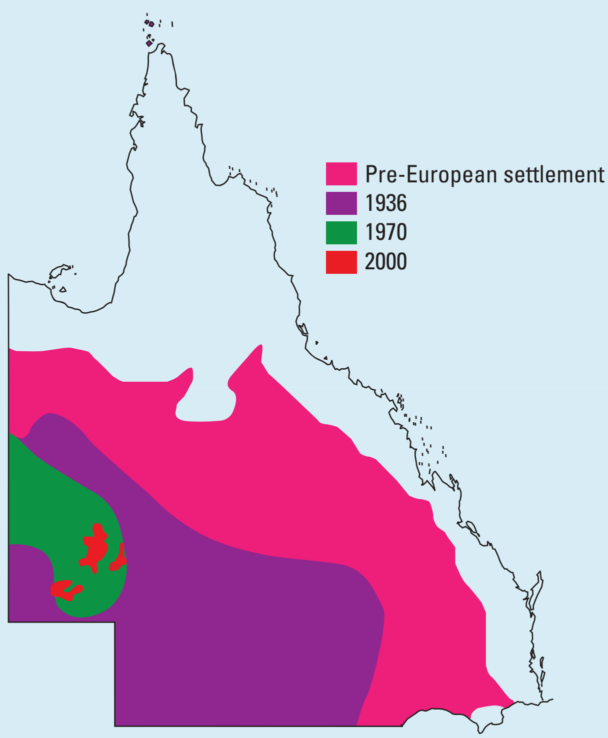
2 Observe the figure of the food web below and then answer the following.



   (a) Suggest possible consequences of a decrease in the population size of:
      (i) rabbits (ii) feral cats (iii) grass.
   (b) Suggest possible consequences of an increase in the population size of:
      (i) grass (ii) sheep (iii) eagles.

3 Habitat loss and introduced species have led to a decline in reptile populations. Find out more about the effects of habitat loss and introduction of cats, foxes and cane toads on Australian reptile populations and the ecosystems in which they live.

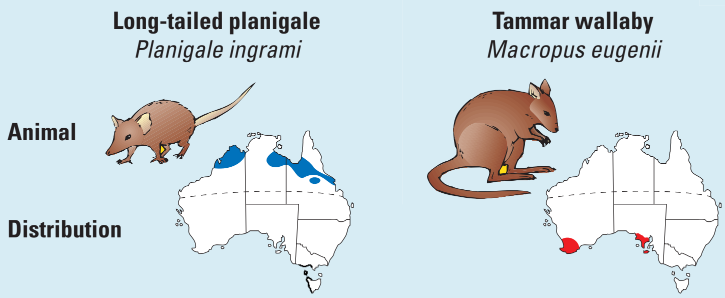
4 Although populations of greater bilbies once ranged over most of mainland Australia, predation by introduced species such as cats and foxes has eliminated them from most of their former habitats.
   (a) Carefully observe the figure below and describe the change in bilby distribution pattern over the recorded times in Queensland.
   (b) From the figure, estimate the percentage population values in Queensland for each year and construct a graph to show your data.
   (c) Find out more about bilbies, their predators and ways in which bilbies try to avoid their predators.
   (d) Find out more about the introduction of either cats or foxes to Australia, their effect on Australian ecosystems, and Australian research projects that are investigating ways in which to reduce their impact.
   (e) Find out more about Australian research into protection of bilby populations.
   (f) Suggest what you think should be done to protect the greater bilby from becoming extinct. Outline how this could possibly be achieved.



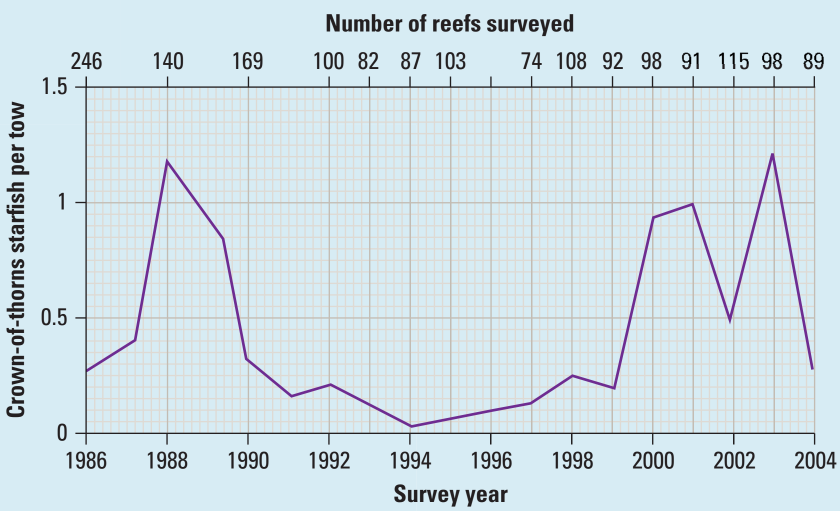
Location of bilby populations in Queensland

5 The lesser bilby, *Macrotis leucura*, is now extinct. Find out more about this species and possible reasons for its extinction. Knowing what we know now, suggest how this could have been avoided.

6 Carefully examine features of the planigale and wallaby, and the location of their distribution in Australia in the figure below. Find out more about each of these organisms and their habitats and relate their features to their suitability in these environments. Research the food webs in which they are linked and discuss possible (or real) implications of human activity to their survival.



7 Carefully examine the graph below showing crown-of-thorns starfish populations recorded in Great Barrier Reef surveys between 1986 and 2004. Suggest why scientists measure and record the size of populations of organisms. Find out more about the food webs that this starfish is linked to. What type of food does it eat? Which organisms eat it? Suggest possible implications of the changes in crown-of-thorns starfish populations for other members of its food web. Research issues relating to the crown-of-thorns starfish and the effect it has had on Australian marine ecosystems.



INVESTIGATE AND DISCUSS

8 Investigate ways in which human activities have affected either the nitrogen cycle or the carbon cycle, leading to an imbalance within an ecosystem.

9 Investigate the introduction of rabbits into Australia and research their effect on our ecosystems. Identify and research examples of methods that have been used to control the population growth of rabbits. Comment on the effectiveness of these methods.

10 Suggest a definition for the term sustainable agriculture. Find out whether your suggestion was correct and find out more about ways in which this form of agriculture differs from unsustainable agriculture.

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11 Find out more about critically endangered and endangered species and ecological communities that are affected by rabbits using the **Invasive animals** weblink in your eBookPLUS.

12 Use the **Feral Focus** weblink in your eBookPLUS to take part in the online interactivities in unit 2, 3 or 4.

13 Get involved in helping to map feral animal sightings in your area using the **FeralScan** weblink in your eBookPLUS. In particular, look at the information about the RabbitScan project.

14 Research one of the following introduced marine species to find out why it is considered an environmental pest.

- Green shore crab (*Carcinus maenas*)
- Pacific oyster (*Crassostrea gigas*)
- European fan worm (*Sabella spallanzanii*)
- Japanese goby (*Tridentiger trigonocephalus*)

15 Find examples of non-indigenous fish or marine vegetation that have been introduced in each of the following ways.

- Ship fouling, ballast waters or dry ballast
- Stock enhancement, mariculture, or biological control
- Wave action or ocean currents

16 Find out more about Susan Wijffels and her research on ocean ecosystems.

17 Find out more about oceanographers and then write a short story about one of their adventures.

18 (a) Use internet research to identify a problem or issue about pests, population control or introduced species that could be investigated.

(b) Design an experiment that could be used to investigate the problem.

work sheet 5.5 Introduced pests